TP 1265

MATHEMATICAL SUBROUTINE MANUAL

SATURN GROUND COMPUTER SYSTEM

2112000-501
THRU
2112000-524

SPECIFICATION IDENTIFICATION NUMBER 2186699

(RADIO CORPORATION OF AMERICA)
49671

NAS 8-11007

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APRIL 1966

CONFIGURATION CHART

TP ISSUE	ECP	SYSTEM EFFECTIVITY	ENGINEERING FIELD CHANGE NUMBER
Original April 1965	110A-49671-0002 110A-49671-0005 110A-49671-0006 110A-49671-0007 110A-49671-0010	508 thru 524 508 thru 524 508 thru 524 508 thru 524 508 thru 524	None None None None None
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Revision April 1966		508 thru 524	None

LIST OF EFFECTIVE PAGES

Section		Drawing Title	Issue
Title			Original
ii thru v			Original
vi Blank			Original
vii			Original
viii Blank			Original
Section 1 Divider			Original
Divider Backup Blank			Original
1	2186634 (12 sheets)	Sin/Cos–Fixed Point	Original
Section 2 Divider			Original
Divider Backup Blank			Original
2	2186635 (14 sheets)	Square Root–Fixed Point	Original
Section 3 Divider			Original
Divider Backup Blank			Original
3	2186636 (14 sheets)	Exponential (2, e, 10)–Fixed Point	Original
Section 4 Divider			Original
Divider Backup Blank			Original
4	2186637 (14 sheets)	Arctangent Routine–Fixed Point	Original
Section 5 Divider			Original
Divider Backup Blank			Original
5	2186638 (13 sheets)	Log x (2, e, 10) Routine–Fixed Point	Original
Section 6 Divider			Original
Divider Backup Blank			Original
6	2186654 (7 sheets)	Floating–Point System	Original
Section 7 Divider			Original
Divider Backup Blank			Original
7	2186639 (19 sheets)	Binary Coded Decimal to Floating Point Binary	Original
Section 8 Divider			Original
Divider Backup Blank			Original
8	2186640 (18 sheets)	Floating Point Binary to BCD Floating Format	Original
Section 9 Divider			Original
Divider Backup Blank			Original
9	2186641 (14 sheets)	Floating Point Add or (Subtract)	Original
Section 10 Divider			Original
Divider Backup Blank			Original
10	2186642 (12 sheets)	Floating Point Multiplication	Original
Section 11 Divider			Original
Divider Backup Blank			Original
11	2186643 (14 sheets)	Floating Point Divide	Original

* The asterisk indicates pages changed, added, or deleted by the current change.

LIST OF EFFECTIVE PAGES

Section		Drawing Title	Issue
Section 12 Divider			Original
Divider Backup Blank			Original
12	2186644 (14 sheets)	Floating Point Square Root	Original
Section 13 Divider			Original
Divider Backup Blank			Original
13	2186645 (18 sheets)	Floating Point Sine or Cosine	Original
Section 14 Divider			Original
Divider Backup Blank			Original
14	2186646 (18 sheets)	Floating Point Arctangent	Original
Section 15 Divider			Original
Divider Backup Blank			Original
15	2186647 (18 sheets)	Floating Point Common Logarithm or (Natural Logarithm)	Original
Section 16 Divider			Original
Divider Backup Blank			Original
16	2186648 (16 sheets)	Floating Point Exponential E^X	Original
Section 17 Divider			Original
Divider Backup Blank			Original
17	2186649 (19 sheets)	Floating Point Tangent or (Cotangent)	Original
Section 18 Divider			Original
Divider Backup Blank			Original
18	2186650 (13 sheets)	Double Precision Divide	Original

* The asterisk indicates pages changed, added, or deleted by the current change.

CONTENTS

PREFACE

This manual presents Mathematical Subroutines which are used to assist both the RCA 110A programmer and machine operator in the writing and debugging of programs. Each subroutine includes a description, a flow chart, and a symbolic listing.

The fixed-point routines can be called and executed independently of each other using the SLAP 2 System, or may be assembled with the program.

The floating-point routines may also be called and executed by the SLAP 2 System, but care should be taken to call each routine needed to run the desired routine. As an example, in order to use the Floating Point Common Logarithm both FLG and DVD would have to be called.

These routines will be periodically revised and supplemented to increase the working tools available to the RCA 110A user.

SECTION 1
SIN/COS–FIXED POINT

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

DRAWN DATE
31 AUG 65

CHECKED DATE
19 SEP 65

DESIGN ACTIVITY APPD REL
1 SEPT 65

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
SIN/COS - FIXED POINT

SIZE	CODE IDENT NO.	
A	49671	2186634

WEIGHT LB

SHEET 1 OF 12

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				1	2		2186634-1	SIN/COS - FIXED POINT	
								SYMBOLIC CARD DECK	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP - 2 SYSTEM	
				X	4		CDV 86634	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								SIN/COS - FIXED POINT	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186634

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

SIN/COS - FIXED POINT

Prepared Under Contract NAS 8-13007
For
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186634
	SCALE		SHEET 3

DEL 1263-3A (2/65)

TABLE OF CONTENTS

1.0 Introduction

The purpose of the fixed point Sin/Cos subroutine is to calculate the sine or cosine of an argument X where $-360° \leq X \leq 360°$.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86634. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

2.0 Mathematical Method

The following expression was used to evaluate the Sin X.

$$\sum_{1}^{5} C_{2K-1} X^{2K-1} \quad \text{for } 0° \leq X \leq 90°$$

where

$C_1 = 1.5707963$

$C_2 = -.64596371$

$C_5 = .07968968$

$C_7 = -.00467377$

$C_9 = .00015148$

Cos X = SIN (X +90°)

Maximum absolute error is less than 10^{-6}.

3.0 Program Operation

3.1 Program Assembly and Loading

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object program card deck, a product of the SLAP 2 assembly, to load the program into core memory.

3.2 Program Control

This program is used as a subroutine by a control program.

3.2.1 Control Program

3.2.1.1 Calling Sequence

Location	OP Code	Address
a	LDL	Argument (see below)
a+1	TSP	SIN or COS (see below)
a+2	Return	

Argument: The fixed point argument in fraction of a circle is scaled at 0 (binary point between bits 23 and 22)
SIN - Symbolic entrance in the sine sub-routine
COS - Symbolic entrance in the Cosine sub-routine

4.0 Output Format

The result of the calculation will be in the left (L) accumulator scaled at 1 (binary point between bits 22 and 21).

Error Alarm - None

5.0 Memory Requirements

See Program listing
Index Registers used - None

6.0 Sin/Cos - Fixed Point Card Deck

The symbolic source card deck for this program is 2186634-1.

7.0 Appendices

7.1 Flow Chart

Flow chart for this program is in Appendix A.

8.0 Tables

8.1 Program Listing

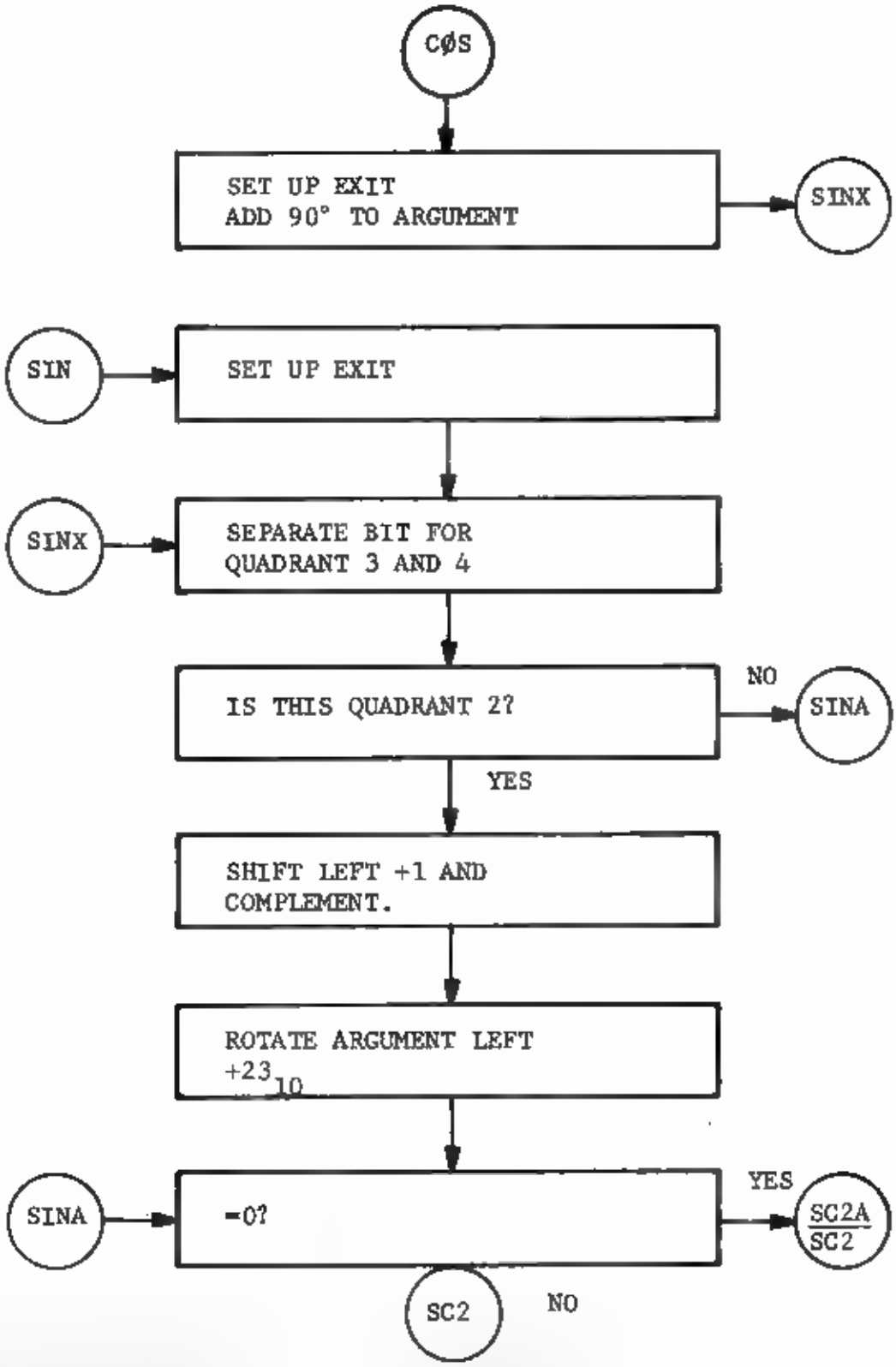
A list of this program showing memory locations (relative to zero) octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

SIN/COS - FIXED POINT

FLOW CHARTS



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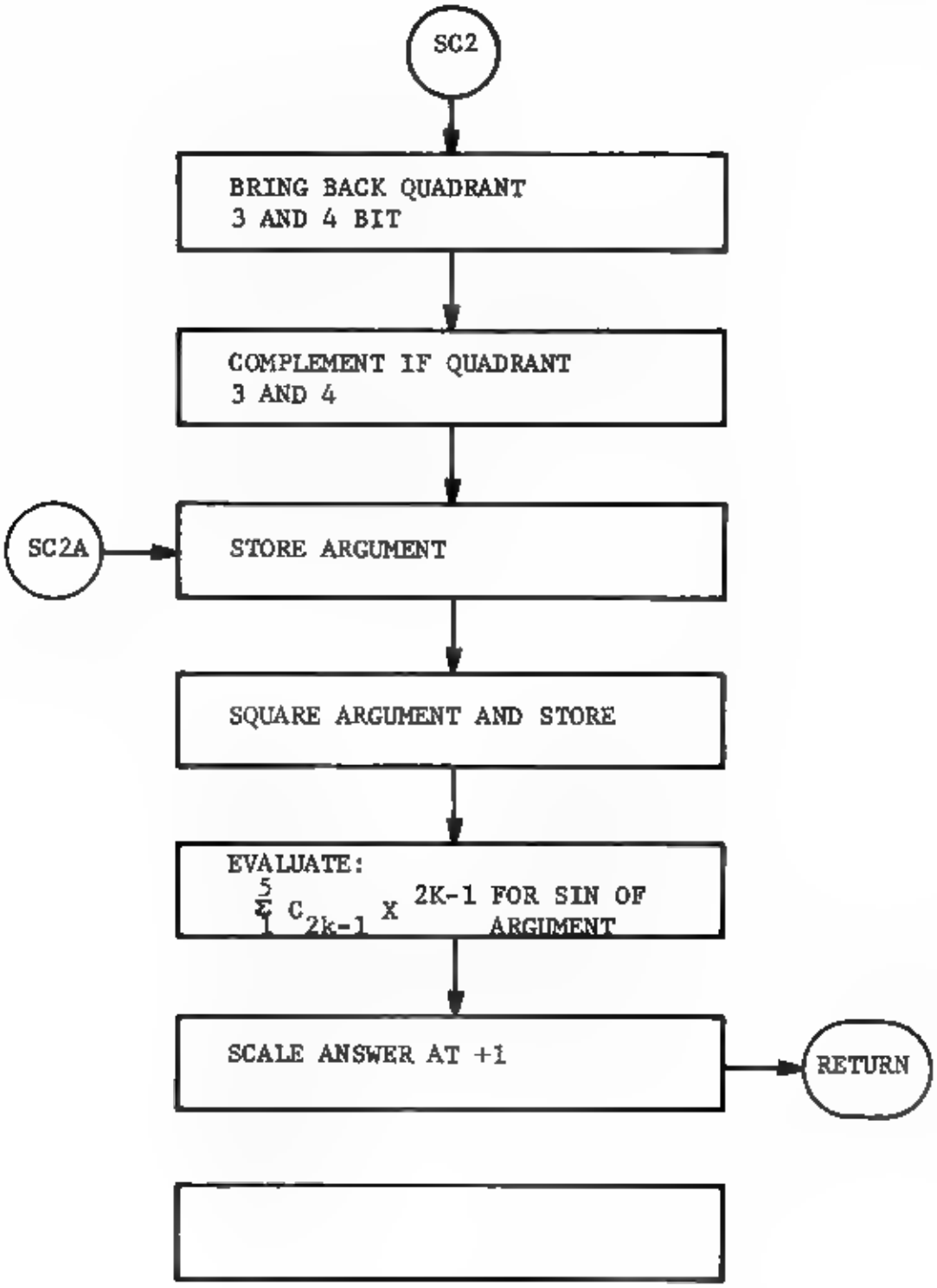
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 9

DEL 1263-3A (2/65)



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.XX = ± .XXX = ±	A	49671	2186634
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 10

DEL 1263-3A (2/65)

TABLE I

SATURN GROUND COMPUTER SYSTEM

SIN/COS - FIXED POINT

PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186634
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET //

DEL 1263-3A (2/65)

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*	SINE C@SINE		00010
00000	00000000		$C@S	NUM	0	RETURN L@CATI@N	00310
00001	517 0 0030			RBL	+24	ARGUMENT REPLACES R	00320
00002	401 0 0000	1		LDL	C@S	L@AD RETURN L@CATI@N	00330
00003	431 0 0042	1		STE	SIN1-1	ST@RE IN EXIT ADDRESS	00340
00004	517 0 0030			RBL	+24	ARGUMENT REPLACES L	00350
00005	100 0 0050	1		ADD	=0100000000	ADD 90 DEGREES	00360
00006	357 0 0014	1		TRA	SINX		00370
00007	00000000		$SIN	NUM	0	RETURN L@CATI@N	00380
00010	517 0 0030			RBL	+24	ARGUMENT REPLACES R	00390
00011	401 0 0007	1		LDL	SIN	L@AD RETURN L@CATI@N	00400
00012	431 0 0042	1		STE	SIN1-1	ST@RE IN EXIT L@CATI@N	00410
00013	517 0 0030			RBL	+24	ARGUMENT REPLACES R	00420
00014	402 0 0051	1	SINX	LDR	=0	ZER@R	00430
00015	517 0 0056			RBL	+46	SEPERATE BIT F@R QUADRANT 3 AND 4	00440
00016	256 00022	2		JPZ	SINA	TRANSFER IF N@T QUADRANT 2	00450
00017	511 0 0001			SLL	+1	ZER@ SIGN BIT	00460
00020	160 0 0000			CML	+*	C@MPLEMENT IF QUADRANT 2	00470
00021	515 0 0027			RLL	+23		00480
00022	252 00025	2	SINA	JRZ	*+3	CONTINUE IF ZER@	00490
00023	517 0 0001			RBL	+1	BRING BACK QUADRANT 3 AND 4 BIT	00500
00024	162 0 0000			CLN	**	C@MPLEMENT IF QUADRANT 3 @R 4	00510
00025	421 0 0000	1		STL	C@S	ST@RE ARGUMENT SCALED AT 1	00520
00026	120 0 0000	1		MPY	C@S	SQUARE X	00530
00027	421 0 0007	1		STL	SIN	ST@RE X SQUARED SCALED AT 2	00540
00030	120 0 0047	1		MPY	SIN9	SCALED AT -4	00550
00031	100 0 0046	1		ADD	SIN7		00560
00032	120 0 0007	1		MPY	SIN	SCALED AT -2	00570
00033	100 0 0045	1		ADD	SIN5		00580
00034	120 0 0007	1		MPY	SIN	SCALED AT 0	00590
00035	100 0 0044	1		ADD	SIN3		00600
00036	120 0 0007	1		MPY	SIN	SCALED AT + 2	00610
00037	100 0 0043	1		ADD	SIN1		00620
00040	120 0 0000	1		MPY	C@S	SCALED AT + 3	00630
00041	500 0 0054			RBA	+44	ANSWER SCALED AT 1	00640
00042	257 00000			JRA	**		00650
00043	14441767		SIN1	NUM	014441767	1.5707963 AT 2	00660
00044	53250420		SIN3	NUM	053250420	-.06459637 AT 0	00670
00045	12146426		SIN5	NUM	012146426	.0796817 AT -2	00680
00046	75466632		SIN7	NUM	075466632	-.0046738 AT -4	00690
00047	00236660		SIN9	NUM	0236660	.0001515 AT -9	00700
				END			00710
00050	10000000						
00051	00000000						

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XX = ± XXX = ±
FRACTIONS = ± ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186934

SCALE | SHEET /2

DEL 1263-3A (2/60)

SECTION 2

SQUARE ROOT–FIXED POINT

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SH 5; SECTION 2.0, LINE 3 WAS "WHERE 1> f >.25". LINE 7 WAS $Y_{i+1} = 1/2\ (Y_1 + {}^f/Y_i)$ SH 10; BOX 1 OF FLOW CHART, "POSITION" WAS "POSITIVE". EQUATION IN BOX 4 WAS $Y_i = F + 1/4 - 1/2\ (F-1/2)$. EQUATION IN BOX 6 WAS $Y_{i+1} + 1/2\ (Y_1 + F/Y_i)$. CLASS II, DCS 642	3 FEB 66 4 FEB 66	AG Mangum J.N. Vanderford (R)

FIRST MADE FOR | USED ON 110A | NEXT ASSY

CONTRACT NO.
NAS 8-13007

DRAWN — DATE
E.M. Stange — 31 AUG 65

CHECKED — DATE
[illegible] — 31 AUG 65

DESIGN ACTIVITY APPD — REL (R)
J.N. Vanderford 31 AUG 65

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
SQUARE ROOT – FIXED POINT

SIZE	CODE IDENT NO.	
A	49671	2186635

WEIGHT — LB — SHEET 1 OF 14

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAMS	
				1	2		2186635-1	SQUARE ROOT - FIXED POINT	
								SYMBOLIC CARD DECK	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				X	4		CDV86635	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								SQUARE ROOT - FIXED POINT	

RADIO CORPORATION OF AMERICA

LTR

SIZE	CODE IDENT NO.	
A	49671	2186635

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

SQUARE ROOT - FIXED POINT

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186635
	SCALE		SHEET 3

TABLE OF CONTENTS

1.0 INTRODUCTION

The fixed point Square Root routine extracts the square root from the 23 most significant bits of an argument in the left (L) and right (R) accumulators. The argument is initially normalized by the Square Root routine.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86635. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

2.0 MATHEMATICAL METHOD

Assume that the argument X is normalized

Unpack X

$$X^{1/2} = (2^{2c} \cdot f)^{1/2} = 2^{c} \cdot f^{1/2} \text{ where } 1 > f \geq .25$$

The first fractional approximation, Y_o, to $f^{1/2}$ is given by $f + 1/4 - 1/2\ (f - 1/2)^2$. This is then followed by three Newtonian iterations of the form:

$$Y_{i+1} = 1/2(Y_i + f/Y_i)$$

Maximum relative error is less than 10^{-6}.

3.0 PROGRAM OPERATION

3.1 Program Assembly and Loading

This program is assembled by the SLAP2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object card deck, a product of the SLAP 2 assembly, to load the program into core memory.

3.2 Program Control

This program is used as a subroutine by a control program.

3.2.1 Control Program

3.2.1.1 Calling Sequence

LOCATION	OP CODE	ADDRESS	
a	-	Argument	(see below)
a + 1	TSP	SQR	(see below)
a + 2	Return		

Argument: The fixed point argument is in the left (L) and right (R) accumulators, scaled at an even number, Q.

SQR - Symbolic entrance in the Square Root subroutine.

4.0 OUTPUT FORMAT

The square root of the argument will be in the L, R accumulators scaled at Q/2.

Error Alarm: If the argument is negative, the square root of the absolute value appears in the L, R accumulators scaled at Q/2 and the overflow indicator is set.

5.0 MEMORY REQUIREMENTS

See Program listing
Index Registers used - none

6.0 SQUARE ROOT - FIXED POINT - CARD DECK

The symbolic source card deck for this program is 2186635-1.

7.0 APPENDICES

7.1 Flow Chart

Flow Chart for this program is in Appendix A.

8.0 TABLES

8.1 Program Listing

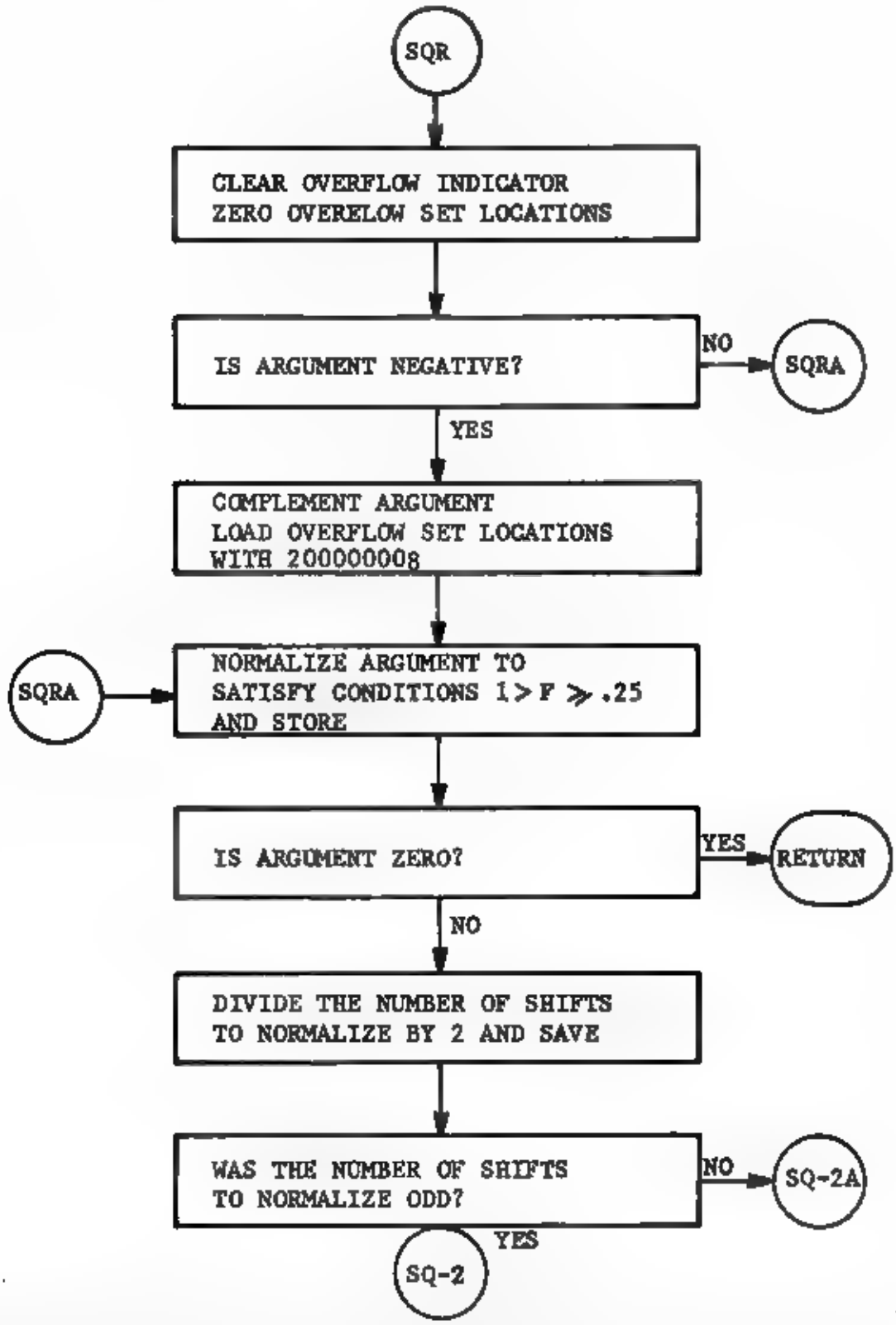
A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

SQUARE ROOT - FIXED POINT

FLOW CHARTS



SQ-1

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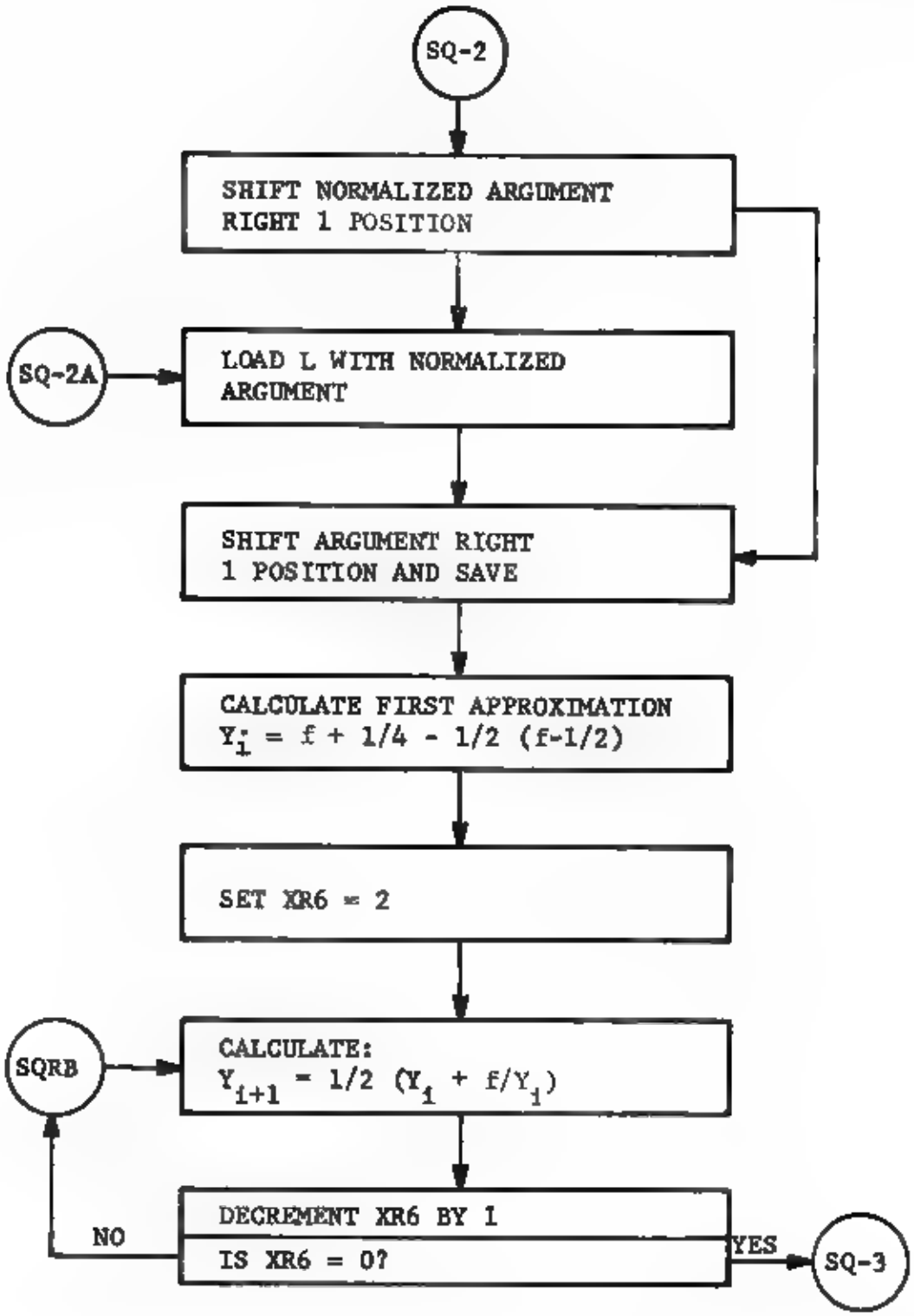
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 9

DEL 1263-3A (2/65)

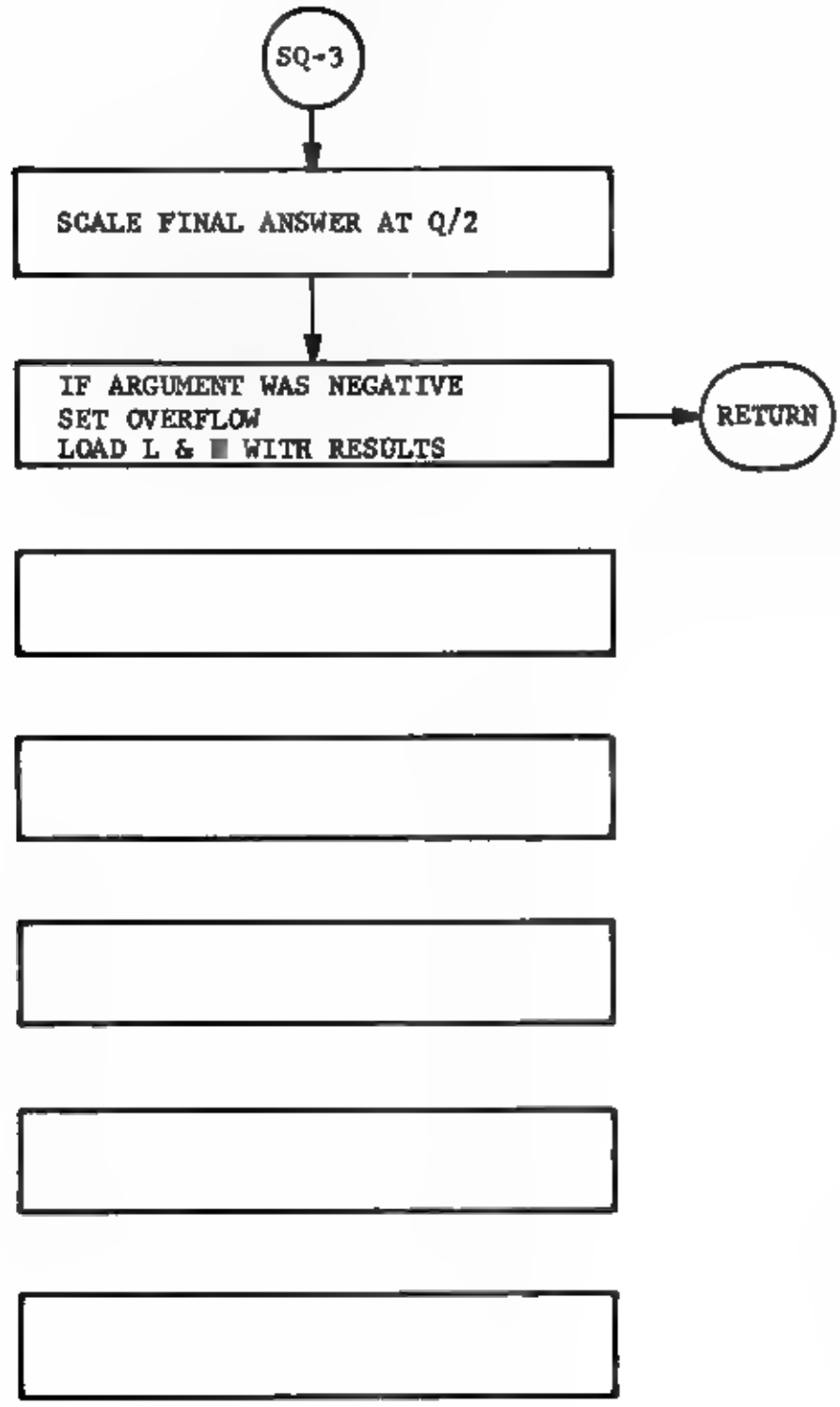


SQ-2

RADIO CORPORATION ■ AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE ■ INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186635
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 10

DEL 1263-3A (2/65)



SQ-3

RADIO CORPORATION ■ AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186635
XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET //

DEL 1263-3A (2/65)

TABLE I

SATURN GROUND COMPUTER SYSTEM

SQUARE ROOT - FIXED POINT

PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186635
	SCALE		SHEET /2

INST. LOC. OCTAL	MEMORY OCTAL	REL TYPE		SYMBOLIC CARD CONTENT		CARD NO.
			*	SQUARE ROOT		00010
						00310
00000	00 0 00000		$SQR	**5	0	00320
00001	250 00002	2		J0F	**+1	CLEAR OVERFLOW INDICATOR	00330
00002	421 0 0065	1		STL	SQRT		00340
00003	420 0 0067	1		STZ	SQR0	INITIALIZE FLAG	00350
00004	356 0 0012	1		TPZ	SQRA	IS ARGUMENT NEGATIVE	00360
00005	161 0 0000			CMB	**	YES, COMPLEMENT	00370
00006	421 0 0065	1		STL	SQRT		00380
00007	401 0 0073	1		LDL	=0?0000000		00390
00010	421 0 0067	1		STL	SQR8	SET FLAG TO DENOTE NEG. ARGUMENT	00400
00011	401 0 0065	1		LDL	SQRT		00410
00012	520 0 0070	1	SQRA	NRM	SQRN	NORMALIZE ARGUMENT	00420
00013	520 0 0071	1		NRM	SQRM		00430
00014	352 7 0000	1		TRZ	SQR.7	NORMAL EXIT IF ARGUMENT IS ZERO	00440
00015	421 0 0065	1		STL	SQRT		00450
00016	401 0 0070	1		LDL	SQRN		00460
00017	100 0 0071	1		ADD	SQRM		00470
00020	515 0 0001			RLL	+1	NUMBER OF SHIFTS FOR NORMALIZATION/2	00480
00021	430 0 0055	1		STA	SQR5	SAVE FOR FINAL RESCALING	00490
00022	356 0 0026	1		TPZ	**4	WAS THE NO. OF SHIFTS ODD	00500
00023	401 0 0065	1		LDL	SQRT	YES	00510
00024	501 0 0001			SBA	+1	SHIFT ARGUMENT (F) RIGHT ONE PLACE	00520
00025	357 0 0027	1		TRA	**2		00530
00026	401 0 0065	1		LDL	SQRT		00540
00027	501 0 0001			SBA	+1	F AT 1	00550
00030	421 0 0065	1		STL	SQRT		00560
00031	110 0 0074	1		SUB	=010000000	(F-1/2) AT 1	00570
00032	421 0 0070	1		STL	SQRN		00580
00033	120 0 0070	1		MPY	SQRN	(F-1/2) SQUARED AT 2	00590
00034	160 0 0000			CML	**	-1/2 (F-1/2)**2 AT 1	00600
00035	100 0 0075	1		ADD	=04000000	1/4-1/2(F-1/2)**2 AT 1	00610
00036	100 0 0065	1		ADD	SQRT	F-1/4-1/2(F-1/2)**2AT 1 = Y1, FIRST GUESS	00620
00037	421 0 0070	1		STL	SQRN		00630
00040	405 0 0006			LDL@	6		00640
00041	421 0 0072	1		STL	SQR6		00650
00042	401 0 0076	1		LDL	=2		00660
00043	425 0 0006			STL@	6		00670
00044	401 0 0065	1	SQR8	LDL	SQRT	F AT 1	00680
00045	501 0 0001			SBA	+1	F AT 2	00690
00046	402 0 0077	1		LDR	=0		00700
00047	130 0 0070	1		DVD	SQRN	F AT 2/Y AT 1	00710
00050	100 0 0070	1		ADD	SQRN	(Y1 + F/Y1) AT 1	

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
.XX = ±
.XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186935

SCALE | SHEET 13

DEL 1263-3A (2/65)

```
00051  501 0 0001                    SBA     +1              1/2 (Y|+F/Y|) AT 1                      00720
00052  421 0 0070   1                 STL     SQRN                                                    00730
00053  31 1 6 0044  1                 TXD     SQR8,6,1                                                00740
00054  500 0 0055                     RBA     +45                                                     00750
00055  501 0 0000             SQRS    SBA     **              FINAL RESCALING                         00760
00056  423 0 0065   1                 STB     SQRT                                                    00770
00057  401 0 0067   1                 LDL     SQR8                                                    00780
00060  100 0 0067   1                 ADD     SQR8            SET OVERFLOW INDICATOR                  00790
00061  401 0 0072   1                 LDL     SQR6                                                    00800
00062  42> 0 0006                     STL@    6                                                       00810
00063  403 0 0065   1                 LDB     SQRT                                                    00820
00064  557 7 0000   1                 TRA     SQR.7                                                   00830
00065  00000000               SQRT    NUM     0.0                                                     00840
00066  00000000
00067  00000000               SQR8    NUM     0                                                       00850
00070  00000000               SQRN    NUM     0                                                       00860
00071  00000000               SQRM    NUM     0                                                       00870
00072  00000000               SQR6    NUM     0                                                       00880
                                      END                                                             00890
00073  20000000
00074  10000000
00075  04000000
00076  00000002
00077  00000000
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET 14

2186635

DEL 1263-3A (2/65)

SECTION 3

EXPONENTIAL (2, e, 10)–FIXED POINT

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SH 11, ADDED EXP-3A TO ENTRANCE TO BOX 2. ADDED FLOW CHART SH NO. EXP-3. CLASS II, DCS 642	7 FEB 66 9 FEB 66	

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS-8-13007

DRAWN DATE
E.R. Hansen 31 AUG 65

CHECKED DATE
31 AUG 65

DESIGN ACTIVITY APPD
J.N. Vandegrift 31 AUG 65

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

EXPONENTIAL (2,e,10) - FIXED POINT

SIZE	CODE IDENT NO.	
A	49671	2186636

WEIGHT LB SHEET 1 OF 14

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAMS	
				1	2		2186636-1	EXPONENTIAL (2,e,10)-FIXED POINT	
								SYMBOLIC CARD DECK	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP - 2 SYSTEM	
				X	4		CDV86636	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								EXPONENTIAL (2,e,10)-FIXED POINT	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186636

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

EXPONENTIAL (2,e,10) - FIXED POINT

Prepared Under Contract NAS8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186636
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 3

DEL 1263-3A (2/65)

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of the fixed point Exponential routine is to calculate the exponential to the base 2, e or 10 of an argument, X.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86636. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

2.0 MATHEMATICAL METHOD

The argument is first converted to its base 2 equivalent using the identity:

$$k^x \equiv 2^{x \log_2 k};\ k = e,\ 10.$$

The result is then shifted to a scaling of 23 to obtain the form

$$2^{i.f} \equiv 2^i \quad 2^{.f}$$

where i and f are the integral and fractional parts of the argument.

The following polynominal is used to compute $2^{.f}$

$$\left[\sum_{k=0}^{6} C_k X^k\right]^2$$

$C_0 = 1.0000000$
$C_1 = .34657210$
$C_2 = .06006622$
$C_3 = .00691806$
$C_4 = .00061973$
$C_5 = .000033177$
$C_6 = .000004208$

and i is used to scale the result since 2^i may be accomplished by a shift in a binary machine.

For $X \geq 0$, the relative error is no greater than 10^{-6} in magnitude. For $X < 0$, the absolute error does not exceed 10^{-6}.

3.0 PROGRAM OPERATION

3.1 Program Assembly and Loading

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object card deck, a product of the SLAP 2 assembly, to load the program into core memory.

3.2 Program Control

This program is used as a subroutine by a control program.

3.2.1 Control Program

3.2.1.1 Calling Sequence

Location	OP Code	Address
a	-	Argument (see below)
a + 1	TSP	Entry Points (see below)
a + 2	Return	

Argument - The fixed point argument is in the left (L) accumulator. The scaling of the argument is in the right (R) accumulator scaled at 23. The approximate maximum values are listed below:

Base	X Max.
2	22.99999
e	15.94238
10	6.923689

Entry Points: The program has three entry points. Select one of the symbolic entry points listed below depending upon the base desired.

Base	Entry
2	EX2
e	EXE
10	EX10

4.0 OUTPUT FORMAT

The result is in the L, R accumulators scaled at 23.

Error Alarm: If the value of the argument is such that its exponential value exceeds the capacity of the L accumulator, the overflow indicator is set and the L, R accumulators contain erroneous data.

5.0 MEMORY REQUIREMENTS

See Program listing.
Index Registers Used - None

6.0 EXPONENTIAL - FIXED POINT - CARD DECK

The symbolic source card deck for this program is 2186636-1.

7.0 APPENDICES

7.1 Flow Chart

The flow chart for this program is in Appendix A.

8.0 TABLES

8.1 Program Listing

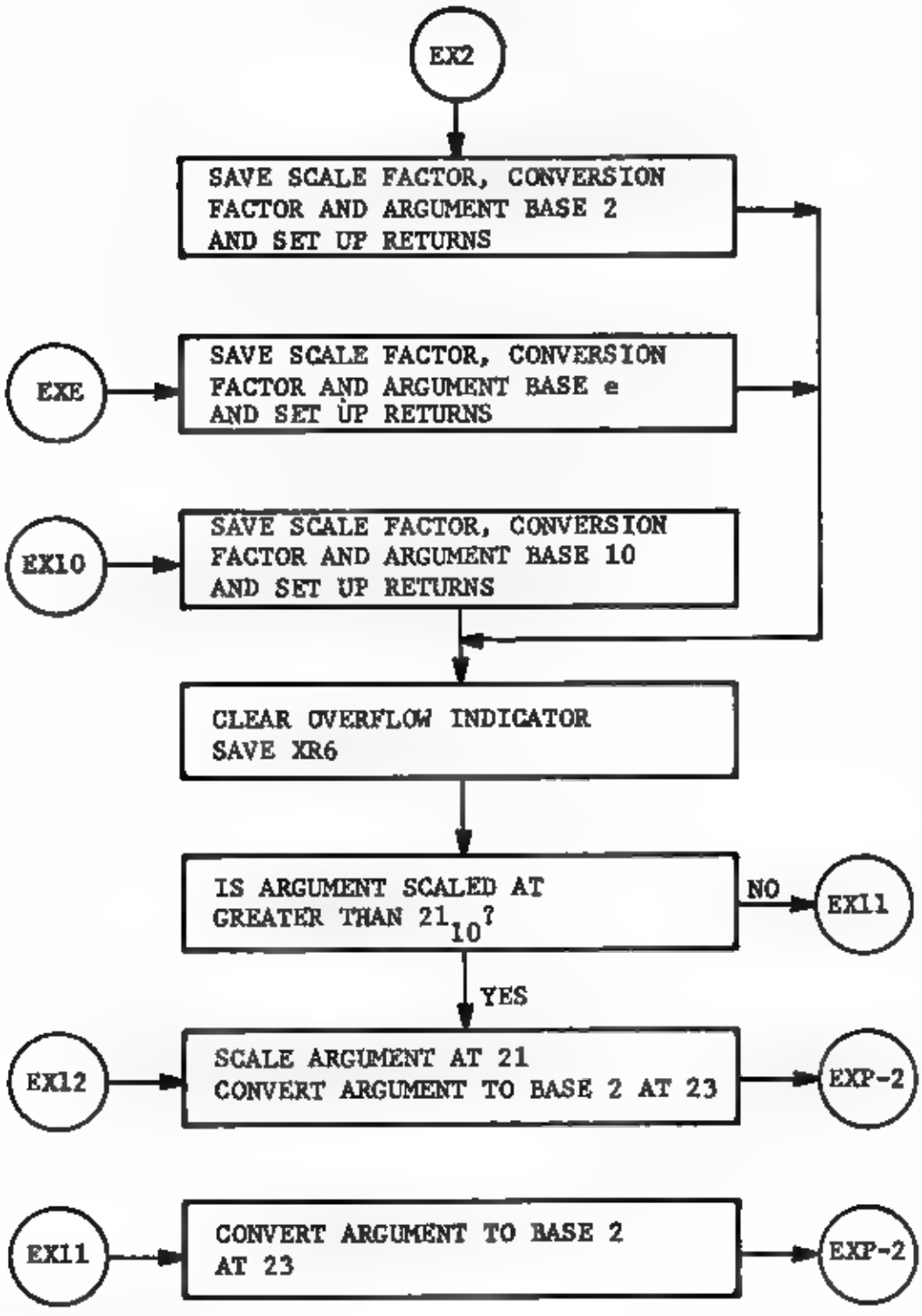
A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

EXPONENTIAL (2,e,10) - FIXED POINT

FLOW CHARTS

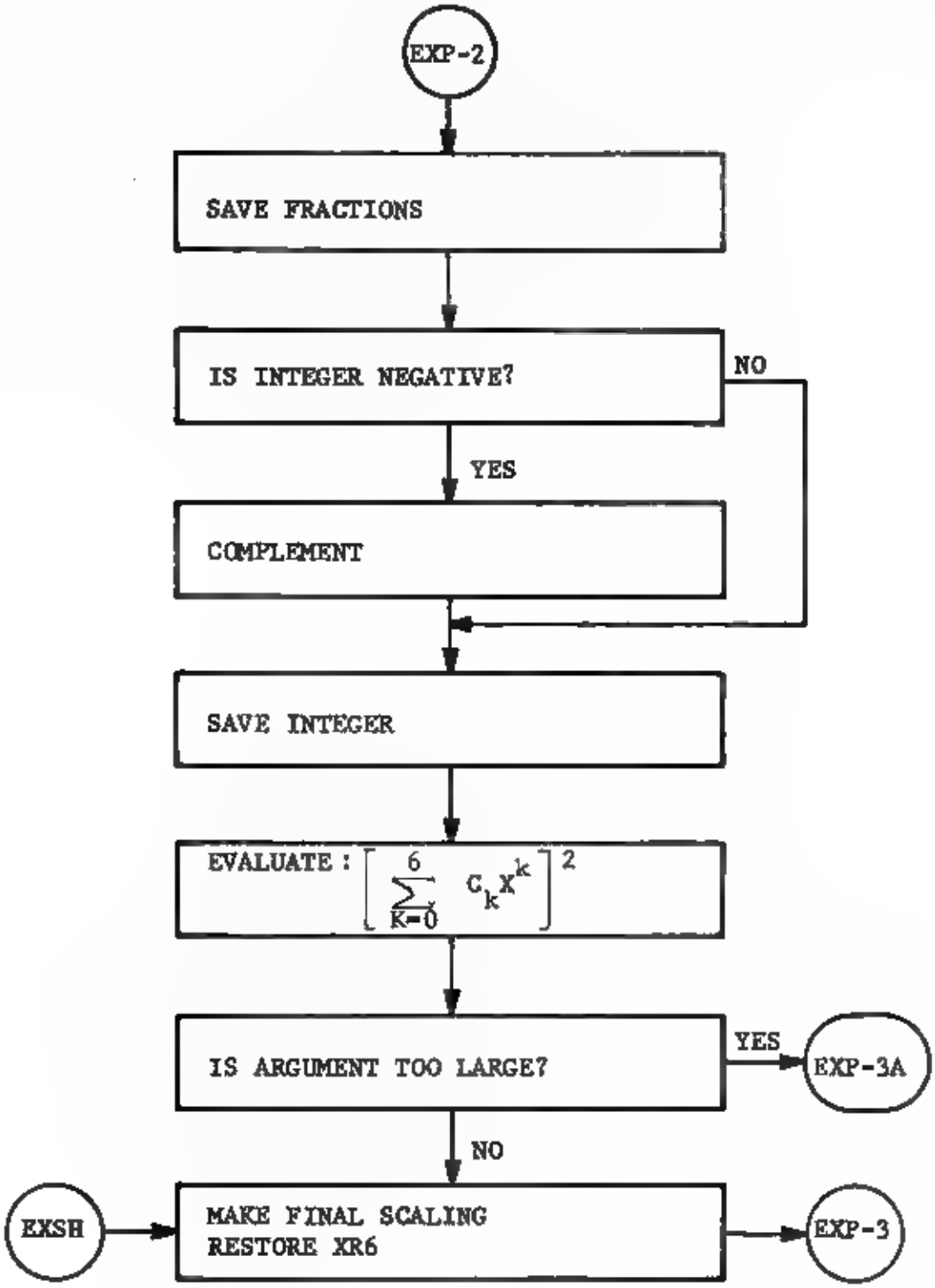


EXP-1

RADIO CORPORATION OF AMERICA

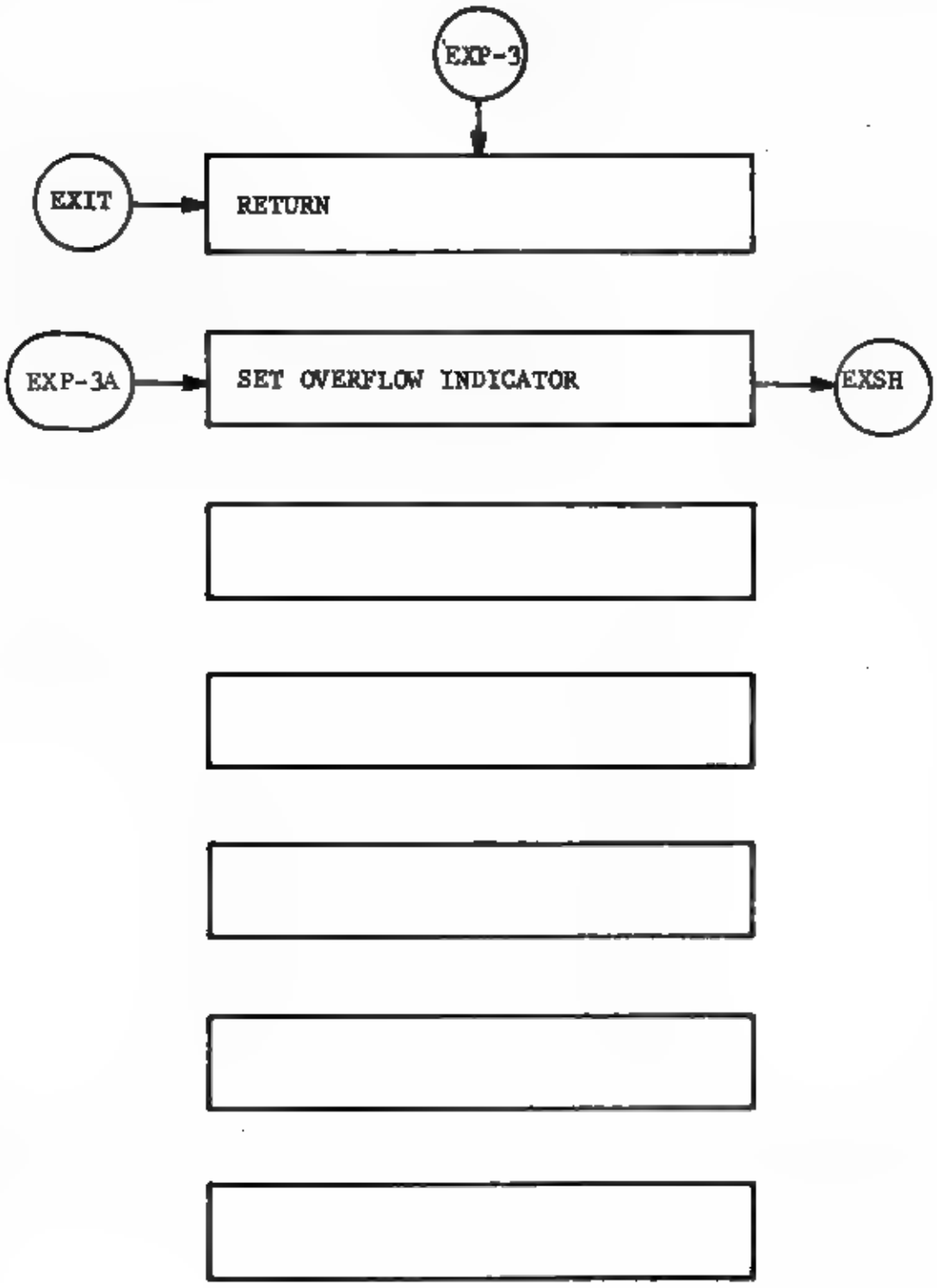
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE ■ INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186636
	SCALE		SHEET 9

DEL 1263-3A (2/66)



EXP-2

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186636
	SCALE		SHEET 10



EXP-3

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186636
XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET //

DEL 1263-3A (2/65)

TABLE I

SATURN GROUND COMPUTER SYSTEM

EXPONENTIAL (2,e,10) - FIXED POINT

PROGRAM LISTING

INST. LOC OCTAL	MEMORY OCTAL	REL TYPE	SYMBOLIC CARD CONTENT				CARD NO.
			*		EXPONENTIAL-(2,E,10)		00010
00000	00000000		$EX2	NUM	0	RETURN LOCATION	00310
00001	423 0 0100	1		STO	EXSF	SAVE SCALE FACTOR AND ARGUMENT BASE 2	00320
00002	402 0 0106	1		LDR	EXC11		00330
00003	357 0 0016	1		TRA	EX10+4		00340
00004	13425217		EXC21	NUM	013425217	LOG BASE 2 OF E AT 2	00350
00005	00000000		$EXE	NUM	0		00360
00006	423 0 0100	1		STO	EXSF	SAVE SCALE FACTOR AND ARGUMENT BASE E	00370
00007	403 0 0004	1		LDQ	EXC21		00380
00010	357 0 0015	1		TRA	EX10+3		00390
00011	32446474		EXC31	NUM	032446474	LOG BASE 2 OF 10 AT 2	00400
00012	00000000		$EX10	NUM	0		00410
00013	423 0 0100	1		STO	EXSF	SAVE SCALE FACTOR AND ARGUMENT BASE 10	00420
00014	403 0 0011	1		LDQ	EXC31		00430
00015	421 0 0000	1		STL	EX2	SAVE RETURN ADDRESS	00440
00016	422 0 0104	1		STR	EXCF	STORE CONVERSION FACTOR	00450
00017	250 00020	2		JOF	*+1	CLEAR OVERFLOW INDICATOR	00460
00020	405 0 0006			LDL0	6		00470
00021	421 0 0102	1		STL	EXR6	SAVE CONTENTS OF INDEX 6	00480
00022	401 0 0100	1		LDL	EXSF	IS ARGUMENT SCALED AT	00490
00023	110 0 0116	1		SUB	=025	GREATER THAN 21	00500
00024	425 0 0006			STL0	6		00510
00025	353 0 0033	1		TNZ	EX11	■	00520
00026	401 0 0101	1	EX12	LDL	EXAG	YES	00530
00027	402 0 0117	1		LDR	=0		00540
00030	500 6 0056			RBA	*46,6	SCALE ARGUMENT LEFT TO 21	00550
00031	120 0 0104	1		MPY	EXCF	CONVERT ARGUMENT TO BASE 2 AT 23	00560
00032	357 0 0036	1		TRA	EX11+3		00570
00033	401 0 0101	1	EX11	LDL	EXAG		00580
00034	120 0 0104	1		MPY	EXCF	CONVERT ARGUMENT TO BASE 2	00590
00035	501 6 0000			SBA	0,6	SCALE TO 23	00600
00036	422 0 0100	1		STR	EXSF	SAVE FRACTIONAL PART, F	00610
00037	356 0 0042	1		TPZ	*+3		00620
00040	161 0 0000			CMB	**		00630
00041	160 0 0000			CNL	**		00640
00042	421 0 0103	1		STL	EXJ	SAVE INTEGER PART	00650
00043	401 0 0120	1		LDL	=5		00660
00044	425 0 0006			STL0	6		00670
00045	400 0 0000			LDZ	**	EVALUATE POLYNOMIAL	00680
00046	100 6 0114	1		ADD	EXC1,6		00690
00047	120 0 0100	1		MPY	EXSF		00700
00050	31 1 6 0046	1		TXD	*-2,6,1		00710

RADIO CORPORATION OF AMERICA

```
00051  501 0 0001            SRA   *1                                    00720
00052  100 0 0115  1         ADD   EXC0                                  00730
00053  421 0 0100  1         STL   EXSF                                  00740
00054  120 0 0100  1         MPY   EXSF        2**F*2                    00750
00055  520 0 0105  1         NRM   EXN         NØRMALIZE                 00760
00056  421 0 0100  1         STL   EXSF                                  00770
00057  401 0 0103  1         LDL   EXI                                   00780
00060  110 0 0121  1         SUB   *027        IS ARGUMENT TØØ LARGE     00790
00061  356 0 0075  1         TPZ   EXIT+1      YES, ERRØR                00800
00062  100 0 0122  1         ADD   *2          NØ                        00810
00063  160 0 0000            CML   **                                    00820
00064  100 0 0105  1         ADD   EXN                                   00830
00065  430 0 0067  1         STA   EXSH                                  00840
00066  401 0 0100  1         LDL   EXSF                                  00850
00067  501 0 0000     EXSH   SRA   **          FINAL SCALING             00860
00070  421 0 0100  1         STL   EXSF                                  00870
00071  401 0 0102  1         LDL   EXR6                                  00880
00072  425 0 0006            STLB  6                                     00890
00073  401 0 0100  1         LDL   EXSF                                  00900
00074  357 7 0000  1  EXIT   TRA   EX2,7                                 00910
00075  401 0 0123  1         LDL   =020000000  SET ØVERFLØW ØN FØR ERRØR 00920
00076  100 0 0123  1         ADD   =020000000  INDICATØR                 00930
00077  357 0 0071  1         TRA   EXSH+2                                00940
00100  00000000       EXSF   NUM   0                                     00950
00101  00000000       EXAG   NUM   0           ARGUMENT                  00960
00102  00000000       EXR6   NUM   0           INDEX REGISTER 6          00970
00103  00000000       EXI    NUM   0           INTEGER PØRTIØN ØF ARGUMENT 00980
00104  00000000       EXCF   NUM   0           CØNVERSIØN FACTØR         00990
00105  00000000       EXN    NUM   0           NUMBER ØF SHIFTS FØR NØRMALIZATIØN 01000
00106  10000000       EXC11  NUM   010000000     LØG BASE 2 ØF 2 AT 2    01010
00107  00000044       EXC6   NUM   044         .000004208 AT 0           01020
00110  00000426       EXC5   NUM   0426        .000033177 AT 0           01030
00111  00012117       EXC4   NUM   012117      .00061973 AT 0            01040
00112  00161261       EXC3   NUM   0161261     .00691806 AT 0            01050
00113  01730100       EXC2   NUM   01730100    .06006622 AT 0            01060
00114  13056171       EXC1   NUM   013056171   .34657210 AT 0            01070
00115  20000000       EXC0   NUM   020000000   1 AT 1                    01080
                             END                                         01090

00116  00000025
00117  00000400
00120  00000005
00121  00000027
00122  00000002
00123  20000000
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186636
	SCALE		SHEET 14

DEL 1263-3A (2/65)

SECTION 4

ARCTANGENT ROUTINE–FIXED POINT

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

DRAWN DATE
Thiri 31 AUG 65

CHECKED DATE
D. A. Dillman 31 AUG 65

DESIGN ACTIVITY APPD
J.N. Vanderford 31 Aug 65

RCA **RADIO CORPORATION OF AMERICA**
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
ARCTANGENT ROUTINE-FIXED POINT

SIZE	CODE IDENT NO.	
A	49671	2186637

WEIGHT LB SHEET 1 OF 14

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAMS	
				1	2		2186637-1	ARCTANGENT ROUTINE - FIXED POINT	
								SYMBOLIC CARD DECK	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				X	4		CDV 86637	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								ARCTANGENT ROUTINE - FIXED POINT	

LTR

SIZE	CODE IDENT NO.	
A	49671	2186637

SHEET 2

RADIO CORPORATION OF AMERICA

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

ARCTANGENT ROUTINE - FIXED POINT

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

TABLE OF CONTENTS

1.0 Introduction

The purpose of the fixed point Arctangent routine is to calculate the arctangent $\frac{Y}{X}$.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86637. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

2.0 Mathematical Method

The relative magnitudes of the two arguments are first determined. If the absolute value of the contents of A is less than the absolute value of the contents of B, then $u = \frac{(A)}{(B)}$ is found and the arctangent of u computed. If the relative magnitudes are not as stated above, then $u = \frac{(B)}{(A)}$ is found and the arcotangent of u is computed. The answer at this point is in either the first or fourth quadrant. The sign of the denominator of the input variable is then inspected and, if negative, 180 degrees are added to the result to obtain the final answer.

The following approximation is used:

$$\arctan u = \sum_{1}^{7} C_{2k-1} U^{2k-1}$$

where:

$C_1 = .15914533$ $C_3 = -.05302625$ $C_5 = .03152520$

$C_7 = -.02106178$ $C_9 = .01267292$ $C_{11} = -.00534860$

$C_{13} = .00108423$

3.0 Program Operation

3.1 Program Assembly and Loading

This program is assembled by the SLAP 2 System (2186651) using this symbolic card deck for this program. The SLAP 2 Loader uses the object card deck, a product of the SLAP 2 Assembly, to load the program into core memory.

3.2 Program Control

This program is used as a subroutine by a control program

3.2.1 Control Program

3.2.1.1 Calling Sequence

Location	OP Code	Address
a	—	Argument (see below)
a + 1	TSP	ATN (see below)
a + 2	Return	

Argument - The fixed point value of the numerator, Y, is in the left (L) accumulator and the fixed point value of the denominator, X, is in the right (R) accumulator. Values Y and X may be at any scale, but the scaling must be identical.

ATN - Symbolic entrance in the arctangent subroutine.

4.0 Output Format

The value of the arctangent $\frac{Y}{X}$ will be in the left (L) accumulator in fractions of a circle scaled at 0. The result is not restricted to principal values, but may take on any value between -180° and 179.99998°.

Maximum relative error is less than 10^{-6}.

Approximate running time is 14.5 milliseconds.

5.0 Memory Requirements

See Program listing.
Index registers used - none

6.0 Arctangent - Fixed Point - Card Deck

The symbolic source card deck for this program is 2186637-1

7.0 Appendices

7.1 Flow Chart

The flow chart for this program is in Appendix A

8.0 Tables

8.1 Program Listing

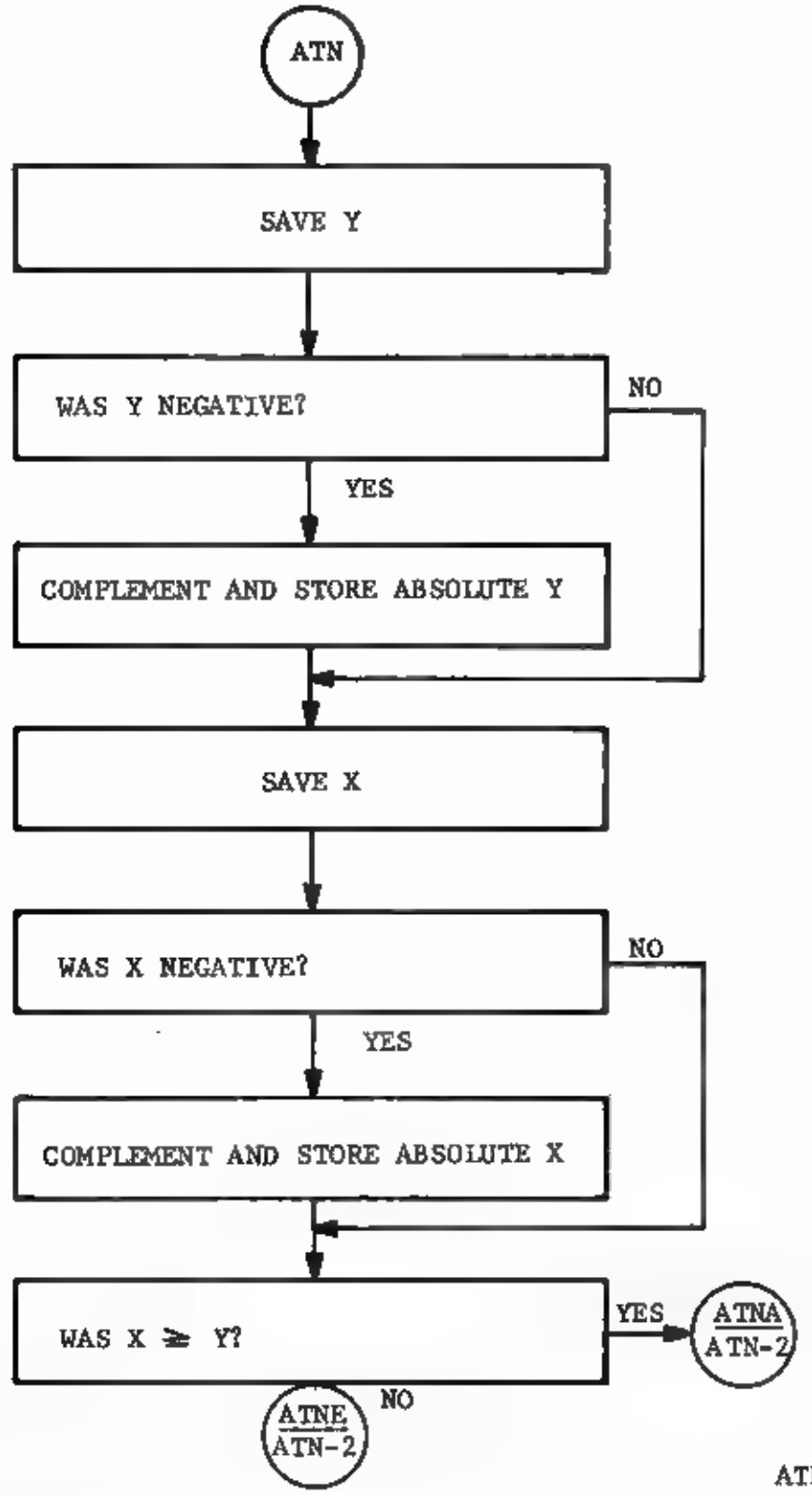
A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

ARCTANGENT ROUTINE - FIXED POINT

FLOW CHARTS

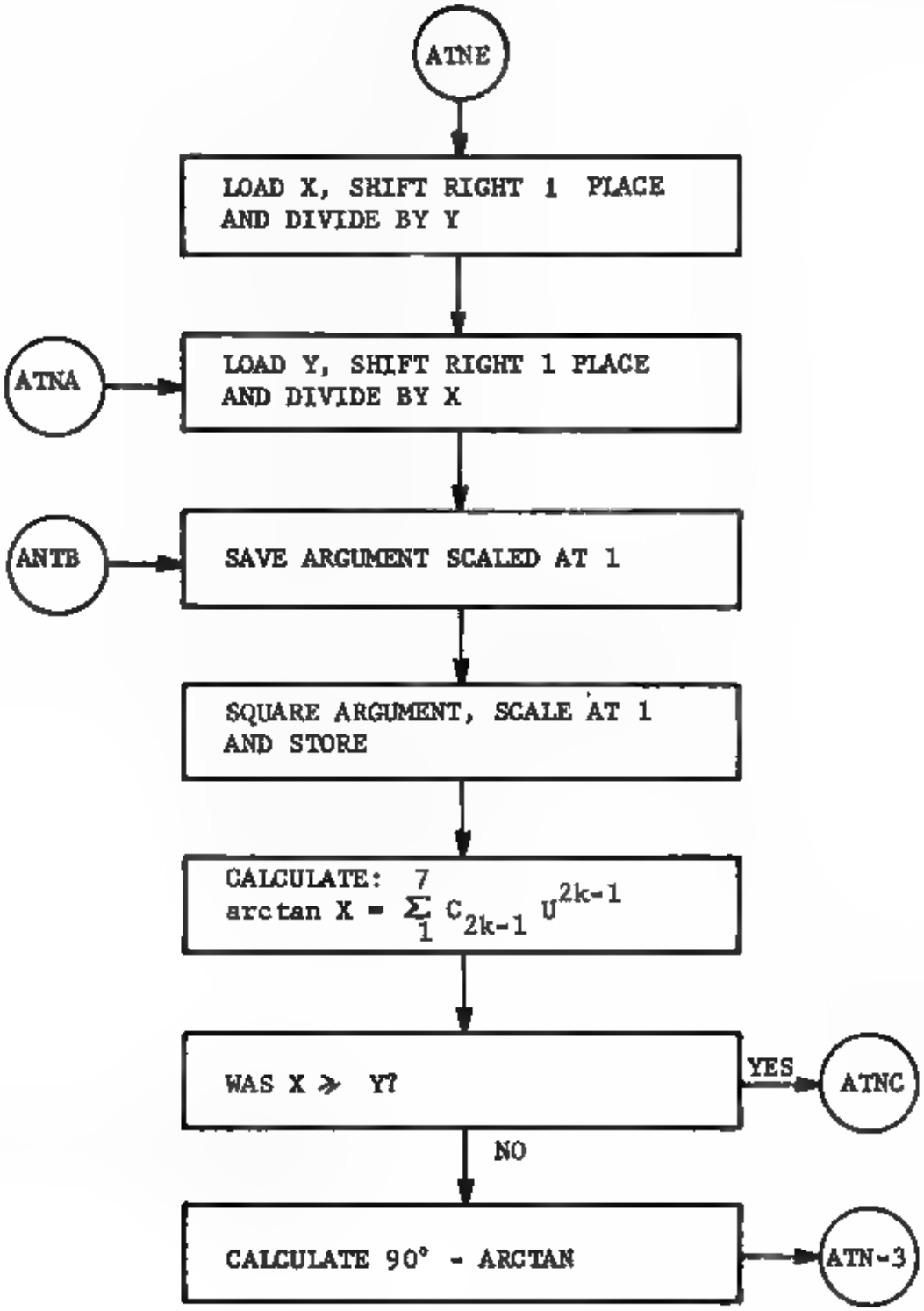


ATN-1

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186637
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 9

DEL 1263-3A (2/65)

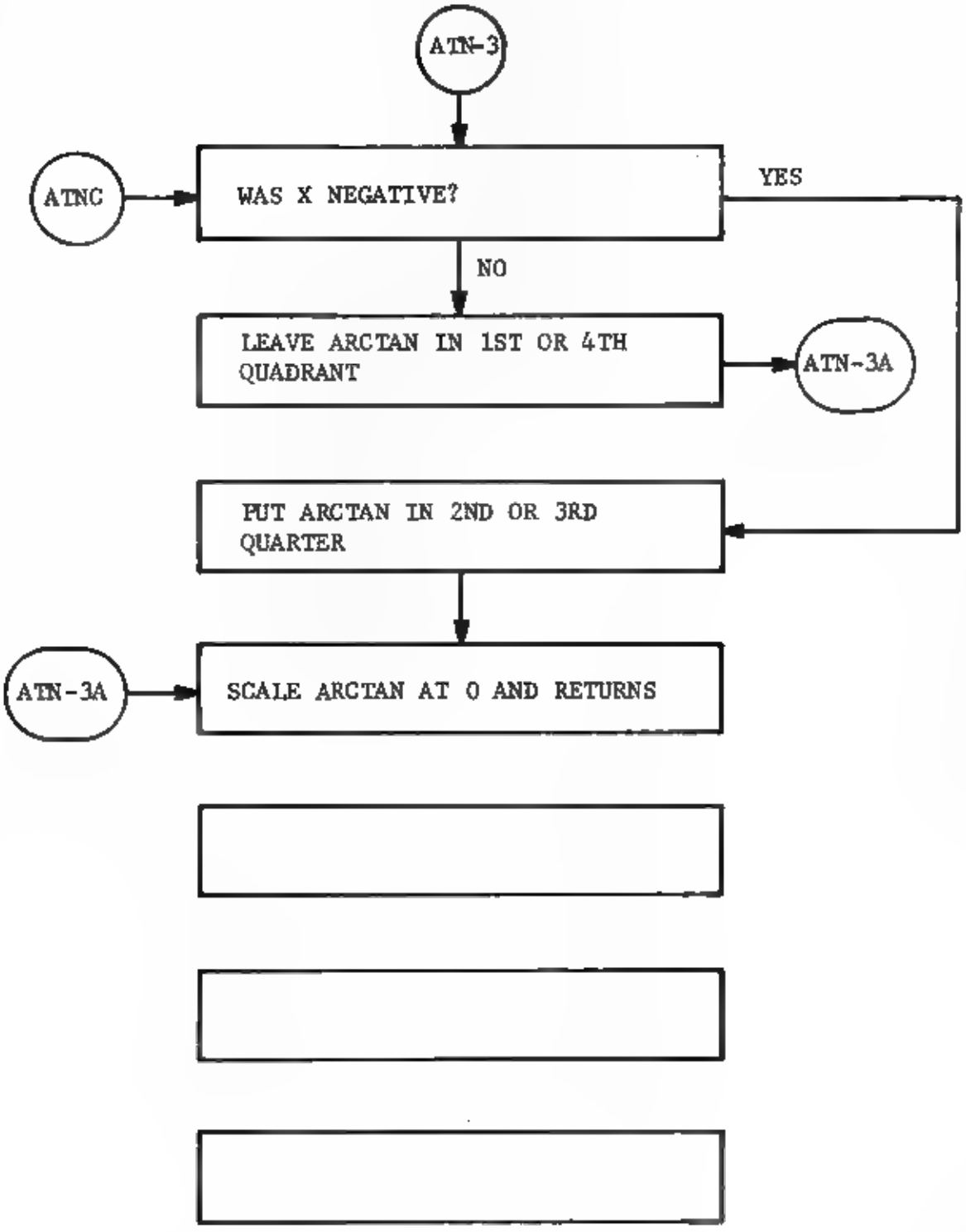


ATN-2

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186637
	SCALE		SHEET 10

DEL 1263-3A (2/65)



ATN-3

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186637
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET //

DEL 1263-3A (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

ARCTANGENT ROUTINE - FIXED POINT

PROGRAM LISTING

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186637
	SCALE		SHEET 12

INST. LOC. OCTAL	MEMORY OCTAL	REL TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*		ARC TAN	00310
00000	00 0 00000		$ATN	**5	0 EXIT	00310
00001	421 0 0064	1		STL	ATNY STORE Y	00320
00002	356 0 0004	1		TPZ	*+2	00330
00003	160 0 0000			CML	**	00340
00004	421 0 0065	1		STL	ATNV STORE ABSOLUTE VALUE OF Y	00350
00005	422 0 0063	1		STR	ATNX STORE X	00360
00006	517 0 0030			RBL	+24	00370
00007	356 0 0011	1		TPZ	*+2 GET ABSOLUTE VALUE OF X	00380
00010	160 0 0000			CML	**	00390
00011	110 0 0065	1		SUB	ATNV	00400
00012	421 0 0062	1		STL	ATNF SET FLAG	00410
00013	356 0 0020	1		TPZ	ATNA TEST FOR LARGER ELEMENT	00420
00014	401 0 0063	1		LDL	ATNX	00430
00015	501 0 0001			SBA	+1	00440
00016	130 0 0064	1		DVD	ATNY X/Y	00450
00017	357 0 0023	1		TRA	ATNB	00460
00020	401 0 0064	1	ATNA	LDL	ATNY	00470
00021	501 0 0001			SBA	+1	00480
00022	130 0 0063	1		DVD	ATNX Y/X	00490
00023	421 0 0065	1	ATNB	STL	ATNV STORE ARGUMENT SCALED AT 1	00500
00024	120 0 0065	1		MPY	ATNV	00510
00025	500 0 0055			RBA	+45	00520
00026	421 0 0066	1		STL	ATNS STORE ARGUMENT SQUARED SCALED AT 1	00530
00027	120 0 0075	1		MPY	ATN7 DEVELOP POLYNOMIAL	00540
00030	100 0 0074	1		ADD	ATN6	00550
00031	120 0 0066	1		MPY	ATNS	00560
00032	100 0 0073	1		ADD	ATN5	00570
00033	120 0 0066	1		MPY	ATNS	00580
00034	100 0 0072	1		ADD	ATN4	00590
00035	120 0 0066	1		MPY	ATNS	00600
00036	100 0 0071	1		ADD	ATN3	00610
00037	120 0 0066	1		MPY	ATNS	00620
00040	100 0 0070	1		ADD	ATN2	00630
00041	120 0 0066	1		MPY	ATNS	00640
00042	100 0 0067	1		ADD	ATN1	00650
00043	120 0 0065	1		MPY	ATNV	00660
00044	421 0 0065	1		STL	ATNV STORE ARCTAN SCALED AT -1	00670
00045	401 0 0062	1		LDL	ATNF TEST FLAG	00680
00046	356 0 0051	1		TPZ	ATNC	00690
00047	401 0 0076	1		LDL	*020000000	00700
00050	111 0 0065	1		SUR	ATNV GET 90- ARCTAN	00710

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2/8663/

SCALE

SHEET 13

DEL 1263-3A (2/65)

```
00051  401 0 0063   1
00052  351 0 0055   1
00053  400 0 0000
00054  357 0 0056   1
00055  401 0 0077   1
00056  170 0 0065   1
00057  501 0 0001
00060  250 00061    2
00061  357 7 0000   1
00062  00000000
00063  00000000
00064  00000000
00065  00000000
00066  00000000
00067  24276254
00070  62331574
00071  20110112
00072  52335436
00073  31750414
00074  52057124
00075  10703454

00076  20000000
00077  40000000
```

```
ATNC   LDL    ATNX        TEST SIGN OF X                          00720
       TRN    *+3                                                 00730
       LDZ    **          LEAVE ARCTAN IN 1ST OR 4TH QUADRANT     00740
       TRA    *+2                                                 00750
       LDL    =0400000000 PUT ARCTAN IN 2ND OR 3RD QUADRANT       00760
       LEO    ATNV                                                00770
       SBA    +1          ARCTAN SCALED AT 0                      00780
       JOF    *+1         RESET OVERFLOW INDICATOR                00790
       TRA    ATN.7                                               00800
ATNF   NUM    0           FLAG                                    00810
ATNX   NUM    0           X                                       00820
ATNY   NUM    0           Y                                       00830
ATNV   NUM    0                                                   00840
ATNS   NUM    0           ARGUMENT SQUARED                        00850
ATN1   NUM    024276254   .1914533 AT -2                          00860
ATN2   NUM    062331574   -.05302625 AT -3                        00870
ATN3   NUM    020110112   .03152920 AT -4                         00880
ATN4   NUM    052335436   -.02106178 AT -5                        00890
ATN5   NUM    031750414   .01267292 AT -6                         00900
ATN6   NUM    052057124   -.00534860 AT -7                        00910
ATN7   NUM    010703454   .00108423 AT -8                         00920
       END                                                        00930
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186937

SCALE

SHEET /4

DEL 1263-3A (2/65)

SECTION 5

LOG X (2, e, 10) ROUTINE–FIXED POINT

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR | USED ON 110A | NEXT ASSY

CONTRACT NO.
NAS-8-13007

DRAWN DATE
C.R. Hansen 31 AUG 65

CHECKED DATE
R.A. Dalton 31 AUG 65

DESIGN ACTIVITY APPD REL
J.N. Vanderford 31 Aug 65

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
LOG X(2, e, 10) ROUTINE - FIXED POINT

SIZE A | CODE IDENT NO. 49671 | 2186638

WEIGHT LB | SHEET 1 OF 13

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAMS	
				1	2		2186638-1	LOG X (2, e, 10) ROUTINE -	
								FIXED POINT	
								SYMBOLIC CARD DECK	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				X	4		CDV 86638	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								LOG X (2, e, 10) ROUTINE	
								FIXED POINT	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186638

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

LOG X (2, e, 10) ROUTINE - FIXED POINT

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

TABLE OF CONTENTS

1.0 Introduction

The purpose of the fixed point Log X routine is to calculate the logarithm to the base 2, e or 10, of an argument X.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86638. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

2.0 Mathematical Method

The argument X is tested and if greater than zero, is normalized. This reduces the argument to the form:

$$X \cdot 2^b = A$$

where $\frac{1}{2} \leq X < 1$

and b = binary scaling

The following approximation is used to compute log X:

$$\log_2 X = \left[\sum_{1}^{3} C_{2K-1} U^{2K-1}\right] - \frac{1}{2}$$

where $U = \dfrac{X - \sqrt{1/2}}{X + \sqrt{1/2}}$

and $C_1 = 2.8853913$

$C_3 = 0.96147063$

$C_5 = 0.59897865$

The result (characteristic) is scaled at 5 and multiplied by the proper conversion factor since

$$\log_K A = \log_2 X \cdot \log_K 2$$

The scaling factor is computed and added to the characteristic and scaled at 5 for the final answer.

3.0 Program Operation

3.1 Program Assembly and Loading

This program is assembled by the SLAP 2 system (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object card deck, a product of the SLAP 2 Assembly, to load the program into core memory.

3.2 Program Control

This program is used as a subroutine by a control program.

3.2.1 Control Program

3.2.1.1 Calling Sequence

Location	OP Code	Address
a	—	Argument (see below)
a + 1	TSP	Entry Points (see below)
a + 2	Return	

Argument - The fixed point argument, X, is in the left (L) accumulator. The scaling of the argument is in the right (R) accumulator scaled at 23.

Entry Points - The program has three entry points. Select one of the symbolic entry points listed below depending upon the base desired

Base	Entry
2	LG2
e	LGE
10	LG10

4.0 Output Format

The result is in the L accumulator scaled at 5.

Error Alarm: If the value of the argument is zero or negative or if the characteristic is greater than 31_{10}, the overflow indicator will be set and the L and R accumulators will contain erroneous data.

5.0 Memory Requirements

See Program listing.
Index Registers Used - none

6.0 Log X (2, e, 10) - Fixed Point - Card Deck

The symbolic source card deck for this program is 2186638-1

7.0 Appendices

7.1 Flow Chart

The flow chart for this program is in Appendix A.

8.0 Tables

8.1 Program Listing

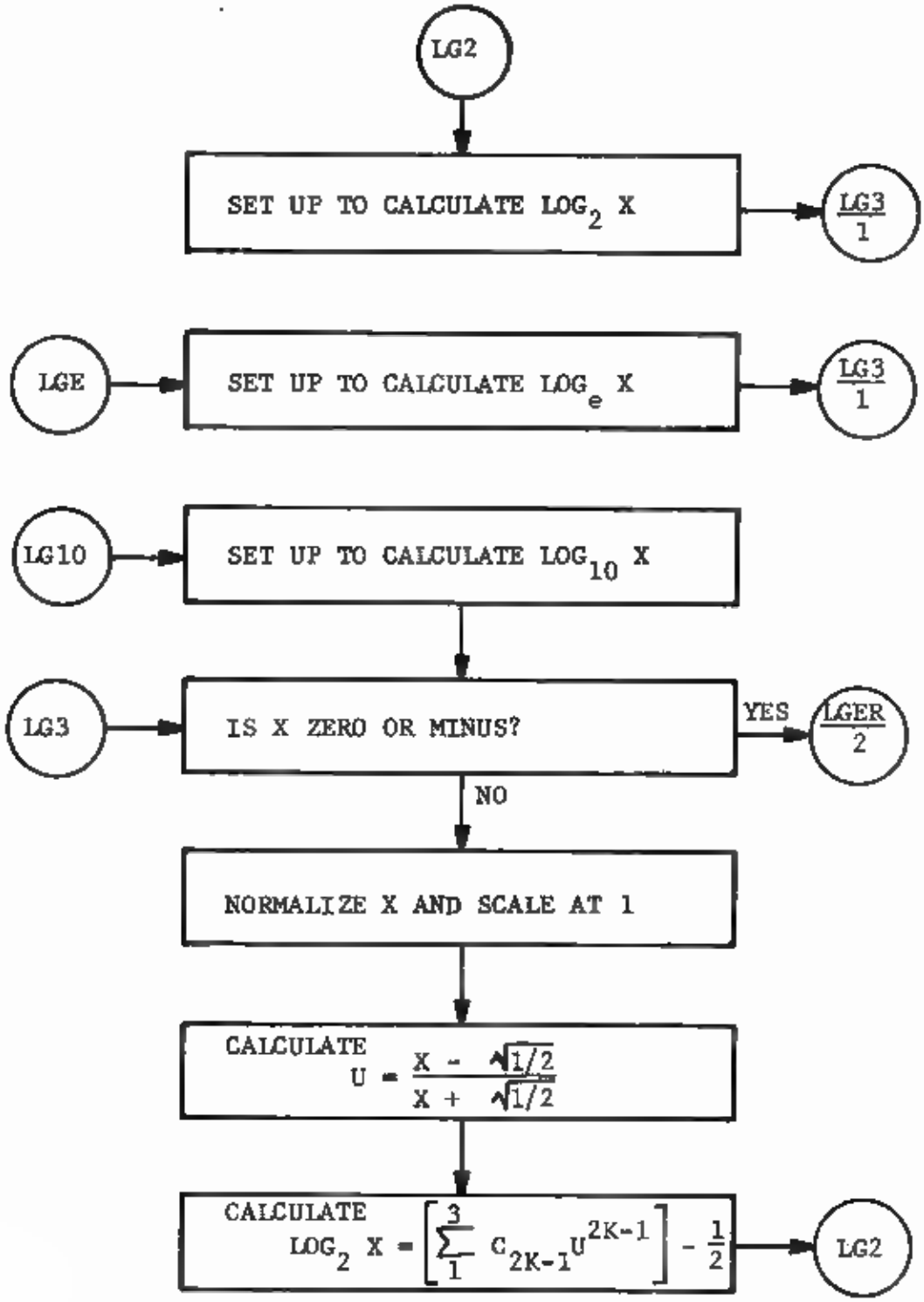
A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

LOG X (2, e, 10) ROUTINE - FIXED POINT

FLOW CHARTS

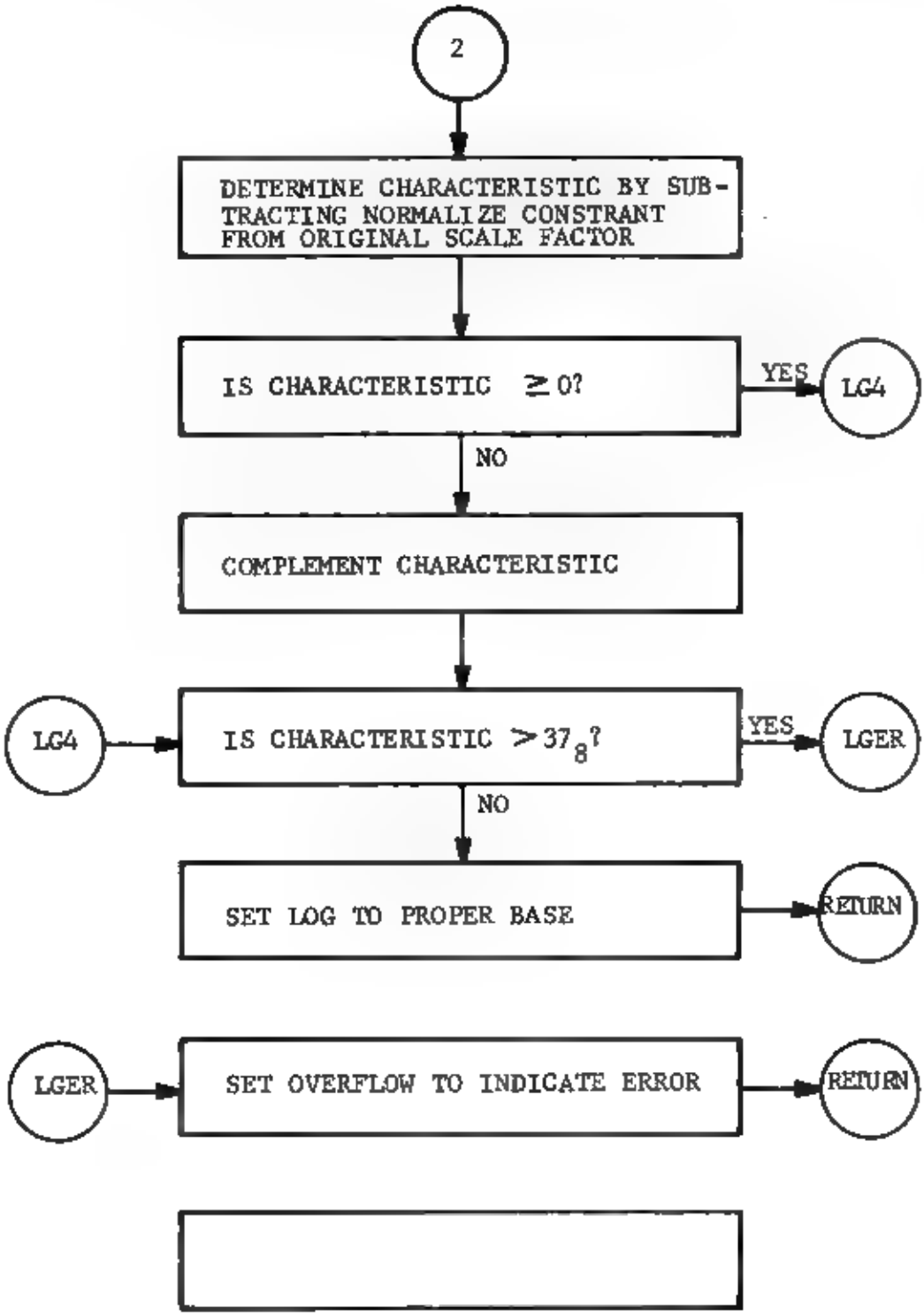


LG-1

RADIO CORPORATION ■ AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186638
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 9

DEL 1263-3A (2/65)



LG-2

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186638
	SCALE		SHEET 10

TABLE 1

SATURN GROUND COMPUTER SYSTEM

LOG ■ (2, e, 10) ROUTINE - FIXED POINT

PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186638
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET //

DEL 1263-3A (2/65)

INST. LOC. OCTAL	MEMORY OCTAL	REL TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*		LOG-(2,10,E)	00010
00000	73135757		LG	NUM	073135757 -LOG 2 BASE 10 AT 1	00310
00001	00000000		$LG10	NUM	0	00320
00002	423 0 0071	1		STB	LGSC STORE ARGUMENT AND SCALE FACTORS	00330
00003	403 0 0000	1		LDB	LG10-1 EXIT MULTIPLYER REPLACES R, RETURN	00340
00004	357 0 0016	1		TRA	LG3 LOCATION REPLACES L	00350
00005	64721573			NUM	064721573 -LOG 2 BASE E AT 1	00360
00006	00000000		$LGE	NUM	0	00370
00007	423 0 0071	1		STB	LGSC STORE ARGUMENT AND SCALE FACTOR	00380
00010	403 0 0005	1		LDB	LGE-1 EXIT MULTIPLYER REPLACES R RETURN	00390
00011	357 0 0016	1		TRA	LG3 LOCATION REPLACES L	00400
00012	60000000			NUM	060000000 -LOG [illegible] BASE 2 AT 8	00410
00013	00000000		$LG2	NUM	0	00420
00014	423 0 0071	1		STB	LGSC STORE ARGUMENT AND SCALE FACTOR	00430
00015	403 0 0012	1		LDB	LG2-1 EXIT MULT REPLACES R,RETURN LOC REPLACES L	00440
00016	431 0 0065	1	LG3	STE	LGEX STORE RETURN LOCATION ADDRESS	00450
00017	422 0 0102	1		STR	LGC6 STORE EXIT MULTIPLYER	00460
00020	401 0 0072	1		LDL	LGAR LOAD ARGUMENT	00470
00021	353 0 0066	1		TNZ	LGER * 0 OR = G0 TO ERROR EXIT	00480
00022	402 0 0073	1		LDR	LGZC 0 REPLACES R	00490
00023	520 0 0001	1		NRM	LG10 NORMALIZE ARGUMENT (X)	00500
00024	511 0 0001			SLL	*1 SCALE (X) AT 1	00510
00025	100 0 0074	1		ADD	LGSQ X + SQ ROOT OF .5 AT 1	00520
00026	421 0 0006	1		STL	LGE SAVE	00530
00027	110 0 0074	1		SUB	LGSQ	00540
00030	110 0 0074	1		SUB	LGSQ X + SQ. ROOT [illegible] .5 AT 1	00550
00031	130 0 0006	1		DVD	LGE U TO Q	00560
00032	421 0 0006	1		STL	LGE SAVE U AT 0	00570
00033	120 0 0006	1		MPY	LGE CALC U SQUARED AT 0	00580
00034	421 0 0013	1		STL	LG2 SAVE U SQUARED AT 0	00590
00035	120 0 0100	1		MPY	LGC5 U2 C5 AT 0	00600
00036	100 0 0077	1		ADD	LGC3 ((U2C5) + C3) AT 0	00610
00037	120 0 0013	1		MPY	LG2 U2((U2C5) + C3) AT 0	00620
00040	511 0 0002			SLL	*2 (U2((U2C5) +C3)) AT 2	00630
00041	100 0 0076	1		ADD	LGC1 (((U2((U2C5) + C3)) + C1) AT 2	00640
00042	120 0 0006	1		MPY	LGE U(((U2((U2C5) + C3)) + C1) AT 2	00650
00043	110 0 0075	1		SUB	LGC0 LOG2 OF X AT 2	00660
00044	120 0 0102	1		MPY	LGC6 LOGK [illegible] 2 TIMES LOG2 OF X AT 3	00670
00045	513 0 0032			SBL	*26 LOG [illegible] 2 TIMES LOG2 [illegible] X IN R AT 5	00680
00046	422 0 0072	1		STR	LGAR	00690
00047	401 0 0071	1		LDL	LGSC LOAD SCALE FACTOR (S)	00700
00050	111 0 0001	1		SUR	LG10 S+N	00710

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186938 | SCALE | SHEET 12

DEL 1263-3A (2/68)

```
00051  356 0 0053  1            TPZ    LG4
00052  160 0 0000               CML    **           COMPLEMENT (S-N)
00053  273 0 0101  1     LG4    SEL    LGC4           TEST FOR (S-N)E 0 37)8
00054  357 0 0066  1            TRA    LGER           NO. GO TO ERROR EXIT
00055  401 0 0001  1            LDL    LG10           LOAD (S-N) AT 23
00056  515 0 0006               RLL    *6          (S-N) CHARACTERISTIC AT 5  * 8
00057  120 0 0102  1            MPY    LGC6        LOOK OF 2 TIMES 8 AT 6
00060  513 0 0027               SBL    *23         LOOK OF 2 TIMES 8 AT 5 IN R
00061  401 0 0072  1            LDL    LGAR
00062  422 0 0072  1            STR    LGAR
00063  100 0 0072  1            ADD    LGAR        LOOK [illegible] ORIGINAL ARGUMENT AT 5
00064  160 0 0000               CML
00065  257 00000         LGEX   JRA    **             RETURN
00066  401 0 0077  1     LGER   LDL    LGC3           SET OVERFLOW
00067  100 0 0077  1            ADD    LGC3
00070  357 0 0065  1            TRA    LGEX           RETURN
00071  00000000          LGSC   NUM    0              SCALE FACTOR
00072  00000000          LGAR   NUM    0              ARGUMENT
00073  00000000          LGZC   NUM    0              ZERO CONSTANT
00074  13240475          LGSQ   NUM    013240475      .70710678 AT 1
00075  04000000          LGC0   NUM    04000000       .5 AT 2
00076  27052437          LGC1   NUM    027052437      2.8853913 AT 2
00077  36610567          LGC3   NUM    036610567      .9614706 AT 0
00100  23125524          LGC5   NUM    023125524      .5989786 AT 0
00101  00000037          LGC4   NUM    037            37)8
00102  00000000          LGC6   NUM    0              EXIT MULTIPLYER
                                END
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
.XX = ± .XXX = ±	A	49671	2186638
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 13

DEL 1263-3A (2/65)

SECTION 6
FLOATING-POINT SYSTEM

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR | USED ON 110A | NEXT ASSY

CONTRACT NO.
NAS 8-13007

DRAWN E.M. Stanger DATE 31 AUG 65

CHECKED A. Peterson DATE 31 AUG 65

DESIGN ACTIVITY APPD J.N. Vanderford DATE 31 AUG 65

RCA RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
FLOATING-POINT SYSTEM

SIZE	CODE IDENT NO.	
A	49671	2186654

WEIGHT LB | SHEET 1 OF 7

DEL 1263-1 (2-65)

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING-POINT SYSTEM

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

TABLE OF CONTENTS

1.0 Introduction

The purpose of this document is to define the areas common to a group of mathematical subroutine written in a floating-point format.

2.0 Description

2.1 Floating Point Number

A floating point binary number (X) is represented by a signed proper fraction (M) times some integral power (c) of 2. In a normalized floating point number the binary point is positioned to the left of the most significant digit of (M).

Examples:

X (binary)		M (binary)		2^c (decimal)
.001	=	.100	X	2^{-2}
-.001	=	.100	X	2^{-2}
.100	=	.100	X	2^{0}
1.01	=	.101	X	2^{1}
110.	=	.110	X	2^{3}
000.	=	.000	X	2^{0}

In the computer a floating point binary number appears in the L and R register as follows:

L-register

s	Characteristic	Most significant part of fraction
23	22 12	11 0

R-register

s	Least significant part of fraction
23	22 0

The fraction is contained in bits 0 through 11 in the L-register and bits 0 through 22 in the R-register. The sign of the fraction is contained in the sign bits of both the L and the R-registers. The characteristic is formed by adding 2000_8 to the exponent (c). For example an exponent of 100_8 would be represented by a characteristic of 2100_8. A zero number has no bits in either the L or R-registers. A negative number is expressed by complementing the absolute value of the fraction and the characteristic together.

Example:

		L-register	R-register
1	expressed in floating point	20014000	00000000
-1	expressed in floating point	57764000	40000000

2.2 Subroutine

Each subroutine is described individually in detail. Associated with each subroutine is an identification code. This symbolic ID code is used in the calling sequence for entry into the subroutine.

In the calling sequence, the various error returns are described. The terms overflow and underflow frequently are given as error returns. Overflow refers to the condition in which the characteristic exceeded 3777_8. Underflow refers to the condition in which the characteristic is less than 0.

The only restrictions for any of the subroutines will be that they require that other subroutines be available. For example, BCD uses the DVD and FEX subroutines, hence these two subroutines must be available when using the BCD subroutine.

The floating point subroutines assume all arguments to be in the floating point binary format. The output of each of the subroutines will be in normalized floating point binary format. While the arguments of the subroutines need not be in normalized floating point, greater accuracy will result if they are normalized.

All of the subroutines are written in SLAP-2 (2186651) assembly language.

The subroutines use a restricted set of defined symbols, thus allowing them to be assembled together and with other programs. The symbols used within any one subroutine are defined by the SLAP-2 ID of that subroutine and the symbol "COM." Each symbol has as its first three letters the subroutine's SLAP-2 ID. For example, the only symbols used in the square root subroutine, FSR, are:

FSR

FSRA

FSRB

.

.

.

.

FSRY

FSRZ

FSR0

FSR1

.

.

.

.

FSR9

The "COM" symbol is used for temporary storage required by subroutines common to this system. The requirements of this common temporary storage is defined in each subroutine as temporary space required in memory. The symbol "COM" appears in the location field and the address field of the subroutines requiring this temporary storage.

To utilize this common storage by a program using more than one of these subroutines, the following steps should be taken:

a) Remove the card, which has the COM symbol defined in the location field, from the symbolic source card deck of each floating point subroutine.

b) Remove the END card from each program.

c) Insert one card, which has the COM symbol defined in the location field, representing the largest number of temporary storage locations required for any one subroutine.

d) Assemble as given under Program Assembly for each subroutine.

3.0 System Subroutines

The subroutines associated with this Floating Point System are listed below:

Program	Program Number
Binary Coded Decimal to Floating Point Binary	2186639
Floating Point Binary to BCD Floating Format	2186640
Floating Point Add or Subtract	2186641
Floating Point Multiplication	2186642
Floating Point Divide	2186643
Floating Point Square Root	2186644
Floating Point Sin or Cosine	2186645
Floating Point Arctangent	2186646
Floating Point Common Logarithm or Natural Logarithm	2186647
Floating Point Exponential, E^X	2186648
Floating Point Tangent or Cotangent	2186649
Double Precision Divide	2186650

SECTION 7

BINARY CODED DECIMAL TO FLOATING POINT BINARY

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE ENGINEERING CHANGE NOTICE ADDED NEW SH 13. SH'S 14 THRU 19 WERE SH'S 13 THRU 18. CLASS II, DCS 642	7 FEB 66 8 FEB 66	D Quinzani J.N. Vanderford (R)

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN DATE
Iwai 31 AUG 65

CHECKED DATE
D. Peterman 3 SEP 65

DESIGN ACTIVITY APPD REL
J.N. Vanderford 3 SEPT 65 (R)

SATURN GROUND COMPUTER SYSTEM MATHEMATICAL ROUTINE BINARY CODED DECIMAL TO FLOATING POINT BINARY

SIZE	CODE IDENT NO.	
A	49671	2186639

WEIGHT LB SHEET 1 OF 19

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186639-1	BINARY CODED DECIMAL TO FLOATING	
								POINT BINARY SYMBOLIC CARD DECK	
				X	5		CDV86639	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE BINARY	
								CODED DECIMAL TO FLOATING POINT	
								BINARY	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186639

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

BINARY CODED DECIMAL TO

FLOATING POINT BINARY

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

TABLE OF CONTENTS

1.0 Identification

ID: BCD

2.0 Introduction

The purpose of "Binary Coded Decimal to Floating Point Binary" program is to convert a floating point binary coded decimal number into binary floating point format. This allows floating point numbers to be entered into the computer in a decimal floating point notation.

This program conforms to the specifications of the Floating Point System (2186654).

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86639. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

To change a Binary Coded Decimal floating point number to binary floating point number, the following procedure is followed:

First compute the value of the input mantissa, M_B, and the input characteristic, C_A.

$$M_B = 10^{-10} \sum_{i=1}^{10} M_i \, 10^{10-i}$$

$$C_A = \sum_{i=1}^{3} C_i \, 10^{3-i}$$

The value of the binary floating point number, X, is

$$X = M_B \ 10^{C_A}$$

$$X = M_B \ 2^{C_A \ (\mathrm{Log}_2 10)}$$

$$X = M_B \ 2^{C_c} \ 2^{C_d} \quad \text{where } C_c \text{ is an integer, } |C_d| < 1$$

Using e^x subroutine to evaluate 2^{C_d}

$$2^{C_d} = M_c \ 2^{C_N} \quad \text{where } C_N \text{ is an integer, } |M_c| < 1$$

Then

$$X = M_B \ M_C \ 2^{C_c} \ 2^{C_N}$$

Combining terms

$$X = M \ 2^C \quad \text{where } C = C_c + C_N$$

$$M = M_B \ M_c$$

4.0 Program Operation

4.1 Program Assembly and Loading

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program and the associated subroutines (Section 7.0). The SLAP 2 Loader uses the object program card deck, a product of the SLAP 2 assembly, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

Calling Sequence:

Location	Operation	Address
a	TSP	BCD (see below)
a + 1	**5	M,T (see below)
a + 2	Return	

BCD - Symbolic entrance in the Binary Coded Decimal to Floating Point Binary Subroutine.

M is the address of the first word of the BCD (Binary Coded Decimal) character table of four words which defines one floating point number.

T ($0 \leq T \leq 6$) is the index tag modifying M.

Input Data errors are indicated by an overflow 'ON' condition upon returning from subroutine. Overflow will be 'RESET' if there are no input data errors.

The BCD character table is in the following format in memory.

Location	23 18	17 12	11 6	5 0
M	M_s	M_1	M_2	M_3
M+1	M_4	M_5	M_6	M_7
M+2	M_8	M_9	M_{10}	C_s
M+3	C_1	C_2	C_3	

Where

M_s - Sign of the mantissa in BCD. It can be +, -, or space.

M_1 - Most significant digit of the mantissa in BCD

-

-

M_{10} - Least significant digit of the mantissa in BCD.

C_s - Sign of the characteristic in BCD. It can be +, -, or space.

C_1 - Most significant digit of the characteristic in BCD.

-

C_3 - Lease significant digit of the characteristic in BCD.

5.0 Output Format

Normal return:

The normalized floating point number equivalent to the specified BCD number will be in the L and R registers upon return.

Error Return:

a. The characteristic of the BCD number is greater than or equal to 1024. The L register will be positive upon return.

b. The characteristic of the BCD number is less than -1024. The L register will be negative upon return.

6.0 Memory Requirements

6.1 Program: See program listing

6.2 Temporary Space: 14 core memory locations

7.0 Restrictions

This program uses the following floating point subroutine:

Name	ID	Number
Exponential, E^X	(FEX)	2186648

8.0 Timing

Approximate timing: 100.9 milliseconds

9.0 "Binary Coded Decimal to Floating Point Binary" Card Deck

The symbolic source card deck for this program is 2186639-1 .

10.0 Appendices

10.1 Flow Chart

Flow Chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

A listing of this program showing memory locations (relative to zero), octal representation and source card content (in symbolic language format) for each memory location used by the program is in Table 1.

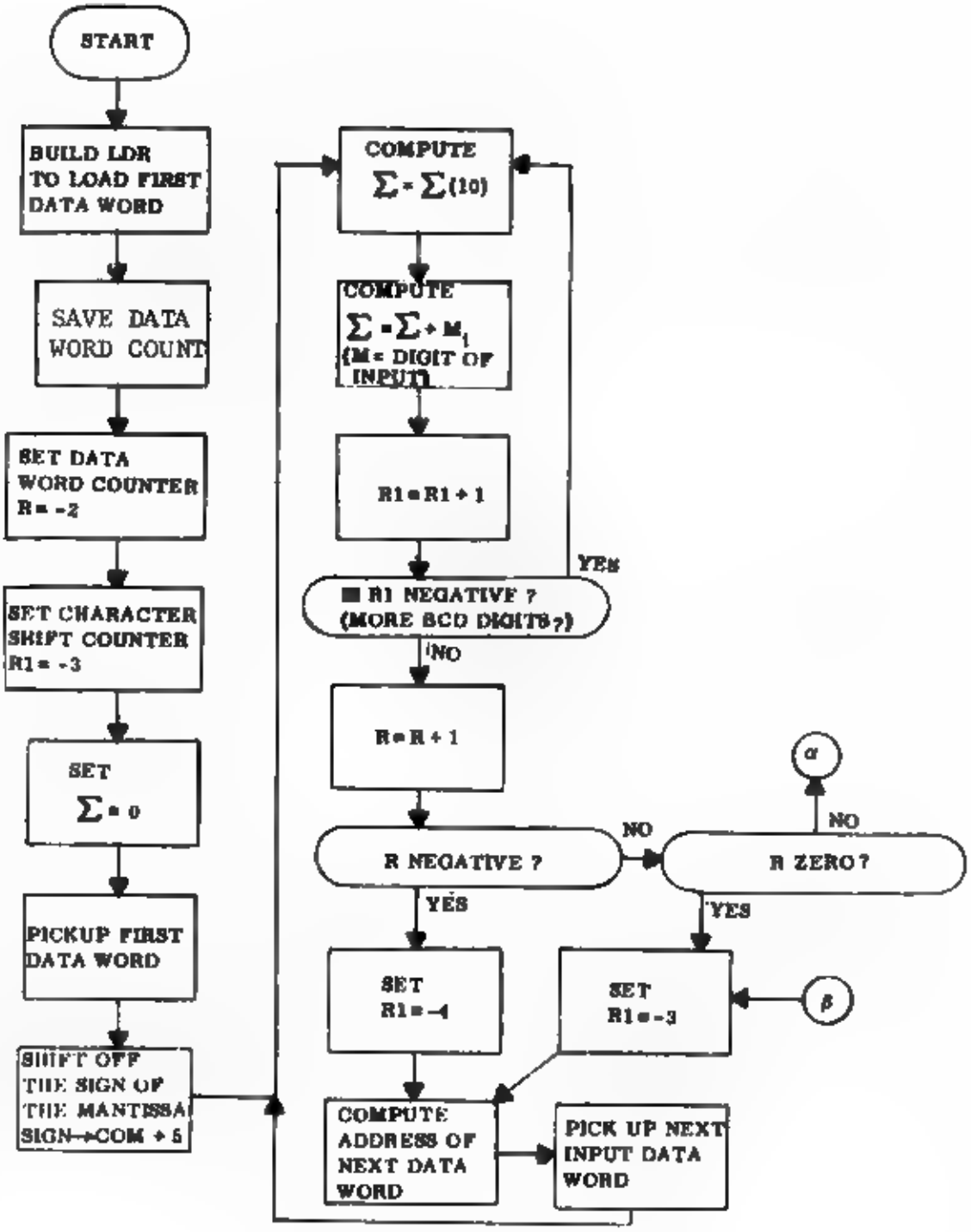
APPENDIX A

SATURN GROUND COMPUTER SYSTEM

BINARY CODED DECIMAL TO

FLOATING POINT BINARY

FLOW CHARTS

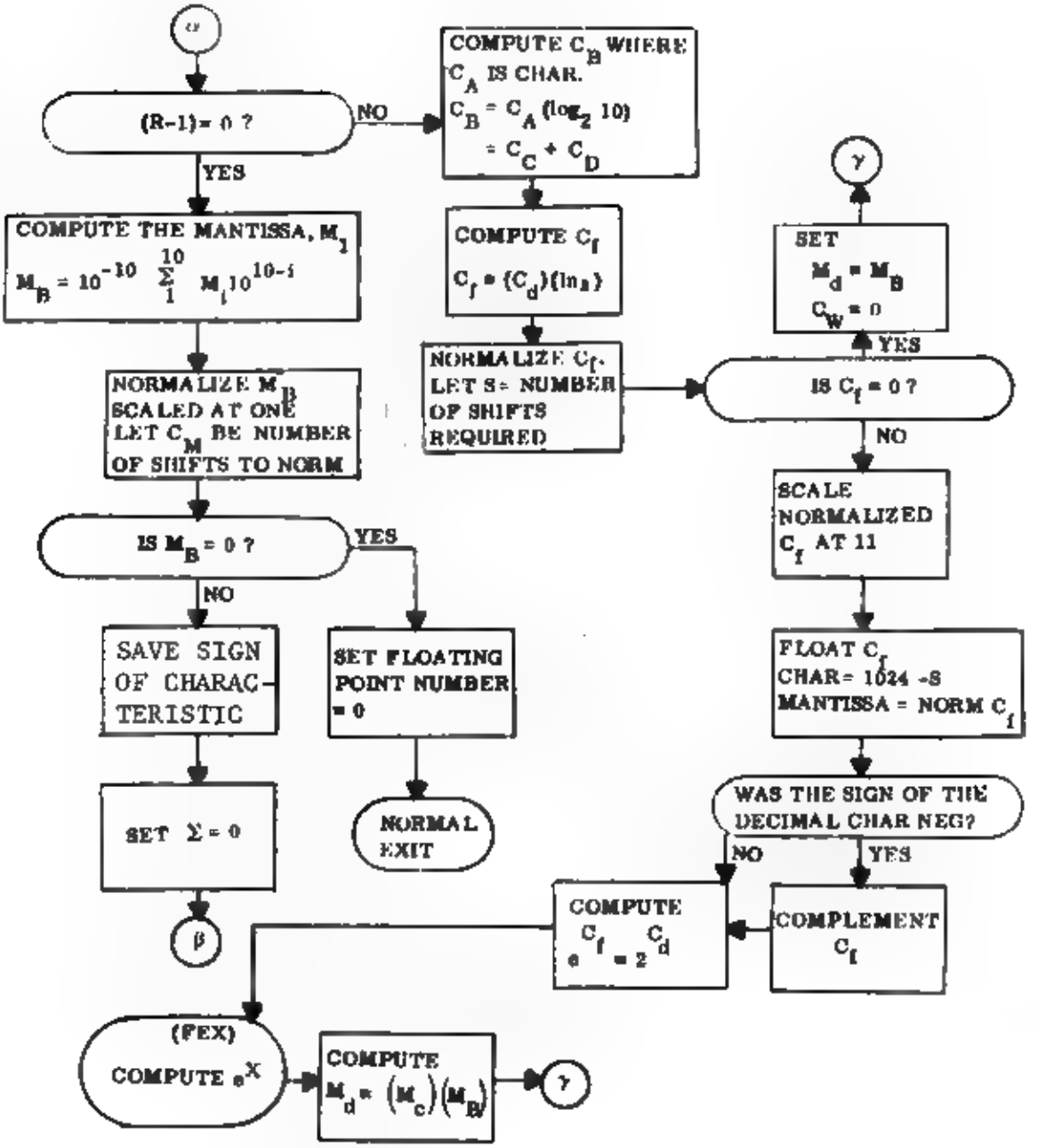


BCD1

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186639
XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET //

DEL 1263-3A (2/65)

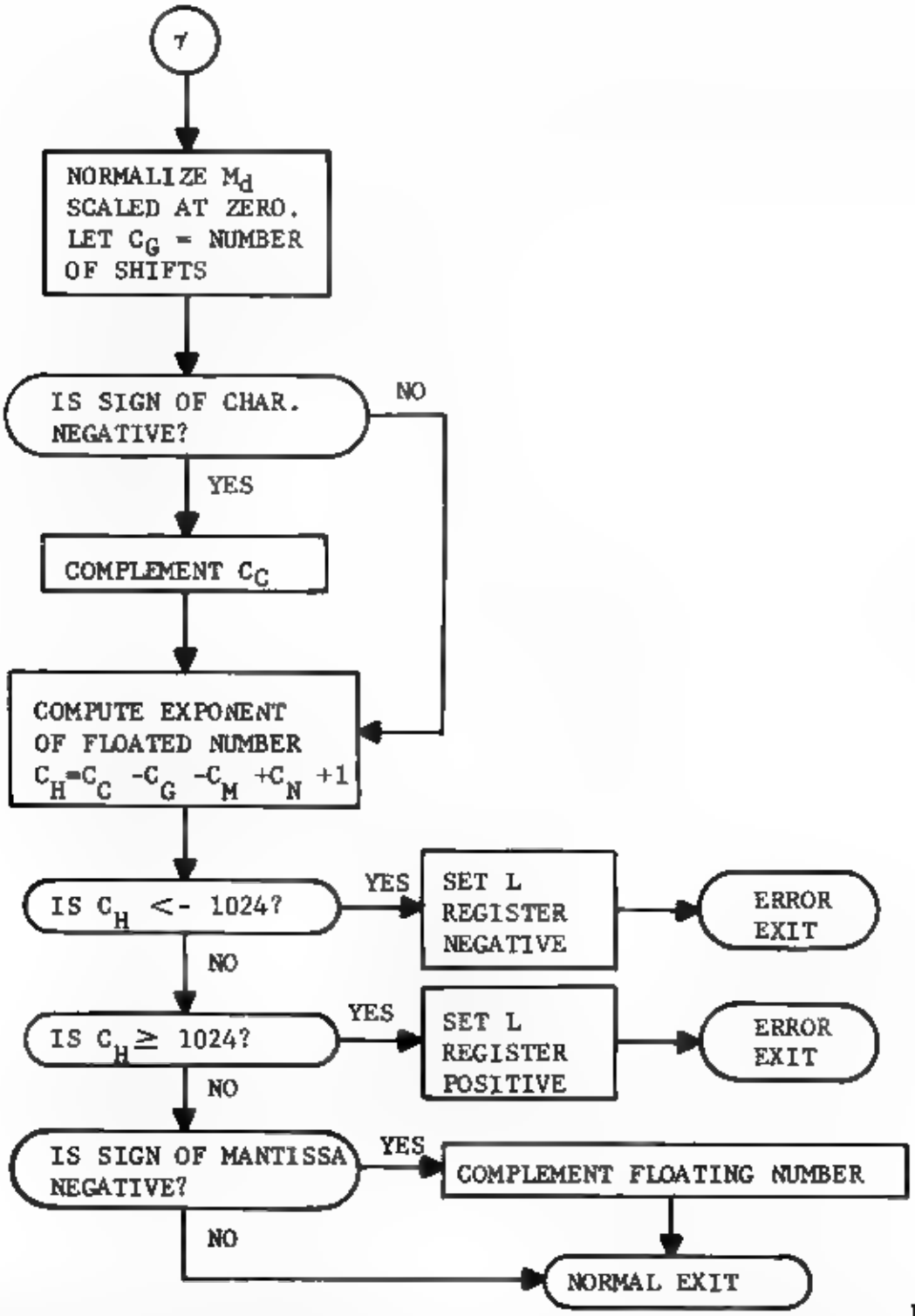


BCD2

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186639
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 12

DEL 1263-3A (2/65)



RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ±1/2°	SIZE A	CODE IDENT NO. 49671	2186639
	SCALE		SHEET 13

DEL 1263-3 (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

BINARY CODED DECIMAL TO

FLOATING POINT BINARY

PROGRAM LISTING

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE ■ INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
.XX = ± .XXX = ±	A	49671	2186639
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 14

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE
00000	00 7 00000	
00001	401 0 0000	1
00002	431 0 0315	1
00003	100 0 0267	1
00004	431 0 0214	1
00005	401 0 0264	1
00006	421 0 0322	1
00007	401 0 0265	1
00010	421 0 0313	1
00011	401 7 0315	1
00012	431 0 0230	1
00013	400 0 0000	
00014	420 0 0315	1
00015	420 0 0316	1
00016	402 7 0000	1
00017	517 0 0052	
00020	421 0 0317	1
00021	422 0 0314	1
00022	401 0 0316	1
00023	120 0 0266	1
00024	500 0 0052	
00025	421 0 0320	1
00026	401 0 0315	1
00027	120 0 0266	1
00030	501 0 0023	
00031	100 0 0320	1
00032	423 0 0315	1
00033	402 0 0314	1
00034	400 0 0000	
00035	517 0 0052	
00036	422 0 0314	1
00037	140 0 0302	1
00040	513 0 0030	
00041	105 0 0315	1
00042	401 0 0267	1
00043	101 0 0313	1
00044	351 0 0022	1
00045	401 0 0267	1
00046	101 0 0322	1
00047	351 0 0224	1

SYMBOLIC CARD CONTENT

```
*          BINARY CODED DECIMAL ■ FLOATING POINT BINARY                  00010
$BCD    s+5     0,7          ENTRANCE @F BCD                             00310
        LDL     BCD                                                      00320
        STE     C@M+3                                                    00330
        ADD     BCDX+5       BUILD EXIT ADDRESS                          00340
        STE     BCDZ                                                     00350
        LDL     BCDX+2       SAVE DATA W@RD COUNT.                       00360
        STL     C@M+8        R=-2                                        00370
        LDL     BCDX+3       SET SHIFT COUNT F@R FIRST W@RD.             00380
        STL     C@M+1        R1=-3                                       00390
        LDL     C@M+3.7                                                  00400
        STE     @CDE                                                     00410
        LDZ                  CLEAR RUNNING SUM @F FRACTION.              00420
        STZ     C@M+3        S=0                                         00430
        STZ     C@M+4                                                    00440
BCD@    LDR     @CD,7        L@AD DATA W@RD                              00450
        RBL     +42          SHIFT LEFT 6. FIRST CHARACTER IN L REG.     00460
        STL     C@M+5        SIGN @F FRACTION INT@ C@M+5                 00470
        STR     C@M+2                                                    00480
BCDA    LDL     C@M+4        C@MPUTE 10 TIMES SUM, S.                    00490
        MPY     BCDX+4                                                   00500
        RBA     +42          MULTIPLY MS SUM BY 10 AT 4                  00510
        STL     C@M+6        SCALE RESULT AT 46                          00520
        LDL     C@M+3                                                    00530
        MPY     BCDX+4       MULTIPLY LS SUM ■ 10 AT 4.                  00540
        SBA     +19          SCALE RESULT AT 46.                         00550
        ADD     C@M+6                                                    00560
        STB     C@M+3        ADD LS AND MS F@R PARTIAL SUM AT 46.        00570
BCDL    LDR     C@M+2        SHIFT IN NEW CHARACTER                      00580
        LDZ                                                              00590
        RBL     +42          SHIFT LEFT 6 PLACES.                        00600
        STR     C@M+2        ADD NEW CHARACTER                           00610
        LAN     BCDX+16      T@ SUM AND REPLACE SUM.                     00620
        SBL     +24                                                      00630
        ALR     C@M+3                                                    00640
        LDL     BCDX+5       CHECK F@R M@RE CHARACTERS T@ BE SHIFTED.    00650
        ADR     C@M+1        R1,R1+1                                     00660
        TRN     BCDA         TRANSFER IF M@RE CHARACTERS.                00670
        LDL     BCDX+5       CHECK WHICH DATA W@RD IS NEXT.              00680
        ADR     C@M+8        R = R+1                                     00690
        TRN     BCDC         2ND DATA W@RD TRANSFER                      00700
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
.XX = ±
.XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186639 | SCALE | SHEET 15

DEL 1263-3A (2/66)

```
00050   352 0 0232   1
00051   110 0 0267   1
00052   352 0 0234   1
00053   401 0 0315   1
00054   515 0 0013
00055   421 0 0315   1
00056   120 0 0305   1
00057   423 0 0320   1
00060   401 0 0315   1
00061   120 0 0304   1
00062   501 0 0027
00063   105 0 0320   1
00064   140 0 0262   1
00065   515 0 0013
00066   421 0 0320   1
00067   401 0 0321   1
00070   140 0 0303   1
00071   500 0 0042
00072   423 0 0315   1

00073   120 0 0310   1
00074   501 0 0001
00075   423 0 0313   1
00076   401 0 0315   1
00077   120 0 0311   1
00100   501 0 0001
00101   104 0 0313   1
00102   501 0 0026
00103   423 0 0313   1
00104   401 0 0316   1
00105   120 0 0311   1
00106   104 0 0313   1
00107   520 0 0306   1
00110   520 0 0307   1
00111   352 0 0220   1
00112   501 0 0013
00113   421 0 0322   1
00114   401 0 0275   1
00115   110 0 0306   1
00116   110 0 0307   1
00117   515 0 0014
00120   101 0 0322   1
00121   401 0 0312   1
00122   515 0 0022
```

```
TRZ     BCDF        3RD DATA WORD TRANSFER                          00710
SUB     BCDX+5                                                      00720
TRZ     BCDG        END OF 3RD DATA WORD.                           00730
LDL     C@M+3       SCALE CHARACTERISTIC AT 10                      00740
RLL     +11                                                         00750
STL     C@M+3                                                       00760
MPY     @CDX+19     CA@L@G 2 M.S. AT 12                             00770
STB     C@M+6                                                       00780
LDL     C@M+3                                                       00790
MPY     @CDX+18     CA@L@G L.S. AT -11.                             00800
SBA     +23         RESCALE AT 12.                                  00810
ALR     C@M+6       CB = CC + CD = CA@L@G 2                         00820
LAN     @CDX                                                        00830
RLL     +11                                                         00840
STL     C@M+6   SEPERATE CC, THE INTEGER PART, FROM CA@L@G2         00850
LDL     C@M+7                                                       00860
LAN     @CDX+17                                                     00870
RBA     +34                                                         00880
STB     C@M+3       SEPERATE CD, THE FRACTIONAL PART,               00890
                    FROM CA@L@G2                                    00900
MPY     @CDX+22     (CD)(LN2) AT-23 (MS) (LS)                       00910
SBA     1                                                           00920
STB     C@M+1                                                       00930
LDL     C@M+3                                                       00940
MPY     @CDX+23     (CD) (LN2) AT-23 (LS) (MS)                      00950
SBA     1                                                           00960
ADL     C@M+1                                                       00970
SBA     +22                                                         00980
STB     C@M+1                                                       00990
LDL     C@M+4                                                       01000
MPY     @CDX+23     (CD) (LN2) AT 0, (MS) (MS)                      01010
ADL     C@M+1       CF=@CD) (LN2) AT 0.                             01020
NRM     @CDX+20     NORMALIZE CF AT 0.                              01030
NRM     @CDX+21                                                     01040
TRZ     @CD5        IS CF ZERO TRANSFER IF YES.                     01050
SBA     +11         NORMALIZED CF AT 11.                            01060
STL     C@M+8                                                       01070
LDL     @CDX+11     LOAD 1024 AT 23                                 01080
SUB     @CDX+20     SUBTRACT NUMBER OF NORMALIZING SHIFTS           01090
SUB     @CDX+21                                                     01100
RLL     +12         BIASED CHARACTERISTIC OF CF AT 11               01110
ADR     C@M+8                                                       01120
LDL     C@M         CHECK SIGN OF CHARACTERISTIC                    01130
RLL     +18                                                         01140
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
.XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186639 | SCALE | SHEET 16

DEL 1263-3A (2/66)

```
00123  110 0 0301  1          SUB   BCDX+15                                    01150
00124  421 0 0312  1          STL   C@M                                         01160
00125  352 0 0130  1          TRZ   BCDI                                        01170
00126  401 0 0327  1          LDL   C@M+6     NO COMPLEMENTING IF POSITIVE      01180
00127  357 0 0132  1          TRA   BCDJ                                        01190
00130  401 0 0322  1    BCDI  LDL   C@M+6     COMPLEMENT IF NEGATIVE            01200
00131  161 0 0000             CMB             EXPONENTIAL SUBROUTINE            01210
00132  321 7 0330  1    BCDJ  TSP   FEX                                         01220
00133  421 0 0325  1          STL   C@M+11    NORMAL RETURN FOR EXPONENTIAL     01230
00134  140 0 0276  1          LAN   BCDX+12                                     01240
00135  515 0 0014             RLL   +12                                         01250
00136  421 0 0322  1          STL   C@M+6     MC AT 11. SAVE EXPONENT, CN, OF M. 01260
00137  401 0 0325  1          LDL   C@M+11                                      01270
00140  140 0 0263  1          LAN   BCDX+1                                      01280
00141  500 0 0043             RBA   +35       MC AT 0                           01290
00142  423 0 0325  1          STB   C@M+11                                      01300
00143  120 0 0323  1          MPY   C@M+9     (MC) (MB) AT -23 (MS) (LS)        01310
00144  501 0 0001             SBA   1                                           01320
00145  423 0 0315  1          STB   C@M+3                                       01330
00146  401 0 0325  1          LDL   C@M+11    MC (LS PART)                      01340
00147  120 0 0324  1          MPY   C@M+10    (MC) (MB) AT-23, (LS) (MS)        01350
00150  501 0 0001             SBA   1                                           01360
00151  104 0 0315  1          ADL   C@M+3                                       01370
00152  501 0 0026             SBA   +22                                         01380
00153  423 0 0315  1          STB   C@M+3     (MC) (MB) AT 0, (LS) (MS) +(MS) (LS) 01390
00154  401 0 0326  1          LDL   C@M+12    MC (MS PART)                      01400
00155  120 0 0324  1          MPY   C@M+10    (MC) (MB) AT 0, (MS) (MS)         01410
00156  104 0 0315  1          ADL   C@M+3     (MD) AT 0,                        01420
00157  520 0 0306  1    BCDT  NRM   BCDX+20    (CB) IS NUMBER OF NORMALIZING SHIFTS 01430
00160  501 0 0013             SBA   +11                                         01440
00161  421 0 0315  1          STL   C@M+3     MD AT 11,                         01450
00162  401 0 0312  1          LDL   C@M       BUILD CHARACTERISTIC OF NUMBER    01460
00163  352 0 0166  1          TRZ   BCDM      CHECK SIGN OF INPUT CHARACTERISTIC, 01470
00164  401 0 0320  1          LDL   C@M+6     CC AT 23,                         01480
00165  357 0 0167  1          TRA   BCDN                                        01490
00166  110 0 0320  1    BCDM  SUB   C@M+6     COMPLEMENT (CC) IF SIGN IS MINUS, 01500
00167  110 0 0306  1    BCDN  SUB   BCDX+20    (CC-CB) AT 23,                    01510
00170  110 0 0273  1          SUB   BCDX+9                                      01520
00171  110 0 0274  1          SUB   BCDX+10    (CC-CB-CM) AT 23                 01530
00172  100 0 0322  1          ADD   C@M+6     (CC-CB-CM+CN) AT 23,              01540
00173  100 0 0267  1          ADD   BCDX+5     (CC-CB-CM+CN+1) AT 23            01550
00174  421 0 0316  1          STL   C@M+4                                       01560
00175  351 0 0215  1          TRN   BCDY      UNDERFLOW IN EXPONENT, (NEGATIVE NB) 01570
00176  110 0 0300  1          SUB   BCDX+14    CHECK FOR EXPONENTS OUT OF RANGE  01580
```

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186639 | SHEET 17

SCALE

DEL 1263-3A (2/60)

```
00177  356 0 0215   1              TPZ     BCDY        OVERFLOW IN EXPONENT (POSITIVE NO.)          01590
00200  401 0 0317   1              LDL     C0M+5       CHECK SIGN OF MANTISSA.                      01600
00201  110 0 0301   1              SUB     BCDX+15                                                  01610
00202  352 0 0207   1              TRZ     BCDP                                                     01620
00203  401 0 0316   1              LDL     C0M+4   IF MANTISSA IS NEGATIVE, COMPLEMENT FLOATING     01630
00204  515 0 0014                  RLL     +12         NUMBER                                       01640
00205  150 0 0315   1              LIO     C0M+3                                                    01650
00206  357 0 0213   1              TRA     BCDR                                                     01660
00207  401 0 0316   1    BCDP      LDL     C0M+4                                                    01670
00210  515 0 0014                  RLL     +12                                                      01680
00211  150 0 0315   1              LIO     C0M+3                                                    01690
00212  161 0 0000                  CMB                                                              01700
00213  250 00214    2    BCDR      JOF     *+1                                                      01710
00214  257 00000         BCDZ      JRA     0                                                        01720
00215  401 0 0276   1    BCDY      LDL     BCDX+12                                                  01730
00216  100 0 0276   1              ADD     BCDX+12                                                  01740
00217  257 00214    2              JRA     BCDZ                                                     01750
00220  401 0 0275   1    BCDS      LDL     BCDX+11     CN=0 CASE.                                   01760
00221  421 0 0322   1              STL     C0M+0       CN=1024 AT 23.                               01770
00222  403 0 0323   1              LDB     C0M+9                                                    01780
00223  357 0 0157   1              TRA     BCDT                                                     01790
00224  401 0 0270   1    BCDC      LDL     BCDX+6      2ND DATA WORD ENTRY. 4 CHARAC. SHIFT.        01800
00225  421 0 0313   1    BCDD      STL     C0M+1       R1=-4                                        01810
00226  401 0 0267   1              LDL     BCDX+5      COMPUTE ADDRESS OF NEXT DATA WORD            01820
00227  101 0 0230   1              ADR     BCDE                                                     01830
00230  402 0 0000        BCDE      LDR     **                                                       01840
00231  357 0 0021   1              TRA     BCDA-1                                                   01850
00232  401 0 0265   1    BCDF      LDL     BCDX+3      3RD DATA WORD ENTRY. 3 CHARACT. SHIFT        01860
00233  357 0 0225   1              TRA     BCDD                                                     01870
00234  403 0 0315   1    BCDG      LDB     C0M+3       END OF 3RD DATA WORD.                        01880
00235  500 0 0042                  RBA     +34         COMPUTE FRACTION *(10**(-10))S               01890
00236  423 0 0315   1              STB     C0M+3       SCALE S AT 34                                01900
00237  120 0 0272   1              MPY     BCDX+8      (10)((-10)) TIMES S AT 1 (MS) (MS)           01910
00240  423 0 0323   1              STB     C0M+9                                                    01920
00241  401 0 0271   1              LDL     BCDX+7                                                   01930
00242  120 0 0316   1              MPY     C0M+4       (10**(-10)) TIMES S AT -22                   01940
00243  423 0 0320   1              STB     C0M+6       STORE THE (LS PART) TIMES (MS PART)          01950
00244  401 0 0272   1              LDL     BCDX+8                                                   01960
00245  120 0 0315   1              MPY     C0M+3       (10**(-10)) TIMES S AT -22 (MS) (LS)         01970
00246  104 0 0320   1              ADL     C0M+6       (MS) (LS) +(LS) (MS) AT -22.                 01980
00247  501 0 0027                  SBA     +23                                                      01990
00250  104 0 0323   1              ADL     C0M+9   FULL PRODUCT (10**(-10)) TIMES S AT 1           02000
00251  520 0 0273   1              NRM     BCDX+9      NORMALIZE FRACTIONAL MANTISSA                02010
00252  520 0 0274   1              NRM     BCDX+10                                                  02020
```

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ± XXX = ±
FRACTIONS = ± ANGLES = ±1/2°

DEL 1263-3A (2/60)

SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET 18

2186639

```
00253  352 0 0213   1              TRZ     BCDR          MANTISSA = 0                                  02030
00254  423 0 0323   1              STB     C@M+9         STORE NORMALIZED MANTISSA. NB.                02040
00255  402 0 0314   1              LDR     C@M+2         SAVE CHARACTERISTICS SIGN.                    02050
00256  422 0 0312   1              STR     C@M                                                         02060
00257  420 0 0315   1              STZ     C@M+3         PREPARE TO GET CHARACTERISTIC                 02070
00260  420 0 0316   1              STZ     C@M+4                                                       02080
00261  357 0 0232   1              TRA     BCDF          4TH DATA WORD. 3 CHARACT. SHIFT.              02090
00262  77774000             BCDX   NUM     077774000                                                   02100
00263  00007777                    NUM     000007777     MASK                                          02110
00264  77777776                    NUM     077777776     -2 AT 23.                                     02120
00265  77777775                    NUM     077777775     -3 AT 23.                                     02130
00266  24000000                    NUM     024000000     10 AT 4.                                      02140
00267  00000001                    NUM     01            1 AT 23                                       02150
00270  77777774                    NUM     077777774     -4 AT 23.                                     02160
00271  14727574                    NUM     014727574     10**(-10) AT -33. LS PART                     02170
00272  33371577                    NUM     033371577     10**(-10) AT -33 MS PART.                     02180
00273  00000000                    NUM     00        CM. NORMALIZATION SHIFTS FOR FRACTIONAL PART.     02190
00274  00000000                    NUM     00            CM                                            02200
00275  00002000                    NUM     02000         1024 AT 23                                    02210
00276  37770000                    NUM     037770000     MASK.                                         02220
00277  40000000                    NUM     040000000     MINUS CODE AT 5.                              02230
00300  00004000                    NUM     000004000     2048 AT 23.                                   02240
00301  00000040                    NUM     040           MINUS SIGN AT 23                              02250
00302  00000017                    NUM     017                                                         02260
00303  00003777                    NUM     03777                                                       02270
00304  00045754                    NUM     0045754       1@LOG AT 2. (LS PART)                         02280
00305  32446474                    NUM     032446474     1@LOG 2 =3,321,928,094,997,716.               02290
00306  00000000                    NUM     [redacted]    NORMALIZING COUNT FOR CF.                     02300
00307  00000000                    NUM     00            NORMALIZING COUNT FOR CF.                     02310
00310  37372162                    NUM     037372162     LN2 AT 0. LS PART.                            02320
00311  26134413                    NUM     026134413     LN2=0.693,147,180,559,945                     02330
00312                        C@M    BSS     14                                                          02340
                                    END                                                               02350

00330  00 0 00000      FEX
```

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ± FRACTIONS = ±
XXX = ± ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186639

SCALE

SHEET 19

DEL 1263-3A (2/65)

SECTION 8
FLOATING POINT BINARY TO BCD FLOATING FORMAT

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE ENGINEERING CHANGE NOTICE CLASS II, DCS 642	3 FEB 66 4 FEB 66	G. Mangum J. N. Vanderfund

FIRST MADE FOR | USED ON 110A | NEXT ASSY

CONTRACT NO.
NAS 8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN E. M. Stanya DATE 2 SEP 65

CHECKED D. A. Steinman DATE 3 SEP 65

DESIGN ACTIVITY APPD J. N. Vanderfund 3 SEPT 65 REL R

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE FLOATING POINT BINARY TO BCD FLOATING FORMAT

SIZE A | CODE IDENT NO. 49671 | 2186640

WEIGHT LB | SHEET 1 OF 18

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186640-1	FLOATING POINT BINARY TO BCD	
								FLOATING FORMAT - SYMBOLIC CARD	
								DECK	
				X	5		CDV 86640	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT BINARY TO	
								BCD FLOATING FORMAT	

LTR

SIZE A | CODE IDENT NO. 49671 | 2186640

SHEET 2

RADIO CORPORATION OF AMERICA

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT BINARY TO

BCD FLOATING FORMAT

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE ■ INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186640
	SCALE		SHEET 3

TABLE OF CONTENTS

1.0 Identification

ID: BIN

2.0 Introduction

The purpose of the Floating Point Binary to BCD Floating Format program is to convert a floating point binary quantity X into a Binary Coded Decimal floating point format.

This program conforms to the specifications of the Floating Point System (2186654).

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86640. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow charts shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

To convert a binary floating point number to a Binary Coded Decimal floating point format, the following procedure is followed.

The floating point binary number is represented thusly:

$$X = M2^{D}$$

$$X = M10^{D \log 2}$$

$$X = M10^{D_2}\ 10^{D_3}$$ where D_2 is an integer, D_3 is a fraction

Using the E^X subroutine to evaluate $10^{D3} = e^{D3 \ln 10}$

$$X = M10^{D2} e^{D3 \ln 10}$$

$$X = F\ 10^{D2} \qquad \text{where } F = Me^{D3 \ln 10}$$

$$F < 10$$

If $F \geq 1$, set $F = F + 10$ and $D_2 = D_2 + 1$.

Since

$$F = \sum_{i=1}^{10} M_i 10^{-i}$$

successive multiplication by 10 yields the M_i terms.

Since

$$D_2 = \sum_{i=1}^{3} C_i 10^{3-i}$$

successive division by 10 yields the C_i terms.

4.0 Program Operation

4.1 Program Assembly and Loading

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program and the required associated subroutine (Section 7.0). The SLAP 2 Loader uses the object program card deck, a product of the SLAP 2 Assembly, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

Calling Sequence:

With the floating point binary quantity, X, in the left (L) and right (R) accumulators

Location	Operation	Address
a	TSP	BIN (see below)
a + 1	**5	M,T (see below)
a + 2	Return	

BIN - Symbolic entrance in the Floating Point Binary to BCD Floating Format subroutine.

M is the address of the first word of the BCD (Binary Coded Decimal) character table of four words which is defined by the given floating point binary number.

T ($0 \leq T \leq 6$) is the index tag modifying M.

Overflow 'ON' indicates input error. Overflow will be reset on the normal return.

The BCD character table is in the following format in memory:

Location	23 18	17 12	11 6	5 0
M	M_s	M_1	M_2	M_3
M+1	M_4	M_5	M_6	M_7
M+2	M_8	M_9	M_{10}	C_s
M+3	C_1	C_2	C_3	

Where

M_s - Sign of the mantissa in BCD. It can be - or space.

M_1 - Most significant digit of the mantissa in BCD.

-

-

M_{10} - Least significant digit of the mantissa in BCD.

C_s - Sign of the characteristic in BCD. It can be - or space

C_1 - Most significant digit of the characteristic in BCD

-

C_3 - Least significant digit of the characteristic in BCD

5.0 Output Format

The binary Coded Decimal floating point format of the given binary floating point number has been stored in table specified by the address M of the calling sequence.

The contents of the (L) and (R) registers have been destroyed by the subroutine.

6.0 Memory Requirements

6.1 Program: See Program Listing

6.2 Temporary Space: 12 core memory locations

7.0 Restrictions

This program uses the following floating point subroutine:

Name	ID	Number
Exponential, E^X	FEX	2186648

8.0 Timing

Approximate Timing: 99.6 milliseconds

9.0 Floating Point Binary to BCD Floating Format Card Deck

The symbolic source card deck for this program is 2186640-1

10.0 Appendices

10.1 Flow Chart

Flow Chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

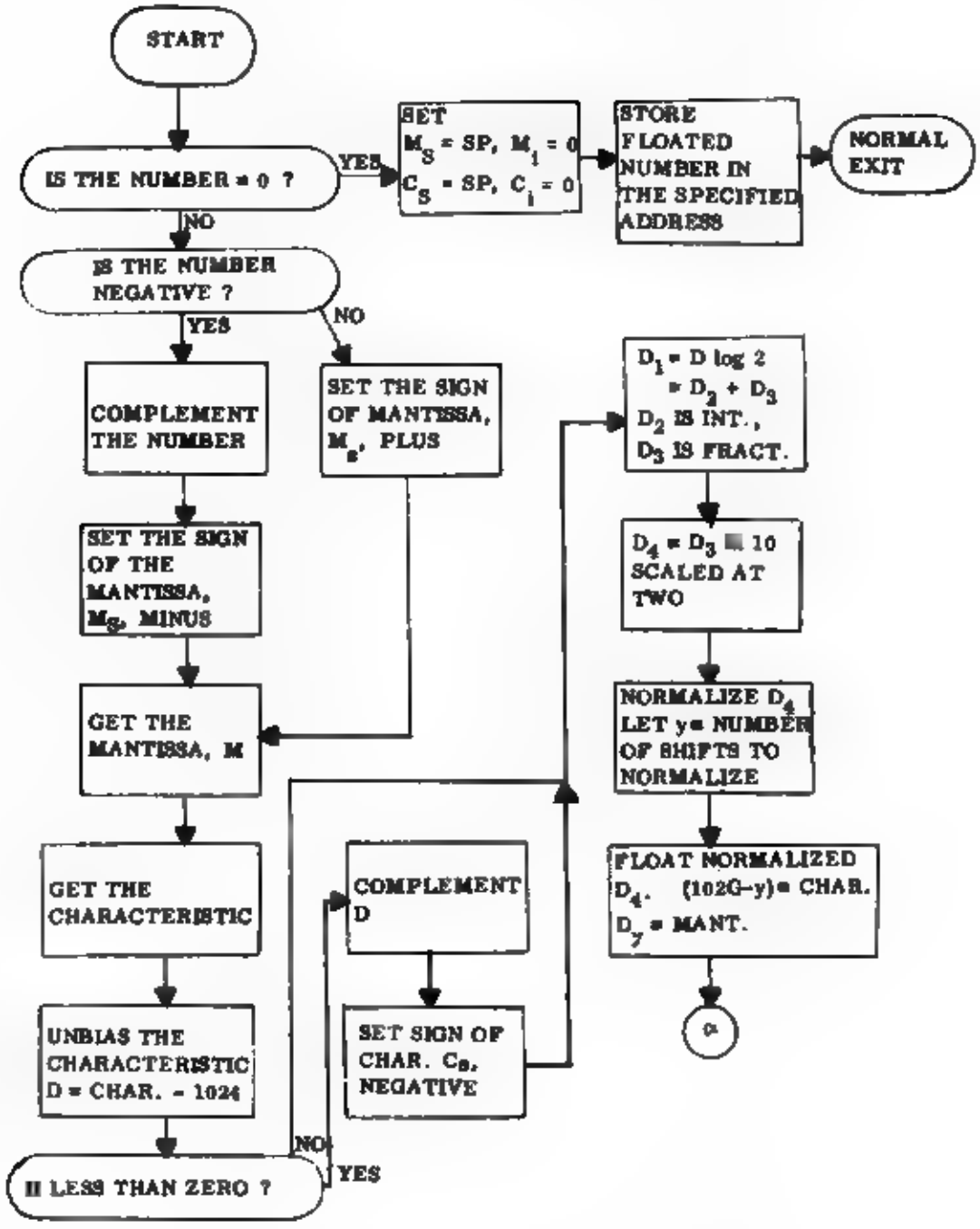
SATURN GROUND COMPUTER SYSTEM

FLOATING POINT BINARY TO

BCD FLOATING FORMAT

FLOW CHARTS

SIZE A | CODE IDENT NO. 49671 | 2186640
SCALE | SHEET 10
DEL 1263-3A (2/65)



FPB1

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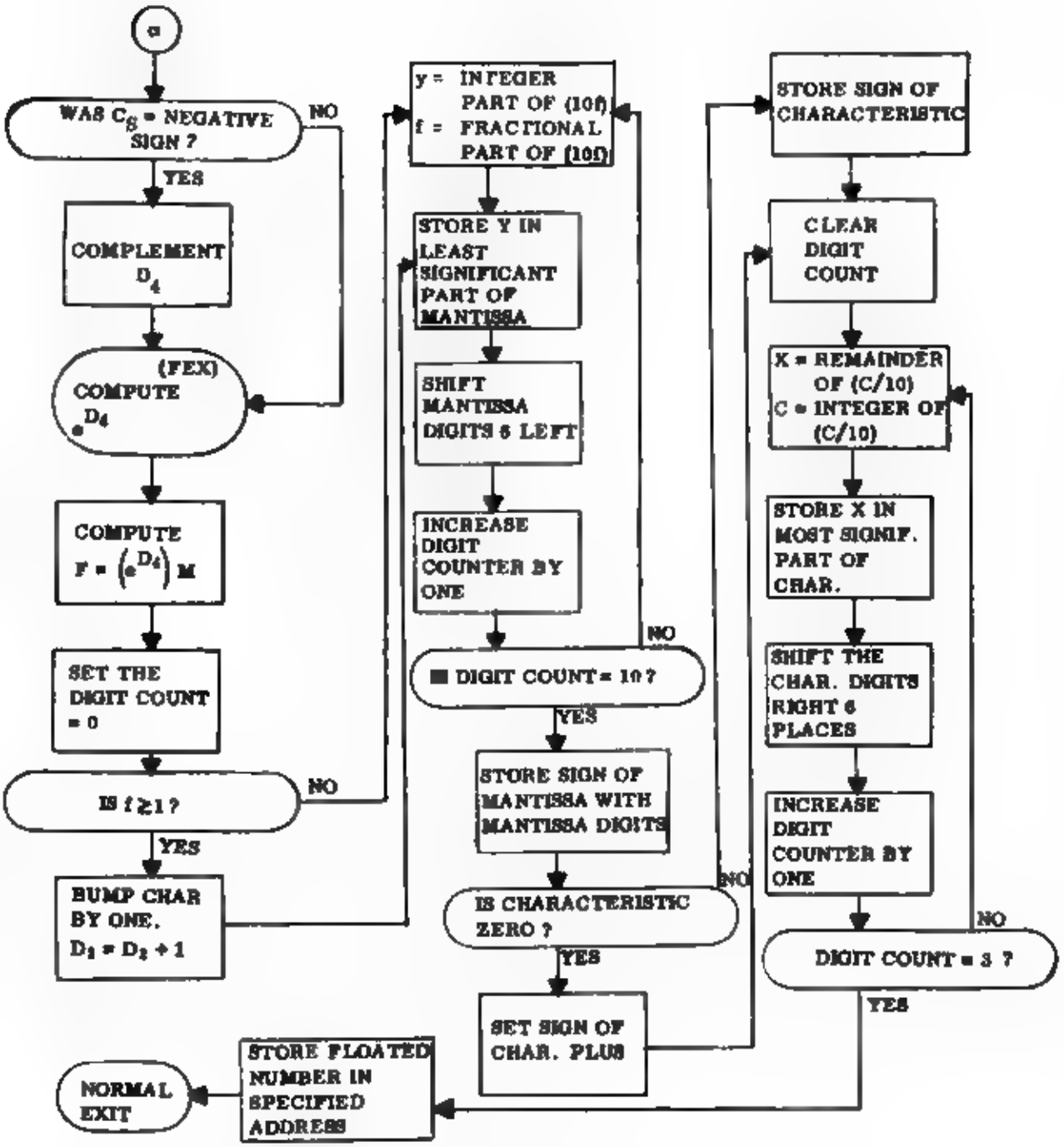
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186640
XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET //

DEL 1263-3A (2/65)



FPB2

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186640
XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 12

DEL 1263-3A (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT BINARY TO

BCD FLOATING FORMAT

PROGRAM LISTING

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE	SYMBOLIC CARD CONTENT			CARD NO.
			* FLOATING POINT BINARY TO BCD			00010
00000	00 0 00000		$BIN +*5 0			00310
00001	355 0 0007	1	TPN BINA		CHECK IF THE ARGUMENT IS ZERO.	00320
00002	403 0 0237	1	LDB BINX		THE ARGUMENT IS ZERO.	00330
00003	423 0 0273	1	STB C@M		PLACE ZERO CODE IN BCD WORDS.	00340
00004	403 0 0241	1	LDB BINX+2			00350
00005	423 0 0275	1	STB C@M+2			00360
00006	357 0 0224	1	TRA BINP		TRANSFER TO THE EXIT.	00370
00007	420 0 0277	1	BINA STZ C@M+4		INITIALIZE THE MANTISSA SIGN FLAG.	00380
00010	354 0 0013	1	TRP BINB		CHECK IF MANTISSA IS NEGATIVE.	00390
00011	161 0 0000		CMB		COMPEMENT FLOATING NUMBER.	00400
00012	421 0 0277	1	STL C@M+4		SET MANTISSA FLAG TO NEGATIVE.	00410
00013	423 0 0273	1	BINB STB C@M			00420
00014	140 0 0243	1	LAN BINX+4		EXTRACT OUT THE CHARACTERISTIC.	00430
00015	500 0 0043		RBA +35		SCALE THE MANTISSA AT 0.	00440
00016	423 0 0275	1	STB C@M+2			00450
00017	403 0 0273	1	LDB C@M		REMOVE THE MANTISSA FROM THE ARG.	00460
00020	140 0 0244	1	LAN BINX+5			00470
00021	110 0 0245	1	SUB BINX+6		UNBIAS THE CHARACTERISTIC.	00480
00022	420 0 0300	1	STZ C@M+5		SET THE CHARACTERISTIC SIGN.	00490
00023	356 0 0026	1	TPZ BINC			00500
00024	160 0 0000		CML		COMPLEMENT NEGATIVE EXPONENT.	00510
00025	421 0 0300	1	STL C@M+5		SET CHARACTERISTIC SIGN MINUS.	00520
00026	421 0 0301	1	BINC STL C@M+6		STORE EXPONENT, D.	00530
00027	120 0 0246	1	MPY BINX+7		D(LOG 2), LEAST SIGNIFICANT PART.	00540
00030	501 0 0027		SBA +23		D(LOG 2) SCALED AT 10.	00550
00031	423 0 0273	1	STB C@M			00560
00032	401 0 0247	1	LDL BINX+8		D(LOG 2), MS PART	00570
00033	120 0 0303	1	MPY C@M+6			00580
00034	105 0 0273	1	ALR C@M		D(LOG 2) AT 10.	00590
00035	501 0 0015		SBA +13		D(LOG 2) AT 23. INTEGER PART IN L.	00600
00036	421 0 0301	1	STL C@M+6		D2, THE INTEGER PART OF D (LOG 2).	00610
00037	403 0 0273	1	LDB C@M		SCALE THE FRACTIONAL PART	00620
00040	140 0 0250	1	LAN BINX+9		OF D (LOG 2) AT 0, THIS IS D3.	00630
00041	500 0 0044		RBA +36			00640
00042	423 0 0273	1	STB C@M			00650
00043	120 0 0251	1	MPY BINX+10		(D3) LN 10 SCALED AT -21, (MS) (LS)	00660
00044	501 0 0001		SBA 1			00670
00045	423 0 0302	1	STB C@M+7			00680
00046	401 0 0273	1	LDL C@M		(D3) LN 10 SCALED AT -21, (LS) (MS)	00690
00047	120 0 0252	1	MPY BINX+11			00700
00050	501 0 0001		SBA 1			00710
00051	104 0 0302	1	ADL C@M+7			00720

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XX = ±
FRACTIONS = ±
.XXX = ±
ANGLES = ± 1/2°

SIZE A | CODE IDENT NO. 49671 | 2186640

SCALE

SHEET 14

DEL 1263-3A (2/66)

```
00052  501 0 0026                    SBA     +22                                                     00730
00053  423 0 0302   1                 STB     C@M+7       (D3) LN 10 SCALED AT 2, PARTIAL PR@DUCT.    00740
00054  401 0 0252   1                 LDL     @INX+11     (D3) LN 10 SCALED AT 2,   (MS) (MS)         00750
00055  120 0 0274   1                 MPY     C@M+1                                                   00760
00056  104 0 0302   1                 ADL     C@M+7                                                   00770
00057  520 0 0253   1                 NRM     @INX+12     N@RMALIZE (D3) LN 10.                       00780
00060  520 0 0254   1                 NRM     @INX+13                                                 00790
00061  501 0 0013                    SBA     +11         SCALE (D3) LN 10 AT11.                      00800
00062  421 0 0302   1                 STL     C@M+7       PREPARE T@ FL@AT (D3) LN 10)                00810
00063  401 0 0255   1                 LDL     @INX+14     C@MPUTE THE CHARACTERISTIC                  00820
00064  110 0 0253   1                 SUB     @INX+12     1026-(N@RMALIZING SHIFTS),                  00830
00065  110 0 0254   1                 SUB     @INX+13                                                 00840
00066  515 0 0014                    RLL     +12                                                     00850
00067  101 0 0302   1                 ADR     C@M+7       MERGE THE MANTISSA CHARACTERISTIC.          00860
00070  401 0 0300   1                 LDL     C@M+5       CHECK THE SIGN @F THE EXP@NENT              00870
00071  352 0 0075   1                 TRZ     @IND        @F THE ARGUMENT,                            00880
00072  401 0 0302   1                 LDL     C@M+7       IF THE SIGN WAS NEGATIVE,                   00890
00073  161 0 0000                    CMB                 C@MPLEMENT (D3) LN 10.                      00900
00074  352 0 0076   1                 TRA     *+2                                                     00910
00075  401 0 0302   1     @IND        LDL     C@M+7                                                   00920
00076  321 7 0307   1                 TSP     FEX         EXP@NENTIAL SUBR@UTINE.                     00930
00077  423 0 0273   1                 STB     C@M         ST@RE A=E@D3 LN 10.                         00940
00100  110 0 0245   1                 SUB     @INX+6      A IS LESS THAN 10 AND GREATER               00950
00101  501 0 0014                    SBA     +12         THAN1.                                      00960
00102  160 0 0000                    CML                 GET THE CHARACTERISTIC @F A AND             00970
00103  100 0 0256   1                 ADD     @INX+15     SCALE MANTISSA.                             00980
00104  421 0 0110   1                 STL     @INF                                                    00990
00105  403 0 0273   1                 LD@     C@M         GET THE MANTISSA @F A.                      01000
00106  140 0 0250   1                 LAN     @INX+9      A IS SCALED AT 11.                          01010
00107  500 0 0043                    R@A     +35         SCALE A AT 0.                               01020
00110  501 0 0000     @INF            SBA     **          ABS@LUTELY SCALE A AT 4.                    01030
00111  423 0 0273   1                 STB     C@M                                                     01040
00112  120 0 0275   1                 MPY     C@M+2       C@MPUTE AM AT -19, (MS) (LS)                01050
00113  501 0 0001                    SBA     1                                                       01060
00114  423 0 0302   1                 STB     C@M+7                                                   01070
00115  401 0 0273   1                 LDL     C@M         C@MPUTE AM AT -19, (LS) (MS)                01080
00116  120 0 0276   1                 MPY     C@M+3                                                   01090
00117  501 0 0001                    SBA     1                                                       01100
00120  104 0 0302   1                 ADL     C@M+7                                                   01110
00121  501 0 0026                    SBA     +22                                                     01120
00122  423 0 0302   1                 STB     C@M+7       PARTIAL PR@DUCT AM AT 4.                    01130
00123  401 0 0274   1                 LDL     C@M+1                                                   01140
00124  120 0 0276   1                 MPY     C@M+3       PARTIAL PR@DUCT AM AT 4, (MS) (MS)          01150
00125  105 0 0302   1                 ALR     C@M+7       FULL PR@DUCT, F=AM AT 4.                    01160
```

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XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186640 | SCALE | SHEET 15

DEL 1263-3A (2/60)

```
00126  110 0 0257  1          SUB   BINX+16     IS F GREATER THAN OR EQUAL TO ONE          01170
00127  420 0 0304  1          STZ   COM+9       SET DIGIT COUNT ZERO.                      01180
00130  420 0 0275  1          STZ   COM+2       INITIALIZE DATA WORD THREE.                01190
00131  351 0 0135  1          TRN   BING        TRANSFER IF F IS LESS THAN ONE.            01200
00132  401 0 0260  1          LDL   BINX+17                                                01210
00133  101 0 0301  1          ADR   COM+6       ADD ONE TO THE DECIMAL EXPONENT.           01220
00134  357 0 0147  1          TRA   BINH                                                   01230
00135  403 0 0302  1  BING    LDB   COM+7       MASK OUT FRACTION AT 4.                    01240
00136  140 0 0261  1          LAN   BINX+18                                                01250
00137  500 0 0052             RBA   +42         SHIFT F TO BE SCALED AT 0.                 01260
00140  422 0 0305  1          STR   COM+10                                                 01270
00141  120 0 0262  1          MPY   BINX+19     10 F SCALED AT 4.                          01280
00142  423 0 0302  1          STB   COM+7       STORE THE SIGNIFICANT HALF OF 10F.         01290
00143  401 0 0305  1          LDL   COM+10                                                 01300
00144  120 0 0262  1          MPY   BINX+19     COMPUTE LEAST SIGNIFICANT HALF OF 10F.     01310
00145  501 0 0027             SBA   +23                                                    01320
00146  105 0 0302  1          ALR   COM+7       10F AT 4.                                  01330
00147  401 0 0273  1  BINH    LDL   COM         SHIFT CHARACTERS 6 LEFT IN THE             01340
00150  402 0 0274  1          LDR   COM+1     BCD DATA WORDS                               01350
00151  517 0 0052             RBL   +42                                                    01360
00152  421 0 0273  1          STL   COM                                                    01370
00153  401 0 0303  1          LDL   COM+8       PLACE THE DIGIT IN THE LEAST SIGNIFICANT   01380
00154  501 0 0023             SBA   +19         CHARACTER OF THE THIRD DATA WORD.          01390
00155  355 0 0157  1          TPN   BINJ        CHECK IF DIGIT IS ZERO.                    01400
00156  401 0 0264  1          LDL   BINX+21                                                01410
00157  150 0 0275  1  BINJ    LIO   COM+2       MERGE THE DIGIT INTO THE THIRD WORD.       01420
00160  513 0 0030             SBL   +24                                                    01430
00161  401 0 0274  1          LDL   COM+1                                                  01440
00162  140 0 0263  1          LAN   BINX+20                                                01450
00163  517 0 0052             RBL   +42         SHIFT WORDS TWO THREE LEFT 6 PLACES.       01460
00164  421 0 0274  1          STL   COM+1       STORE WORD 2.                              01470
00165  422 0 0275  1          STR   COM+2       STORE WORD 3.                              01480
00166  401 0 0257  1          LDL   BINX+16     BUMP THE DIGIT COUNT BY ONE.               01490
00167  101 0 0304  1          ADR   COM+9                                                  01500
00170  110 0 0262  1          SUB   BINX+19     CHECK IF TEN DIGITS HAVE BEEN PROCESSED.   01510
00171  351 0 0135  1          TRN   BING        NO. RETURN FOR NEXT DIGIT.                 01520
00172  401 0 0277  1          LDL   COM+4       MERGE SIGN OF THE MANTISSA                 01530
00173  352 0 0176  1          TRZ   BINK        INTO DATA WORD ONE IF SIGN IS MINUS.       01540
00174  401 0 0265  1          LDL   BINX+22     SIGN IS NORMALLY A SPACE.                  01550
00175  101 0 0273  1          ADR   COM                                                    01560
00176  401 0 0301  1  BINK    LDL   COM+6       SIGN OF EXPONENT IS PLUS IF                01570
00177  352 0 0204  1          TRZ   BINM        EXPONENT IS ZERO.                          01580
00200  401 0 0300  1          LDL   COM+5       MERGE SIGN OF THE CHARACTERISTIC           01590
00201  352 0 0204  1          TRZ   BINM        INTO DATA WORD THREE IF SIGN IS MINUS.      01600
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186640

SCALE

SHEET 1/1

DEL 1263-3A (2/63)

```
00202  401 0 0266   1                LDL     BINX+23                                  01610
00203  101 0 0275   1                ADR     C8M+2                                    01620
00204  420 0 0304   1     BINM       STZ     C8M+9       SET DIGIT COUNT ZERO.        01630
00205  420 0 0276   1                STZ     C8M+3       INITIALIZE THE FOURTH DATA WORD. 01640
00206  402 0 0301   1     BINN       LDR     C8M+6       LOAD THE EXPONENT,           01650
00207  400 0 0000                    LDZ                                              01660
00210  130 0 0267   1                DVD     BINX+24     DIVIDE THE EXPONENT BY 10 TO GET 01670
00211  517 0 0030                    RBL     +24         THE LEAST SIGINIFICANT DIGIT. 01680
00212  422 0 0301   1                STR     C8M+6       SHIFT THE DIGIT INTO THE FOURTH 01690
00213  402 0 0276   1                LDR     C8M+3       DATA WORD AT ITS MOST        01700
00214  355 0 0216   1                TPN     *+2         SIGINIFICANT DIGIT.          01710
00215  401 0 0264   1                LDL     BINX+21                                  01720
00216  513 0 0006                    SBL     6                                        01730
00217  422 0 0276   1                STR     C8M+3                                    01740
00220  401 0 0260   1                LDL     BINX+17     BUMP THE DIGIT COUNT BY ONE. 01750
00221  101 0 0304   1                ADR     C8M+9                                    01760
00222  110 0 0270   1                SUB     BINX+25     CHECK IF DIGIT COUNT IS THREE. 01770
00223  351 0 0206   1                TRN     BINN                                     01780
00224  401 7 0000   1     BINP       LDL     BIN,7     STORE THE 4 DATA WORDS         01790
00225  431 0 0271   1                STE     BINY                                     01800
00226  403 0 0273   1                LDQ     C8M                                      01810
00227  423 7 0271   1     BINR       STB     BINY,7      STORE THE FIRST AND SECOND DATA WORDS. 01820
00230  401 0 0272   1                LDL     BINY+1                                   01830
00231  101 0 0271   1                ADR     BINY                                     01840
00232  403 0 0275   1                LDB     C8M+2                                    01850
00233  423 7 0271   1     BIN$       STB     BINY,7      STORE THE THIRD AND FOURTH DATA WORDS. 01860
00234  401 0 0260   1                LDL     BINX+17                                  01870
00235  101 0 0000   1                ADR     BIN                                      01880
00236  357 7 0000   1                TRA     BIN,7                                    01890
00237  00202020           BINX       NUM     000202020   ZERO BCD WORD.               01900
00240  20202020                      NUM     020202020   ZERO BCD WORD                01910
00241  20202000                      NUM     020202000   ZERO BCD WORD                01920
00242  20202000                      NUM     020202000   ZERO BCD WORD                01930
00243  00007777                      NUM     000007777   MASK FOR MANTISSA            01940
00244  77770000                      NUM     077770000   MASK FOR EXPONENT            01950
00245  20000000                      NUM     020000000   1024 AT 11.                  01960
00246  10234560                      NUM     010234560   LOG 2 AT -1. LS PART         01970
00247  23210115                      NUM     023210115   MS PART                      01980
00250  00017777                      NUM     000017777   MASK FOR LOWER 12 BITS.      01990
00251  35665252                      NUM     035665252   LN 10 AT 2. LS PART          02000
00252  22327306                      NUM     022327306   MS PART                      02010
00253  00000000                      NUM     00          NORMALIZING FACTOR FOR (D3) LN 10 02020
00254  00000000                      NUM     00          NORMALIZING FACTOR FOR (D3) LN 10 02030
00255  00002002                      NUM     02002       1026 AT 23.                  02040
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
.XX = ±
.XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 7186940 | SCALE | SHEET 17

DEL 1263-3A (2/65)

RADIO CORPORATION OF AMERICA

```
00256  S01 0 0004                      SBA    4                                                02050
00257  02000000                        NUM    002000000   1 AT 4.                             02060
00260  00000001                        NUM    01          1 AT 23.                            02070
00261  01777777                        NUM    001777777   MASK FOR FRACTIONS AT 4             02080
00262  24000000                        NUM    024000000   10 AT 4.                            02090
00263  00777777                        NUM    000777777                                       02100
00264  00000020                        NUM    020         ZERO TYPE CODE                      02110
00265  40000000                        NUM    040000000   MINUS SIGN IN FIRST 6 DIGITS        02120
00266  00000040                        NUM    040         MINUS SIGN                          02130
00267  00000012                        NUM    012         10 AT 23.                           02140
00270  00000003                        NUM    03          3 AT 23.                            02150
00271  00 0 00000               BINY   **5    0                                                02160
00272  00000002                        NUM    02                                               02170
00273                           CBM    BSS    12                                               02180
                                       END                                                     02190
00307  00 0 00000      FEX
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:

.XX = ± .XXX = ±

FRACTIONS = ± ANGLES = ± 1/2°

SIZE	CODE IDENT NO.	
A	49671	2186640

SCALE SHEET 18

DEL 1263-3A (2/65)

SECTION 9
FLOATING POINT ADD OR (SUBTRACT)

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN E.M. Stange DATE 2 SEP 65

CHECKED [signature] DATE 8 SEP 65

DESIGN ACTIVITY APPD J.W. Vanderford 8 SEP 65 REL (R)

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
FLOATING POINT ADD OR (SUBTRACT)

SIZE	CODE IDENT NO.	
A	49671	2186641

WEIGHT LB SHEET 1 OF 14

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186641-1	FLOATING POINT ADD OR (SUBTRACT)	
								SYMBOLIC CARD DECK	
				X	5		CDV 86641	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT ADD OR (SUBTRACT)	

LTR

SIZE A | CODE IDENT NO. 49671 | 2186641

SHEET 2

RADIO CORPORATION OF AMERICA

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT ADD OR (SUBTRACT)

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186641
	SCALE		SHEET 3

DEL 1263-3A (2/65)

TABLE OF CONTENTS

1.0 Identification

ID: FAD or (FSB)

2.0 Introduction

The purpose of the Floating Point Add or (Subtract) program is to compute the floating point sum, X + Y, or the remainder, X - Y, where both X and Y are floating point arguments.

This program conforms to the specifications of the Floating Point System, 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86641. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Program Operation

3.1 Program Assembly and Loading

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object program card deck, to load the program into core memory.

3.2 Program Control

This program is used as a subroutine by a control program.

3.2.1 Control Program

Calling Sequence:

With the floating point argument, X, in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	FAD or (FSB) (see below)
a + 1	**5	M, T (see below)
a + 2	Return	

FAD - Symbolic entrance in the Floating Point Add subroutine

FSB - Symbolic entrance in the Floating Point Subtract subroutine.

M is the address of Y the addend or (subtrahend)

T ($0 \leq T \leq 6$) is the index tag modifying M

4.0 Output Format

Error return:

An error return is indicated by overflow 'ON'.

a. Overflow condition exists. The (L) register will be positive upon return.

b. Underflow condition exists. The (L) register will be negative upon return.

Normal return:

Normal condition is indicated by overflow 'OFF'.

The sum or (remainder) of the two arguments, X and Y, will be in the L and R registers upon return. The result will be in normalized floating point format.

5.0 Memory Requirements

5.1 Program: see program listing

5.2 Temporary Space: 7 core memory locations

6.0 Restrictions

None

7.0 Timing

Approximate Timing - 5.25 milliseconds

8.0 Floating Point Add or (Subtract)Card Deck

Symbolic source card deck for this program is 2186641-1

9.0 Appendices

9.1 Flow Chart

Flow chart for this program is in Appendix A.

10.0 Tables

10.1 Program Listing

A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT ADD OR (SUBTRACT)

FLOW CHARTS

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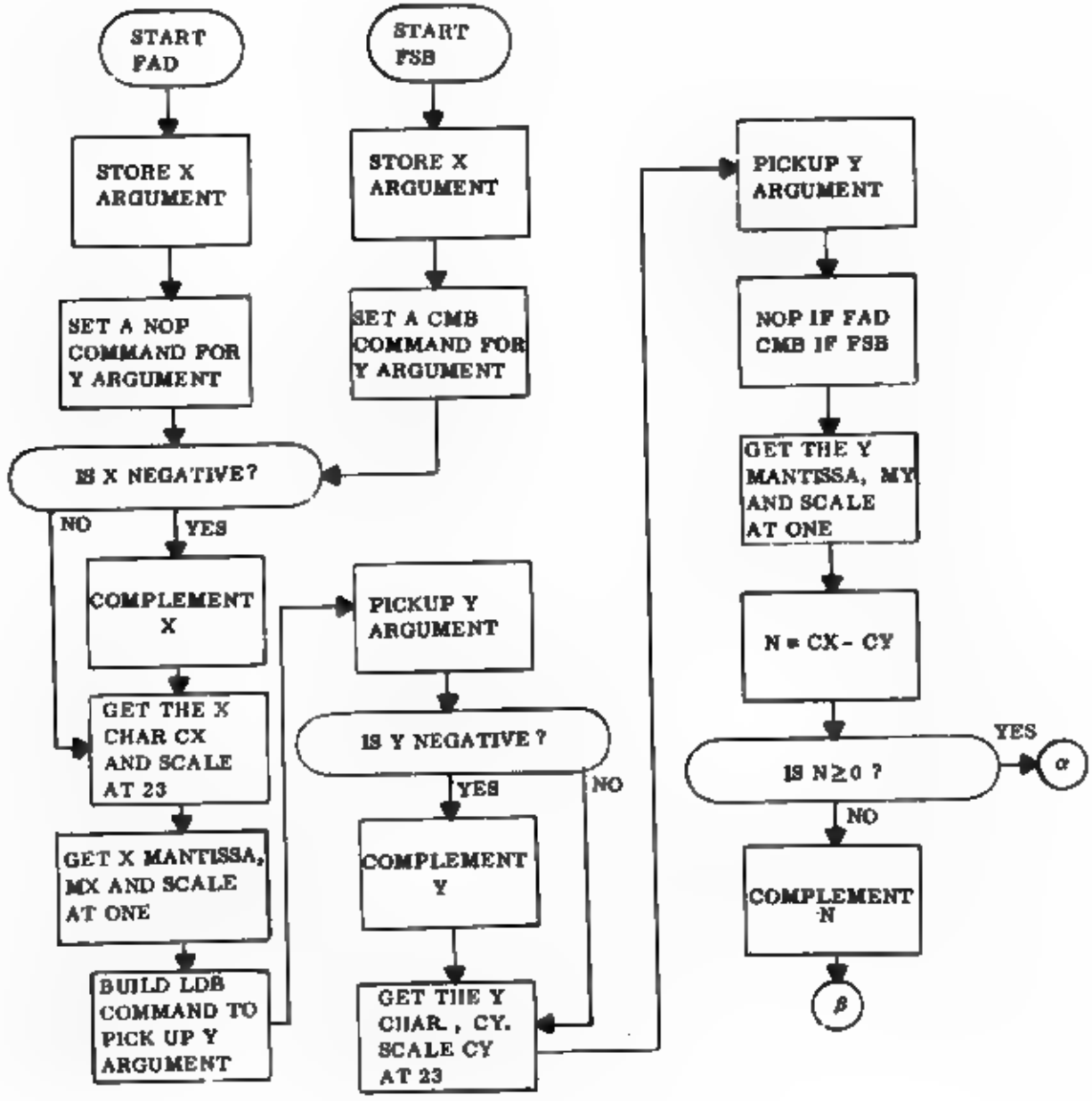
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186641
	SCALE		SHEET 8

DEL. 1263-3A (2/65)

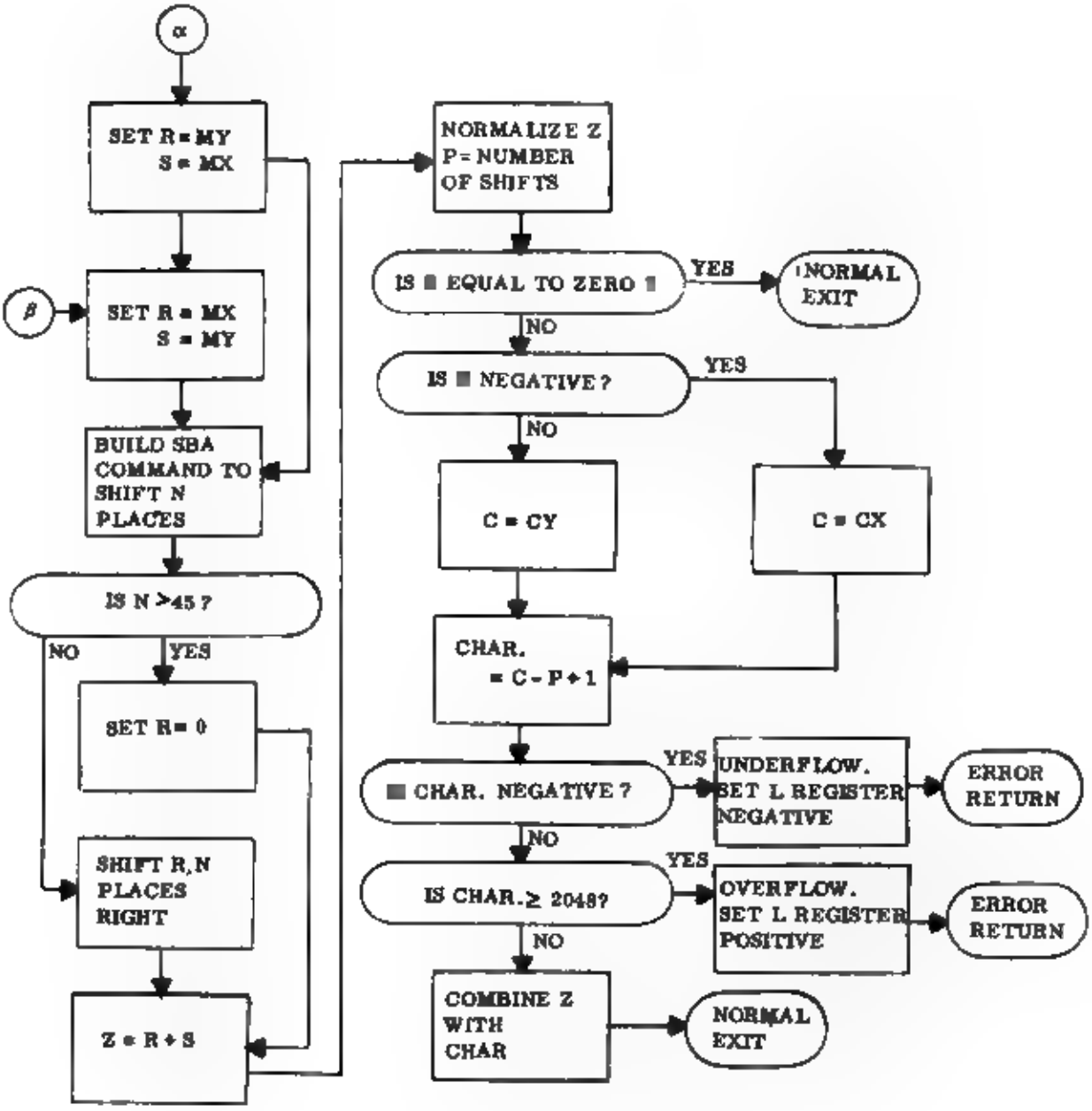


FPA1

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186641
XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 9

DEL 1263-3 (2/65)



FPA2

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
.XX = ± .XXX = ±	A	49671	2186641
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 10

DEL 1263-3 (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT ADD OR (SUBTRACT)

PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186641
	SCALE		SHEET 11

DEL 1263-3A (2/65)

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*		FLOATING POINT ADD OR (SUBTRACT)	00310
00000	00 7 00000		$FSB	**5	0,7	00310
00001	423 0 0142	1		STB	C@M ENTRY FOR SUBTRACTION, STORE X.	00320
00002	402 0 0000	1		LDA	FSB	00330
00003	422 0 0006	1		STA	FAD	00340
00004	402 0 0125	1		LDA	FADX GET CMB INSTRUCTION FOR Y ARGUMENT	00350
00005	357 0 0011	1		TRA	FADA	00360
00006	00 7 00000		$FAD	**5	0,7	00370
00007	423 0 0142	1		STB	C@M ENTRY FOR ADDITION	00380
00010	402 0 0126	1		LDA	FADX+1 GET NOP INSTRUCTION FOR Y ARGUMENT	00390
00011	422 0 0035	1	FADA	STA	FADB	00400
00012	356 0 0014	1		TPZ	*+2 COMPLEMENT X IF NEGATIVE	00410
00013	160 0 0000			CML		00420
00014	511 0 0014			SLL	+12 GET X CHARACTERISTIC, CX, SCALED AT 23	00430
00015	421 0 0144	1		STL	C@M+2 STORE CX AT 23	00440
00016	401 0 0006	1		LDL	FAD	00450
00017	100 0 0141	1		ADD	FADX+12	00460
00020	431 0 0124	1		STE	FADY	00470
00021	403 0 0142	1		LDB	C@M PICK UP X	00480
00022	140 0 0127	1		LAN	FADX+2 EXTRACT OUT THE CHARACTERISTIC	00490
00023	500 0 0043			RBA	+35	00500
00024	501 0 0001			SBA	1 SCALE MANTISSA, MX AT 1	00510
00025	423 0 0142	1		STB	C@M STORE MX AT 1	00520
00026	403 7 0006	1		LDB	FAD,7 LOAD Y ARGUMENT	00530
00027	423 0 0145	1		STB	C@M+3	00540
00030	356 0 0032	1		TPZ	*+2 COMPLEMENT Y IF NEGATIVE	00550
00031	160 0 0000			CML		00560
00032	511 0 0014			SLL	+12 GET Y CHARACTERISTIC, CY, SCALED AT 23	00570
00033	421 0 0147	1		STL	C@M+5 STORE CY AT 23	00580
00034	403 0 0145	1		LDB	C@M+3 PICK UP Y	00590
00035	350 0 0000		FADB	NOP	** COMPLEMENT Y IF THIS IS SUBTRACTION	00600
00036	140 0 0127	1		LAN	FADX+2 EXTRACT OUT THE CHARACTERISTIC	00610
00037	500 0 0043			RBA	+35	00620
00040	501 0 0001			SBA	1 SCALE MANTISSA MY AT 1	00630
00041	423 0 0145	1		STB	C@M+3 STORE [redacted] AT 1	00640
00042	401 0 0144	1		LDL	C@M+2 LOAD CX	00650
00043	110 0 0147	1		SUB	C@M+5 CX-CY	00660
00044	421 0 0150	1		STL	C@M+6 IF PLUS, THE CX WILL [redacted] CHARACTERISTIC [redacted] ANS.	00670
00045	356 0 0053	1		TPZ	FADC TRANSFER IF X IS THE LARGEST NUMBER	00680
00046	160 0 0000			CML	COMPLEMENT (CX-CY) IF NEGATIVE	00690
00047	402 0 0132	1		LDR	FADX+5 X ARGUMENT IS SMALLER, MX MUST [redacted]	00700
00050	422 0 0064	1		STR	FADE SHIFTED RIGHT	00710

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186641

SCALE

SHEET 12

DEL 1263-3A (2/66)

```
00051  402 0 0133   1          LDR     FADX+6      SPECIFY MY ARGUMENT AS BEING ADDED          00720
00052  357 0 0056   1          TRA     FADD                                                    00730
00053  402 0 0134   1  FADC    LDR     FADX+7      Y ARGUMENT IS SMALLER, MY MUST              00740
00054  422 0 0064   1          STR     FADE        BE SHIFTED RIGHT.                           00750
00055  402 0 0135   1          LDR     FADX+8      SPECIFY MX TO BE ADDED                      00760
00056  422 0 0066   1  FADD    STR     FADG                                                    00770
00057  430 0 0065   1          STA     FADF        SET THE NUMBER OF SHIFTS TO BE MADE         00780
00060  110 0 0136   1          SUB     FADX+9      TO THE SMALLER ARGUMENT. IF                 00790
00061  353 0 0064   1          TNZ     FADE        THE NUMBER OF SHIFTS EXCEED 45,             00800
00062  513 0 0055              SBL     +45         FORCE A ZERO INTO THE REGISTER              00810
00063  357 0 0066   1          TRA     FADG        AND ADD THE LARGER NUMBER                   00820
00064  403 0 0000      FADE    LDD     **          LOAD THE SMALLER NUMBER                     00830
00065  501 0 0000      FADF    SBA     **          PROPERLY SCALE THE NUMBER RIGHT             00840
00066  100 0 0000      FADG    ADD     **          ADD THE LARGER NUMBER                       00850
00067  520 0 0137   1          NRM     FADX+10     NORMALIZE THE RESULT                        00860
00070  520 0 0140   1          NRM     FADX+11                                                 00870
00071  501 0 0013              SBA     +11         SCALE THE RESULTANT MANTISSA AT 11          00880
00072  352 0 0124   1          TRZ     FADY        IF ZERO, TRANSFER WITH LEGAL ZERO           00890
00073  421 0 0142   1          STL     C0M         TEMPORARILY STORE PART OF MANTISSA.         00900
00074  401 0 0150   1          LDL     C0M+6       PICK UP CHARACTERISTIC INDICATOR.           00910
00075  351 0 0100   1          TRN     FADH        IF NEGATIVE, USE CY.                        00920
00076  401 0 0144   1          LDL     C0M+2       USE CX AS THE CHARACTERISTIC.               00930
00077  357 0 0101   1          TRA     *+2                                                     00940
00100  401 0 0147   1  FADH    LDL     C0M+5       USE CY AS THE CHARACTERISTIC                00950
00101  100 0 0141   1          ADD     FADX+12     CY+1 DUE TO SCALING OF ONE                  00960
00102  110 0 0137   1          SUB     FADX+10     SUBTRACT NORMALIZING SHIFTS                 00970
00103  110 0 0140   1          SUB     FADX+11     CHARACTERISTIC =*CY+1-N1-N2                 00980
00104  256 00107    2          JPZ     *+3         UNDERFLOW CONDITION                         00990
00105  102 0 0131   1          ADDI    FADX+4                                                  01000
00106  257 00124    2          JRA     FADY                                                    01010
00107  515 0 0014              RLL     +12                                                     01020
00110  351 0 0122   1          TRN     FADK        OVERFLOW CONDITION                          01030
00111  421 0 0143   1          STL     C0M+1       TEMPORARILY STORE THE CHARACTERISTIC.       01040
00112  401 0 0142   1          LDL     C0M         PICK UP THE MANTISSA.                       01050
00113  351 0 0116   1          TRN     *+3         CHECK IF MANTISSA IS NEGATIVE.              01060
00114  150 0 0143   1          LI0     C0M+1       COMBINE MANTISSA AND CHARACTERISTIC.        01070
00115  257 00124    2          JRA     FADY        NORMAL EXIT                                 01080
00116  160 0 0000              CML                 MAKE MANTISSA POSITIVE.                     01090
00117  150 0 0143   1          LI0     C0M+1       COMBINE MANTISSA AND CHARACT.               01100
00120  160 0 0000              CML                 RETURN TO NEGATIVE VALUE.                   01110
00121  257 00124    2          JRA     FADY        NORMAL EXIT                                 01120
00122  102 0 0131   1  FADK    ADDI    FADX+4                                                  01130
00123  160 0 0000              CML                 OVERFLOW CONDITION, EXIT WITH               01140
00124  257 00000      FADY     JRA     0           THE L REGISTER POSITIVE. EXIT               01150
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 218641

SCALE

SHEET 13

DEL 1263-3A (2/65)

```
00125   161 0 0000              FADX    CMB                                                     01160
00126   350 0 0000                      NOP                                                     01170
00127   40007777                        NUM     040007777       MASK FOR CHARACTERISTIC         01180
00130   00077777                        NUM     000077777       MASK FOR ALL BUT ADDRESS        01190
00131   40000000                        NUM     040000000                                       01200
00132   403 0 0142  1                   LDB     C@M             PICK UP MX,                     01210
00133   104 0 0145  1                   ADL     C@M+3           ADD MY                          01220
00134   403 0 0145  1                   LDB     C@M+3           PICK UP MY                      01230
00135   104 0 0142  1                   ADL     C@M             ADD MX                          01240
00136   00000055                        NUM     055             45 AT 23,                       01250
00137   00000000                        NUM     00              NORMALIZING SHIFTS              01260
00140   00000000                        NUM     00              NORMALIZING SHIFTS              01270
00141   00000001                        NUM     01                                              01280
00142                           C@N     BSS     7                                               01290
                                        END                                                     01300
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
.XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186941

SCALE

SHEET 4

DEL 1263-3A (2/65)

SECTION 10
FLOATING POINT MULTIPLICATION

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN DATE
E. M. Stayer 25EP65

CHECKED DATE
M. A. Patterson 8 SEP 65

DESIGN ACTIVITY APPD REL
J. W. Vanderford 8 SEP 65 (R)

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
FLOATING POINT MULTIPLICATION

SIZE	CODE IDENT NO.	
A	49671	2186642

WEIGHT LB

SHEET 1 OF 12

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186642-1	FLOATING POINT MULTIPLICATION	
								SYMBOLIC CARD DECK	
				X	5		CDV 86642	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT MULTIPLICATION	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186642

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT MULTIPLICATION

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186642
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 3

DEL 1263-3A (2/65)

TABLE OF CONTENTS

1.0 Identification

ID: FMP

2.0 Introduction

The purpose of the Floating Point Multiplication program is to compute the floating point product XY where X and Y are both floating point numbers.

This program conforms to the specifications of the Floating Point System, 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86642. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

For ease of notation, let M designate the most significant part and L the least significant part of the multiplicand X. Similarly, let R designate the most significant part and S the least significant part of the multiplier Y.

$$XY = MR + (MS + LR)$$

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object program card deck, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

Calling Sequence:

With the multiplicand X in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	FMP (see below)
a + 1	**5	M,T (see below)
a + 2	Return	

FMP - Symbolic entrance in the Floating Point Multiplication subroutine.

M is the address of the multiplier, Y,

T ($0 \leq T \leq 6$) is the index tag modifying M.

5.0 Output Format

Error return:

An error return is indicated by overflow 'ON'.

a. Underflow condition exists. The (L) register will be negative upon return.

b. Overflow condition exists. The (L) register will be positive upon return.

Normal return:

Normal return is indicated by overflow 'OFF'.

The product of XY will be in the (L) and (R) registers upon return. The product will be in normalized floating point format.

6.0 Memory Requirements

6.1 Program: see program listing

6.2 Temporary Space: 10 core memory locations

7.0 Restrictions

None

8.0 Timing

Approximate timing: 6.4 milliseconds

9.0 Floating Point Multiplication Card Deck

Symbolic source card deck for this program is 2186642-1.

10.0 Appendices

10.1 Flow Chart

Flow chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

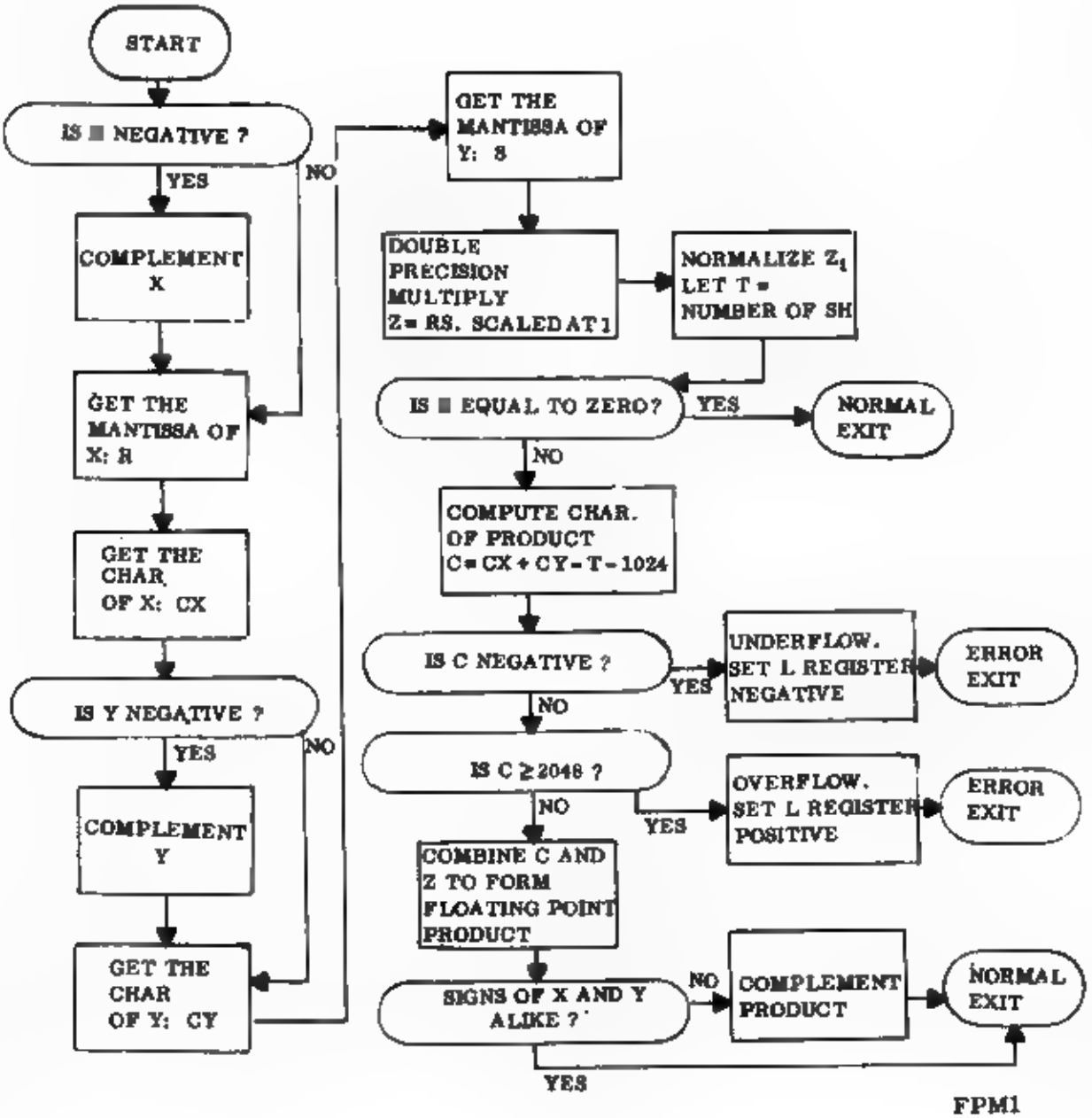
A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT MULTIPLICATION

FLOW CHARTS



FPM1

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE ■ INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186642
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 9

DEL 1263-3 (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT MULTIPLICATION

PROGRAM LISTING

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186642
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ±1/2°	SCALE		SHEET 10

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE		SYMBOLIC CARD CONTENT		CARD NO.
			*	FLOATING POINT MULTIPLICATION		00310
00000	00 7 00000		SFMP	##5	0,7	00320
00001	421 0 0104	1		STL	C@M	ENTRANCE TO MULTIPLY 00330
00002	356 0 0004	1		TPZ	*+2	X IS IN THE L AND R REGISTERS. SAVE THE SIGN 00340
00003	161 0 0000			CMB		COMPLEMENT X IF IT IS NEGATIVE 00350
00004	421 0 0107	1		STL	C@M+3	00360
00005	140 0 0076	1		LAN	FMPX	GET THE X MANTISSA, R, 00370
00006	500 0 0044			RBA	+36	00380
00007	423 0 0105	1		STB	C@M+1	STORE R AT 1 00390
00010	401 0 0107	1		LDL	C@M+3	GET THE X CHARACTERISTIC, CX, 00400
00011	511 0 0014			SLL	+12	00410
00012	421 0 0107	1		STL	C@M+3	STORE CX AT 23 00420
00013	401 0 0000	1		LDL	FMP	00430
00014	100 0 0100	1		ADD	FMPX+2	00440
00015	431 0 0075	1		STE	FMPC	00450
00016	403 7 0000	1		LDB	FMP,7	00460
00017	421 0 0110	1		STL	C@M+4	STORE SIGN OF Y, 00470
00020	356 0 0022	1		TPZ	*+2	00480
00021	161 0 0000			CMB		COMPLEMENT Y IF IT IS NEGATIVE 00490
00022	421 0 0111	1		STL	C@M+5	00500
00023	511 0 0014			SLL	+12	GET THE Y CHARACTERISTIC, CY 00510
00024	421 0 0113	1		STL	C@M+7	STORE CY AT 23 00520
00025	401 0 0111	1		LDL	C@M+5	GET THE Y MANTISSA, S 00530
00026	140 0 0076	1		LAN	FMPX	00540
00027	500 0 0044			RBA	+36	00550
00030	423 0 0111	1		STB	C@M+5	STORE S SCALED AT 1 00560
00031	120 0 0105	1		MPY	C@M+1	MULTIPLY SR SCALED AT -21 (MS) (LS) 00570
00032	423 0 0114	1		STB	C@M+8	00580
00033	401 0 0111	1		LDL	C@M+5	PICK UP S 00590
00034	120 0 0106	1		MPY	C@M+2	MULTIPLY SR SCALED AT -21 (LS) (MS) 00600
00035	104 0 0114	1		ADL	C@M+8	00610
00036	501 0 0027			SBA	+23	00620
00037	423 0 0114	1		STB	C@M+8	SR SCALED AT 2 (LS) (MS) 00630
00040	401 0 0112	1		LDL	C@M+6	PICK UP S 00640
00041	120 0 0106	1		MPY	C@M+2	MULTIPLY SR SCALED AT 2. (MS) (MS) 00650
00042	104 0 0114	1		ADL	C@M+8	PRODUCT SR 00660
00043	520 0 0101	1		NRM	FMPX+3	T IS THE NUMBER OF SHIFTS TO NORMALIZE 00670
00044	520 0 0102	1		NRM	FMPX+4	00680
00045	252 00075	2		JRZ	FMPC	ZERO PRODUCT, NORMAL RETURN 00690
00046	501 0 0013			SBA	+11	00700
00047	421 0 0114	1		STL	C@M+8	00710
00050	401 0 0107	1		LDL	C@M+3	COMPUTE THE CHARACTERISTIC [redacted] THE PRODUCT

```
00051  100 0 0113  1            ADD     C0M+7          *CX+CY-1023-T                    00720
00052  110 0 0103  1            SUB     FMPX+5                                          00730
00053  110 0 0101  1            SUB     FMPX+3                                          00740
00054  110 0 0102  1            SUB     FMPX+4                                          00750
00055  256 00060   2            JPZ     *+3            UNDERFLOW CONDITION, ERROR RETURN 00760
00056  102 0 0077  1            ADDI    FMPX+1         SET OVERFLOW                     00770
00057  257 00075   2            JRA     FMPC                                            00780
00060  515 0 0014               RLL     +12                                             00790
00061  351 0 0073  1            TRN     FMPB           OVERFLOW CONDITION               00800
00062  151 0 0114  1            LIR     C0M+8                                           00810
00063  401 0 0104  1            LDL     C0M            LOGICALLY EXCLUSIVE OR THE SIGNS 00820
00064  170 0 0110  1            LER     C0M+4          TOGETHER. COMPLEMENT THE PRODUCT 00830
00065  351 0 0070  1            TRN     FMPA           IF THEY ARE DIFFERENT            00840
00066  401 0 0114  1            LDL     C0M+8          PICK UP PRODUCT                  00850
00067  357 0 0075  1            TRA     FMPC           NORMAL RETURN.                   00860
00070  401 0 0114  1     FMPA   LDL     C0M+8                                           00870
00071  161 0 0000               CMB                    COMPLEMENT PRODUCT               00880
00072  357 0 0075  1            TRA     FMPC           NORMAL RETURN                    00890
00073  102 0 0077  1     FMPB   ADDI    FMPX+1                                          00900
00074  160 0 0000               CML                    OVERFLOW CONDITION, SET L-REGISTER 00910
00075  357 0 0000        FMPC   TRA     0              POSITIVE, ERROR RETURN           00920
00076  00007777          FMPX   NUM     000007777      MASK FOR CHARACTERISTIC          00930
00077  40000000               NUM     040000000      MASK FOR ALL BUT ADDRESS AND INDEX 00940
00100  00000001               NUM     01                                              00950
00101  00000000               NUM     00             SHIFTS TO NORMALIZE THE PRODUCT  00960
00102  00000000               NUM     00             SHIFTS TO NORMALIZE THE PRODUCT  00970
00103  00001776               NUM     01776          1022 AT 23                       00980
00104                 C0M      BSS     10                                             00990
                               END                                                    01000
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186942

SCALE

SHEET 12

DEL 1263-3A (2/60)

SECTION 11
FLOATING POINT DIVIDE

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR | USED ON 110A | NEXT ASSY

CONTRACT NO.
NAS-8-13007

DRAWN DATE
E. R. Hanson 2 SEPT 65

CHECKED DATE
W. A. Dalton 3SEP 65

DESIGN ACTIVITY APPD REL
J. N. Vanderford 3 Sept 65 (R)

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
FLOATING POINT DIVIDE

SIZE	CODE IDENT NO.	
A	49671	2186643

WEIGHT LB | SHEET 1 OF 14

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186643-1	FLOATING POINT DIVIDE	
								SYMBOLIC CARD DECK	
				X	5		CDV86643	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT DIVIDE	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186643

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT DIVIDE

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
.XX = ± .XXX = ±	A	49671	2186643
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 3

TABLE OF CONTENTS

1.0 Identification

ID: FDV

2.0 Introduction

The purpose of the Floating Point Divide program is to compute the floating point quotient of X ÷ Y where both X and Y are floating point numbers.

The program conforms to the specifications of the Floating Point System, 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86643. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

For ease of notation, let M designate the most significant part and L the least significant part of the divisor Y.

$$\frac{X}{Y} \approx \frac{X}{M}\left[1 - \left(\frac{L}{M}\right) + \left(\frac{L}{M}\right)^2\right]$$

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object program card deck to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

Calling Sequence:

With the dividend X in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	FDV (see below)
a + 1	**5	M,T (see below)
a + 2	Return	

FDV - Symbolic entrance in the Floating Point Divide subroutine.

M is the address of the floating point divisor Y.

T ($0 \leq T \leq 6$) is the index tag modifying M.

5.0 Output Format

Error return:

An error return is indicated by overflow 'ON'.

a. The divisor is zero. The L and R registers are both zero upon return.

b. Underflow condition exists. The L register will be negative upon return.

c. Overflow condition exists. The L register will be positive non-zero upon return.

Normal return:

A normal return is indicated by overflow 'OFF'.

The quotient of X ÷ Y will be in the L and R registers upon return. The quotient will be in normalized floating point format.

6.0 Memory Requirements

6.1 Program: see program listing

6.2 Temporary Space: 10 core memory locations

7.0 Restrictions

None

8.0 Timing

Approximate timing: 9.85 milliseconds

9.0 Floating Point Divide Card Deck

Symbolic source card deck for this program is 2186643-1

10.0 Appendices

10.1 Flow Chart

Flow chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

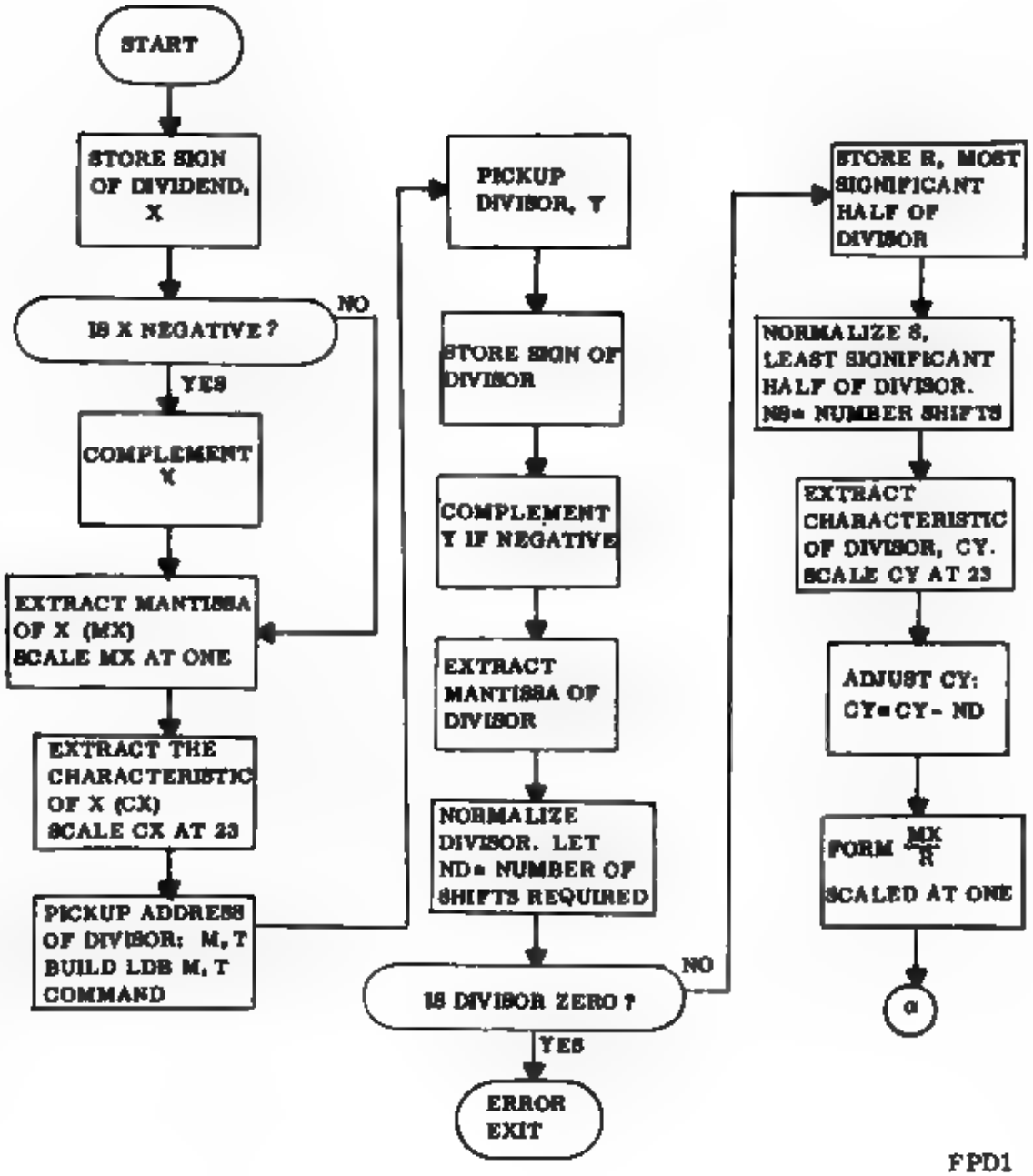
A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT DIVIDE

FLOW CHART



FPD1

RADIO CORPORATION OF AMERICA

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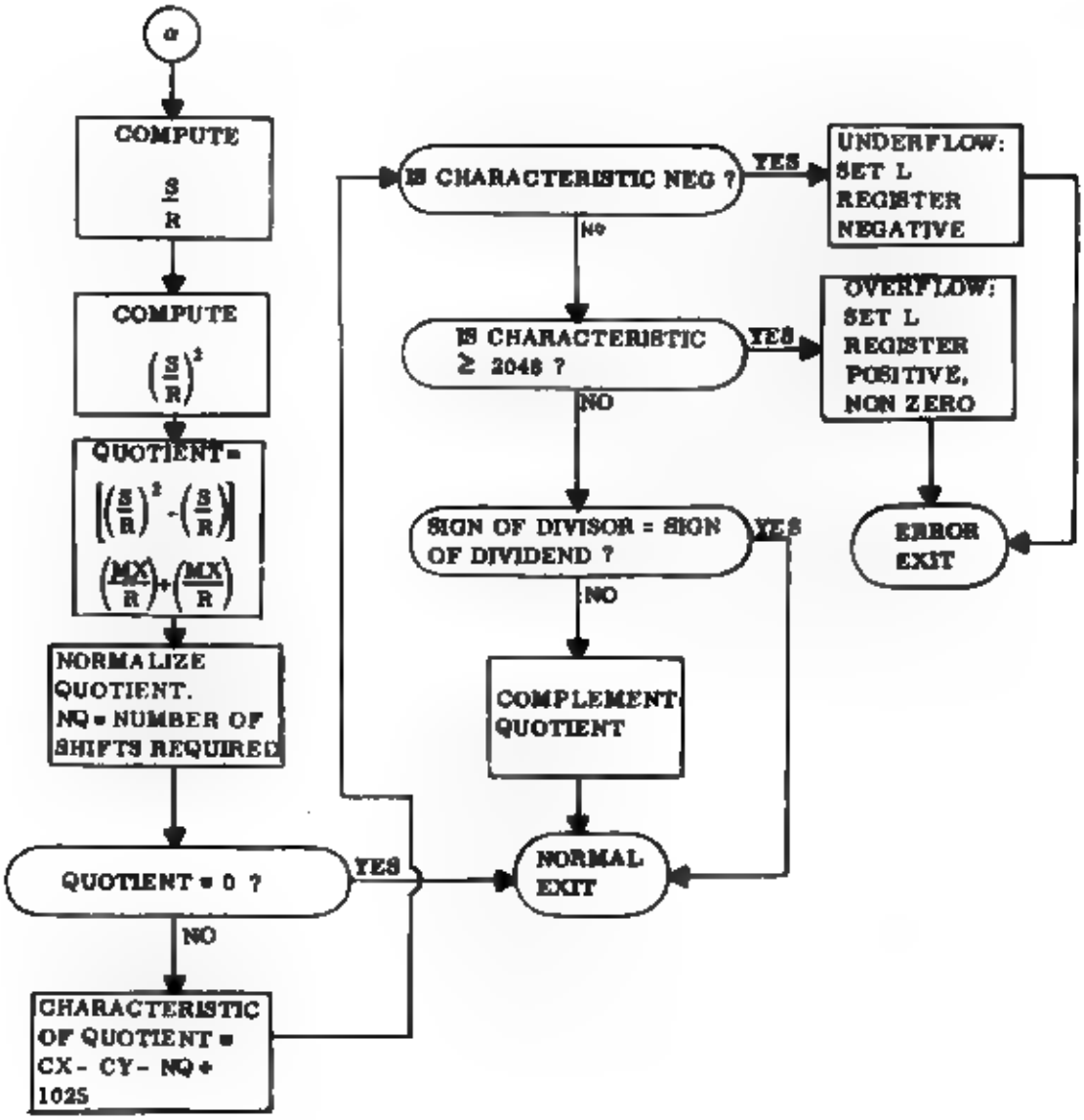
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 9

DEL 1263-3A (2/65)



FPD2

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186643
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 10

TABLE 1

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT DIVIDE

PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186643
	SCALE		SHEET //

DEL 1263-3A (2/65)

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*		FLOATING POINT DIVIDE	00310
00000	00 7 00000		$FDV	**5	0,7	00310
00001	421 0 0135	1		STL	C0M	STORE SIGN OF X 00320
00002	356 0 0004	1		TPZ	**2	CHECK IF X IS NEGATIVE. 00330
00003	161 0 0000			CMB		COMPLEMENT X IF NEGATIVE 00340
00004	421 0 0136	1		STL	C0M+1	00350
00005	140 0 0123	1		LAN	FDVX	GET THE MANTISSA OF X, MX, 00360
00006	500 0 0044			RBA	+36	SCALE MX AT 1. 00370
00007	423 0 0137	1		STB	C0M+2	STORE MX AT 1. 00380
00010	401 0 0136	1		LDL	C0M+1	GET THE CHARACTERISTIC, CX. 00390
00011	501 0 0014			SBA	+12	SCALE CX AT 23. 00400
00012	421 0 0136	1		STL	C0M+1	STORE CX AT 23. 00410
00013	401*0 0000	1		LDL	FDV	00420
00014	100 0 0133	1		ADD	FDVY	00430
00015	431 0 0117	1		STE	FDVD	00440
00016	403 7 0000	1		LDB	FDV,7	LOAD THE DIVISOR, Y 00450
00017	421 0 0141	1		STL	C0M+4	STORE THE SIGN OF Y 00460
00020	356 0 0022	1		TPZ	*+2	00470
00021	161 0 0000			CMB		COMPLEMENT Y IF NEGATIVE 00480
00022	421 0 0142	1		STL	C0M+5	00490
00023	140 0 0123	1		LAN	FDVX	GET THE MANTISSA OF THE DIVISOR. 00500
00024	500 0 0043			RBA	+35	00510
00025	520 0 0126	1		NRM	FDVX+3	NORMALIZE THE DIVISOR 00520
00026	520 0 0127	1		NRM	FDVX+4	ND IS NUMBER OF NORMALIZING SHIFTS. 00530
00027	252 00117	2		JRZ	FDVD	EXIT - ZERO DIVISOR. 00540
00030	421 0 0143	1		STL	C0M+6	STORE THE MOST SIGNIFICANT HALF OF DIVISOR 00550
			*			, R. 00560
00031	400 0 0000			LDZ		NORMALIZE THE LEAST SIGNIFICANT 00570
00032	500 0 0027			RBA	+23	HALF OF THE DIVISOR, S 00580
00033	520 0 0130	1		NRM	FDVX+5	NS EQUALS NUMBER OF SHIFTS TO NORMALIZE S. 00590
00034	421 0 0144	1		STL	C0M+7	STORE S 00600
00035	401 0 0142	1		LDL	C0M+5	GET THE CHARACTERISTIC [redacted] DIVISOR, CY. 00610
00036	501 0 0014			SBA	+12	00620
00037	110 0 0126	1		SUB	FDVX+3	ADJUST CHARACTERISTIC FOR NORMALIZATION. 00630
00040	110 0 0127	1		SUB	FDVX+4	00640
00041	421 0 0142	1		STL	C0M+5	CY =(NUMBER OF SHIFTS TO NORMALIZE Y) 00650
			*			SCALED AT 23. 00660
00042	401 0 0131	1		LDL	FDVX+6	BUILD COMMAND [redacted] PROPERLY 00670
00043	100 0 0130	1		ADD	FDVX+5	SCALE SOR. 00680
00044	430 0 0063	1		STA	FDVA	(SBA 22+NS) 00690
00045	430 0 0066	1		STA	FDV8	00700
00046	403 0 0137	1		LDB	C0M+2	LOAD THE DIVIDEND, MX SCALED AT 1. 00710

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET 12

2/86643

DEL 12633A (2/65)

```
00047  130 0 0143   1            DVD     C0M+6          MXoR                                    00720
00050  421 0 0146   1            STL     C0M+9          STORE MXoR AT 1, MOST SIGNIFICANT HALF. 00730
00051  400 0 0000                 LDZ                                                            00740
00052  500 0 0027                 RBA     +23            MXoR, THE LEAST SIGNIFICANT HALF.       00750
00053  130 0 0143   1            DVD     C0M+6                                                  00760
00054  421 0 0145   1            STL     C0M+8          STORE MXoR AT -22, LEAST SIGNIFICANT HALF 00770
00055  402 0 0144   1            LDR     C0M+7          GET S AND SCALE AT 1.                   00780
00056  400 0 0000                 LDZ                                                            00790
00057  500 0 0030                 RBA     +24                                                    00800
00060  130 0 0143   1            DVD     C0M+6          SoR SCALED AT -22-NS                    00810
00061  421 0 0144   1            STL     C0M+7                                                  00820
00062  120 0 0144   1            MPY     C0M+7          (So)R) (SoR) SCALED AT 2 (-22-NS)       00830
00063  501 0 0000          FDVA   SBA     **                                                     00840
00064  110 0 0144   1            SUB     C0M+7          Z=(SoR)**2-(SoR) SCALED AT (-22-NS)     00850
00065  120 0 0146   1            MPY     C0M+9          (MXoR) Z SCALED AT +1+(-22-NS)          00860
00066  501 0 0000          FDVB   SBA     **             (MXoR) SCALED AT 1.                     00870
00067  104 0 0145   1            ADL     C0M+8          (MXoR)+(MXoR) Z SCALED AT 1.            00880
00070  520 0 0126   1            NRM     FDVX+3         NORMALIZE THE QUOTIENT.                 00890
00071  520 0 0127   1            NRM     FDVX+4         NO                                      00900
00072  252 00117    2            JAZ     FDVD           ZERO QUOTIENT, NORMAL EXIT              00910
00073  501 0 0013                 SBA     +11                                                    00920
00074  421 0 0140   1            STL     C0M+3          STORE THE QUOTIENT MANTISSA.            00930
00075  401 0 0136   1            LDL     C0M+1          COMPUTE THE CHARACTERISTIC OF THE QUOTIENT 00940
00076  110 0 0142   1            SUB     C0M+5          CHARACTERISTIC =CX-CY-NO+1025           00950
00077  110 0 0126   1            SUB     FDVX+3                                                 00960
00100  110 0 0127   1            SUB     FDVX+4                                                 00970
00101  100 0 0132   1            ADD     FDVX+7         CHARACTERISTIC AT 23                    00980
00102  256 00105    2            JPZ     *+3            UNDERFLOW CONDITION, ERROR RETURN.      00990
00103  102 0 0134   1            ADDI    FDVY+1                                                 01000
00104  257 00117    2            JRA     FDVD                                                   01010
00105  515 0 0014                 RLL     +12                                                    01020
00106  351 0 0120   1            TRN     FDVF           OVERFLOW CONDITION                      01030
00107  151 0 0140   1            LIR     C0M+3          MERGE THE MANTISSA AND CHARACTERISTIC   01040
00110  401 0 0135   1            LDL     C0M            DETERMINE THE SIGN OF THE               01050
00111  170 0 0135   1            LEO     C0M            QUOTIENT, LOGICAL EXCLUSIVE OR THE SIGNS. 01060
00112  351 0 0115   1            TRN     FDVC           OPPOSITE SIGNS YIELD A NEGATIVE QUOTIENT 01070
00113  401 0 0140   1            LDL     C0M+3          POSITIVE QUOTIENT                       01080
00114  357 0 0117   1            TRA     FDVD                                                   01090
00115  401 0 0140   1      FDVC  LDL     C0M+3          THE QUOTIENT IS NEGATIVE.               01100
00116  161 0 0000                 CMB                    COMPLEMENT THE QUOTIENT                 01110
00117  257 00000           FDVD  JRA     0              NORMAL EXIT                             01120
00120  102 0 0134   1      FDVF  ADDI    FDVY+1                                                 01130
00121  161 0 0000                 CMB                    OVERFLOW SITUATION. MAKE L REGISTER     01140
00122  257 00117    2            JRA     FDVD           POSITIVE AND TRANSFER. ERROR EXIT.      01150
```

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ± FRACTIONS = ±
XXX = ± ANGLES = ±1/2°

DEL 1263-3A (2/60)

SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET /3

2/86643

RADIO CORPORATION OF AMERICA

```
00123  00007777           FDVX  NUM   000007777   MASK FOR CHARACTERISTIC                      01160
00124  00077777                 NUM   000077777   MASK FOR ALL BUT ADDRESS AND TAG.            01170
00125  403 0 0000               LDB   **                                                       01180
00126  00000000                 NUM   00          NORMALIZE DIVISOR COUNT                      01190
00127  00000000                 NUM   00          NORMALIZE DIVISOR COUNT                      01200
00130  00000000                 NUM   00          NORMALIZE THE LEAST SIGNIFICANT PART         01210
00131  00000026                 NUM   026         22 AT 23,                                    01220
00132  00002001                 NUM   02001       1025 AT 23                                   01230
00133  00000001           FDVY  NUM   01                                                       01240
00134  40000000                 NUM   040000000                                                01250
00135                     CBM   BSS   10                                                       01260
                                END                                                            01270
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
.XX = ±   .XXX = ±
FRACTIONS = ±   ANGLES = ± 1/2°

SIZE	CODE IDENT NO.	
A	49671	2186643
SCALE		SHEET 14

DEL 1263-3A (2/65)

SECTION 12
FLOATING POINT SQUARE ROOT

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR | USED ON 110A | NEXT ASSY

CONTRACT NO.
NAS 8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN E. M. Stanger DATE 2 SEP 65

CHECKED W. A. Patterman DATE 8 SEP 65

DESIGN ACTIVITY APPD J. H. Vanderford DATE 8 SEPT 65 REL (R)

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
FLOATING POINT SQUARE ROOT

SIZE A | CODE IDENT NO. 49671 | 2186644

WEIGHT LB | SHEET 1 OF 14

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186644-1	FLOATING POINT SQUARE ROOT	
								SYMBOLIC CARD DECK	
				X	5		CDV86644	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SQUARE ROOT	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186644

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT SQUARE ROOT

PREPARED UNDER CONTRACT NAS8-13007
FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

RADIO CORPORATION OF AMERICA

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	SCALE		SHEET 3

DEL 1263-3A (2/65)

TABLE OF CONTENTS

1.0 Identification

ID: FSR

2.0 Introduction

The purpose of the Floating Point Square Root program is to compute the floating point square root of X where X is in the floating point format.

The program conforms to the specifications of the Floating Point System 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86644. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

Assume that the argument X is normalized although this is not a program requirement. If the argument is not normalized, it will immediately be normalized.

Unpack X,

$$X^{1/2} = (2^{2c} \cdot f)^{1/2} = 2^{c} \cdot f^{1/2} \text{ where } 1 > f \geq .25$$

The first fractional approximation, y_o, to $f^{1/2}$ is given by $f + 1/4 - 1/2(f - 1/2)^2$. This is then followed by three Newtonian iterations of the form:

$$y_{i+1} = 1/2 \left(y_i + \frac{f}{y_i}\right)$$

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object program card deck, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

Calling Sequence:

With the argument X in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	FSR (see below)
a + 1	Return	

FSR - Symbolic entrance in the Floating Point Square Root subroutine.

5.0 Output Format

Error Return:

An error return is indicated by overflow 'ON'.

The argument X was negative. The L and R register will contain the negative argument.

Normal Return:

A normal return is indicated by overflow 'OFF'.

The square root of the argument X will be in the L and R registers upon return. The square root will be in normalized floating point format.

6.0 Memory Requirements

6.1 Program: see program listing.

6.2 Temporary Space: 12 core memory locations.

7.0 Restrictions

None

8.0 Timing

Approximate timing: 26.6 milliseconds.

9.0 Floating Point Square Root Card Deck

Symbolic source card deck for this program is 2186644-1.

10.0 Appendices

10.1 Flow Chart

Flow chart for this program is in Appendix A.

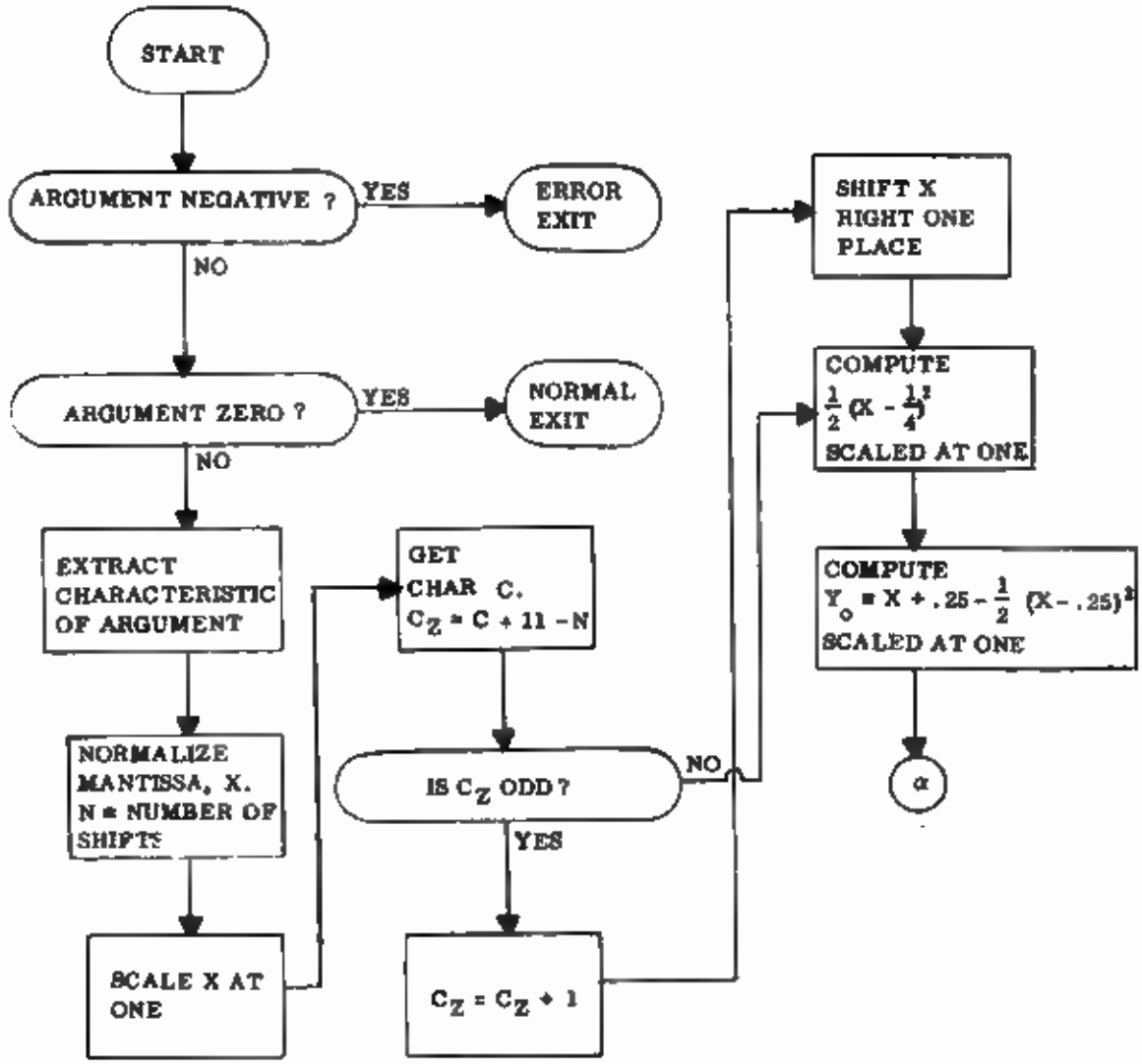
11.0 Tables

11.1 Program Listing

A listing of this program shown memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A
SATURN GROUND COMPUTER SYSTEM
FLOATING POINT SQUARE ROOT
FLOW CHART

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
.XX = ± .XXX = ±	A	49671	2186644
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 8



FPSR1

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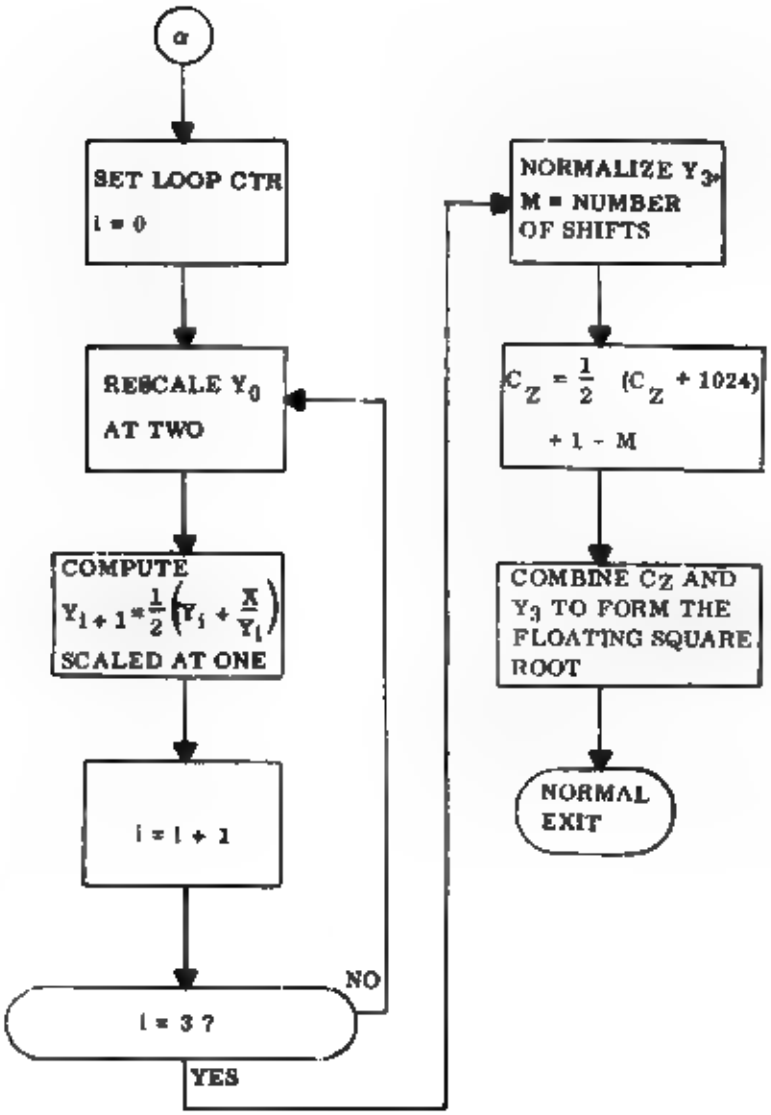
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 9

DEL 1263-3 (2/65)



FPSR2

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.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 10

DEL 1263-3 (2/65)

TABLE I
SATURN GROUND COMPUTER SYSTEM
FLOATING POINT SQUARE ROOT
PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186644
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET //

DEL 1263-3A (2/65)

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*		FLOATING POINT SQUARE ROOT	00310
00000	00 0 00000		$FSR	*+5	0	00310
00001	256 00004	2		JPZ	*+3	NEGATIVE ARGUMENT, ERROR RETURN.	00320
00002	102 0 0145	1		ADDI	FSRX+12	TURN OVERFLOW ON	00330
00003	357 7 0000	1		TRA	FSR,7		00340
00004	423 0 0146	1		STO	COM		00350
00005	140 0 0131	1		LAN	FSRX	MASK OUT THE CHARACTERISTIC.	00360
00006	520 0 0144	1		NRM	FSRX+11	NORMALIZE.	00370
00007	520 0 0132	1		NRM	FSRX+1	N EQUALS NORMALIZING SHIFTS.	00380
00010	352 7 0000	1		TRZ	FSR,7	ZERO ARGUMENT. NORMAL EXIT.	00390
00011	501 0 0001			SBA	1		00400
00012	423 0 0150	1		STO	COM+2	STORE THE NORMALIZED MANTISSA.	00410
00013	403 0 0146	1		LDO	COM		00420
00014	501 0 0014			SBA	+12	SHIFT ALL BUT THE CHARACTERISTIC, C.	00430
00015	100 0 0133	1		ADD	FSRX+2	OUT OF THE L REGISTER.	00440
00016	110 0 0132	1		SUB	FSRX+1	CZ=C+11-N	00450
00017	110 0 0144	1		SUB	FSRX+11		00460
00020	421 0 0152	1		STL	COM+4		00470
00021	515 0 0001			RLL	1		00480
00022	356 0 0030	1		TPZ	FSRA	CHECK IF CZ IS ODD.	00490
00023	401 0 0134	1		LDL	FSRX+3	CZ IS ODD. ADD ONE TO CZ AND	00500
00024	101 0 0152	1		ADR	COM+4	SHIFT THE NORMALIZED MANTISSA. X.	00510
00025	403 0 0150	1		LDO	COM+2	RIGHT ONE PLACE.	00520
00026	501 0 0001			SBA	1		00530
00027	423 0 0150	1		STO	COM+2		00540
00030	403 0 0150	1	FSRA	LDO	COM+2	Z=X-(1o4) AT 1.	00550
00031	110 0 0135	1		SUB	FSRX+4		00560
00032	423 0 0153	1		STO	COM+5		00570
00033	120 0 0153	1		MPY	COM+5	ZZ AT -21.	00580
00034	501 0 0026			SBA	+22		00590
00035	423 0 0146	1		STO	COM		00600
00036	401 0 0154	1		LDL	COM+6	ZZ AT 2. (MS) (MS) PART	00610
00037	120 0 0154	1		MPY	COM+6		00620
00040	104 0 0146	1		ADL	COM	ZZo2 AT 1.	00630
00041	161 0 0000			CHS			00640
00042	100 0 0135	1		ADD	FSRX+4	.25 -ZZo AT 1.	00650
00043	104 0 0150	1		ADL	COM+2	Y=Xo .25 -ZZo2 AT 1.	00660
00044	423 0 0146	1		STO	COM	Y SCALED 1.	00670
00045	420 0 0155	1		STZ	COM+7	SET LOOP COUNTER TO ZERO.	00680
00046	403 0 0146	1	FSRD	LDO	COM	RESCALE Y AT 2.	00690
00047	501 0 0001			SBA	1		00700
00050	423 0 0153	1		STO	COM+5		00710

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

DEL 1263-3A (2/66)

SCALE

SIZE A

CODE IDENT NO. 49671

2189944

SHEET 12

```
00051  401 0 0147   1          LDL     C@M+1       NORMALIZE MOST SIGNIFICANT Y.                    00720
00052  402 0 0141   1          LDR     FSRX+8                                                       00730
00053  520 0 0142   1          NRM     FSRX+9      Y2 IS NUMBER OF SHIFTS TO NORMALIZE.             00740
00054  421 0 0160   1          STL     C@M+10                                                       00750
00055  401 0 0146   1          LDL     C@M         NORMALIZE LEAST SIGNIFICANT Y.                   00760
00056  520 0 0136   1          NRM     FSRX+5      Y1 IS NUMBER OF SHIFTS.                          00770
00057  421 0 0161   1          STL     C@M+11                                                       00780
00060  401 0 0137   1          LDL     FSRX+6      BUILD AN SBA INSTRUCTION TO                      00790
00061  100 0 0136   1          ADD     FSRX+5      SCALE L(Y)@M(Y).                                 00800
00062  110 0 0142   1          SUB     FSRX+9                                                       00810
00063  421 0 0102   1          STL     FSR@                                                         00820
00064  421 0 0105   1          STL     FSRC                                                         00830
00065  403 0 0150   1          LDB     C@M+2       X, THE MANTISSA SCALED AT 1.                     00840
00066  501 0 0002              SBA     2           X SCALED AT 3.                                   00850
00067  130 0 0147   1          DVD     C@M+1       X@Y SCALED AT 2, MS PART.                        00860
00070  421 0 0157   1          STL     C@M+9                                                        00870
00071  400 0 0000              LDZ                                                                  00880
00072  500 0 0027              R@A     +23                                                          00890
00073  130 0 0147   1          DVD     C@M+1       X@Y SCALED AT -21, LS PART.                      00900
00074  421 0 0156   1          STL     C@M+8                                                        00910
00075  401 0 0161   1          LDL     C@M+11      LEAST SIGNIDICANT PART OF Y.                     00920
00076  501 0 0001              SBA     1                                                            00930
00077  130 0 0160   1          DVD     C@M+10      Z=L(Y)@M(Y) AT Y2-Y1-22.                         00940
00100  421 0 0160   1          STL     C@M+10                                                       00950
00101  120 0 0160   1          MPY     C@M+10      ZZ SCALED AT 2(Y2-Y1-22).                        00960
00102  501 0 0000      FSR@    SBA     **          ZZ AT (Y2-Y1-22).                                00970
00103  110 0 0160   1          SUB     C@M+10      ZZ-Z                                             00980
00104  120 0 0157   1          MPY     C@M+9       (ZZ-Z)(X@Y) AT Y2-Y1-22-2)                       00990
00105  501 0 0000      FSRC    SBA     **                                                           01000
00106  104 0 0156   1          ADL     C@M+8       (X@Y)+(ZZ-Z)(X@Y) AT 2.                          01010
00107  104 0 0153   1          ADL     C@M+5       Y EQUALS HALF Y+(X@Y)+(ZZ-Z)(X@Y)                01020
00110  423 0 0148   1          ST@     C@M         STORE Y AT 1.                                    01030
00111  401 0 0134   1          LDL     FSRX+3                                                       01040
00112  101 0 0155   1          ADR     C@M+7                                                        01050
00113  110 0 0140   1          SUB     FSRX+7                                                       01060
00114  351 0 0046   1          TRN     FSR0                                                         01070
00115  403 0 0146   1          LDB     C@M         NORMALIZE Y, THE SQUARE R@@T.                    01080
00116  520 0 0142   1          NRM     FSRX+9                                                       01090
00117  501 0 0013              SBA     +11                                                          01100
00120  421 0 0155   1          STL     C@M+7                                                        01110
00121  401 0 0152   1          LDL     C@M+4       PICK UP THE CHARACTERISTIC, CZ.                  01120
00122  100 0 0143   1          ADD     FSRX+10     ADD 1024 TO CZ.                                  01130
00123  515 0 0001              RLL     1           TAKE ONE HALF OF CZ.                             01140
00124  110 0 0142   1          SUB     FSRX+9      SUBTRACT THE NORMALIZING COUNT.                  01150
```

```
00125  100 0 0134   1          ADD     FSRX+3          CHARACTERISTIC PLUS ONE.                01160
00126  515 0 0014              RLL     +12                                                     01170
00127  150 0 0155   1          LIB     C@M+7           MERGE MANTISSA AND CHARACT.             01180
00130  357 7 0000   1          TRA     FSR.7           NORMAL EXIT.                            01190
00131  00007777            FSRX NUM     000007777       MASK FOR MANTISSA                       01200
00132  00000000                 NUM     00              SHIFTS TO NORMALIZE THE MANTISSA.       01210
00133  00000013                 NUM     013             11 AT 23.                               01220
00134  00000001                 NUM     01                                                      01230
00135  04000000                 NUM     004000000       .25 AT 1.                               01240
00136  00000000                 NUM     00              Y2. SHIFTS TO NRM LEAST SIG. Y.         01250
00137  501 0 0026               SBA     +22                                                     01260
00140  00000003                 NUM     03              3 AT 23.                                01270
00141  00000000                 NUM     00              ZERO.                                   01280
00142  00000000                 NUM     00              SHIFTS TO NRM MOST SIG. Y.              01290
00143  00002000                 NUM     02000           1024 AT 23.                             01300
00144  00000000                 NUM     00              SHIFTS TO NRM MANTISSA.                 01310
00145  40000000                 NUM     040000000                                               01320
00146                       C@M  BSS     12                                                      01330
                                 END                                                             01340
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186644

SCALE | SHEET 4/

DEL 1263-3A (2/60)

SECTION 13
FLOATING POINT SINE OR COSINE

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE ENGINEERING CHANGE NOTICE CLASS II, DCS 642	4 FEB 66	J.H. Vanderford (R)

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS-8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN DATE
E.R. Hansen 2 SEPT 65

CHECKED DATE
D.A. Peterson 3 SEP 65

DESIGN ACTIVITY APPD REL
J.H. Vanderford 3 SEPT 65 (R)

SATURN GROUND COMPUTER SYSTEM MATHEMATICAL ROUTINE FLOATING POINT SINE OR COSINE

SIZE	CODE IDENT NO.	
A	49671	2186645

WEIGHT LB SHEET 1 OF 18

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186645-1	FLOATING POINT SINE OR (COSINE)	
								SYMBOLIC CARD DECK	
				X	5		CDV86645	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SINE OR (COSINE)	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186645

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT SINE OR (COSINE)

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

TABLE OF CONTENTS

1.0 Identification

ID: FSN or (FCS)

2.0 Introduction

The purpose of the Floating Point Sine or (Cosine) is to compute the floating point sine or (cosine) of a floating point radian argument X.

The program conforms to the specifications of the Floating Point System 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86645. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

To evaluate sin X, the argument ■ is first adjusted in the following manner: For positive X, change from radians to parts of a circle.

$\frac{X}{2\pi} = K + L$ where K is an integer and $L < 1$.

$4L = I + F$ where I is an integer and $F < 1$.

If $I = 0$, let $Z = F\left(\frac{\pi}{2}\right)$

If $I = 1$, let $Z = \frac{\pi}{2} - F\left(\frac{\pi}{2}\right)$

If $I = 2$, let $Z = -F\left(\frac{\pi}{2}\right)$

If $I = 3$, let $Z = F\left(\frac{\pi}{2}\right) - \left(\frac{\pi}{2}\right)$

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	SCALE		SHEET 5

3.0 Mathematical Method (Cont'd)

$$\text{Sin } X = \sum_{N=1}^{6} S_N Z^{2N-1}$$

$S_1 = 0.999999999979082$

$S_2 = -0.166666666092171$

$S_3 = 0.008333330730723$

$S_4 = -0.000198408338222$

$S_5 = 0.000002752401177$

$S_6 = -0.000000023868930$

To compute cosin X, the following relationship is used:

$$\text{cosin } X = \sin\left(X + \frac{\pi}{2}\right)$$

For negative X, the following relationships are used:

$$\sin(-X) = -\sin X$$

$$\text{Sin } (-X) = \cos X$$

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object program card deck to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

Calling Sequence:

With the angle in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	FSN or FCS (see below)
a + 1	Return	

FSN - Symbolic entrance in the Floating Point Sin subroutine.

FCS - Symbolic entrance in the Floating Point Cosin subroutine.

5.0 Output Format

Error Return:

An error return is indicated by overflow 'ON'.

The $|X| > 2^{34}$.

Normal Return:

A normal return is indicated by overflow 'OFF'.

The sine or (cosine) of the argument X will be in the L and R registers upon return. The sine or (cosine) is in normalized floating point format.

6.0 Memory Requirements

6.1 Program: see program listing

6.2 Temporary space: 12 core memory locations

7.0 Restrictions

None

8.0 Timing

Approximate timing: 39.3 milliseconds

9.0 Floating Point Sine or (Cosine) Card Deck

Symbolic source card deck for this program is 2186645-1.

10.0 Appendices

10.1 Flow Chart

Flow chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

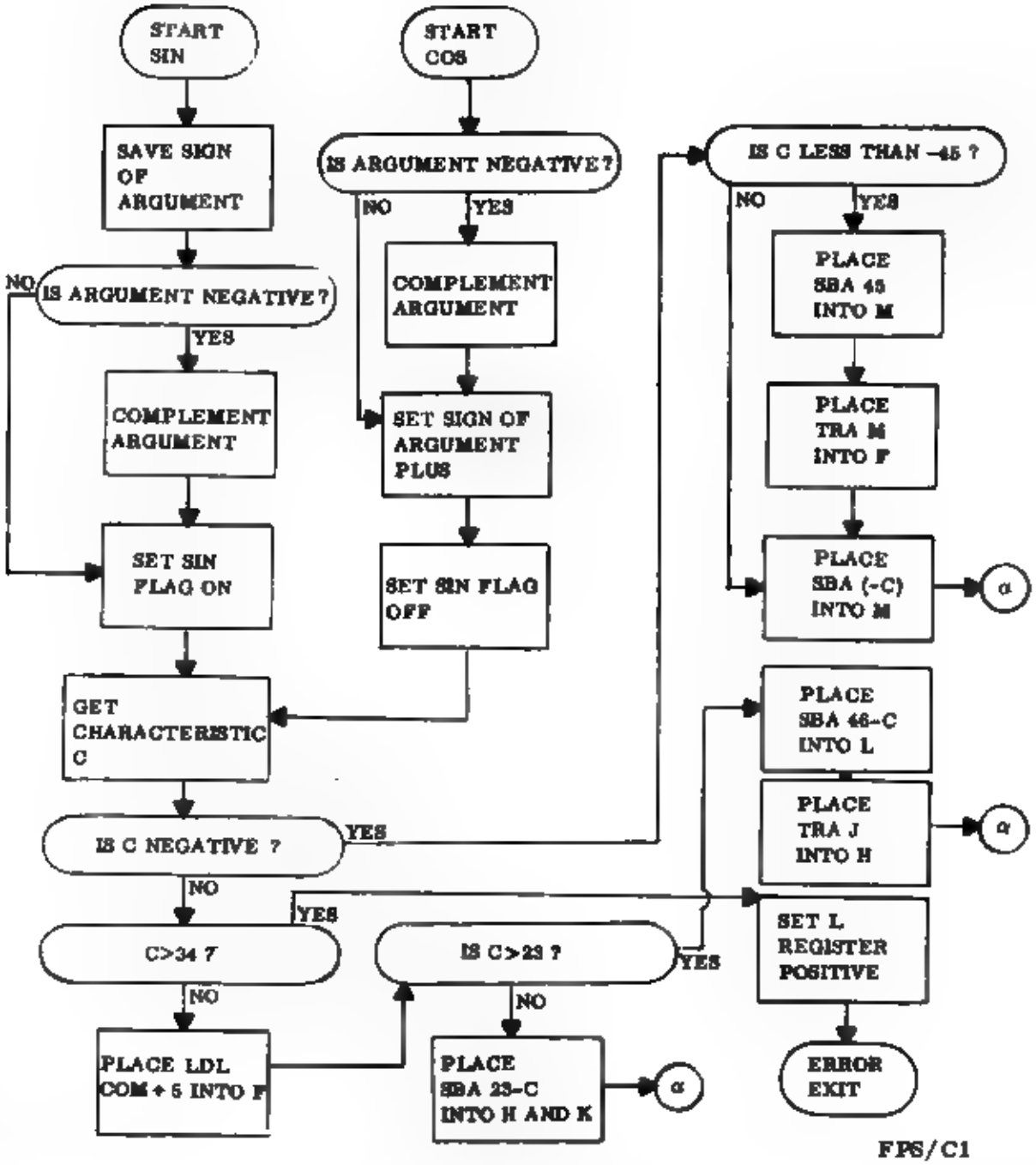
A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT SINE OR (COSINE)

FLOW CHART



FPS/C1

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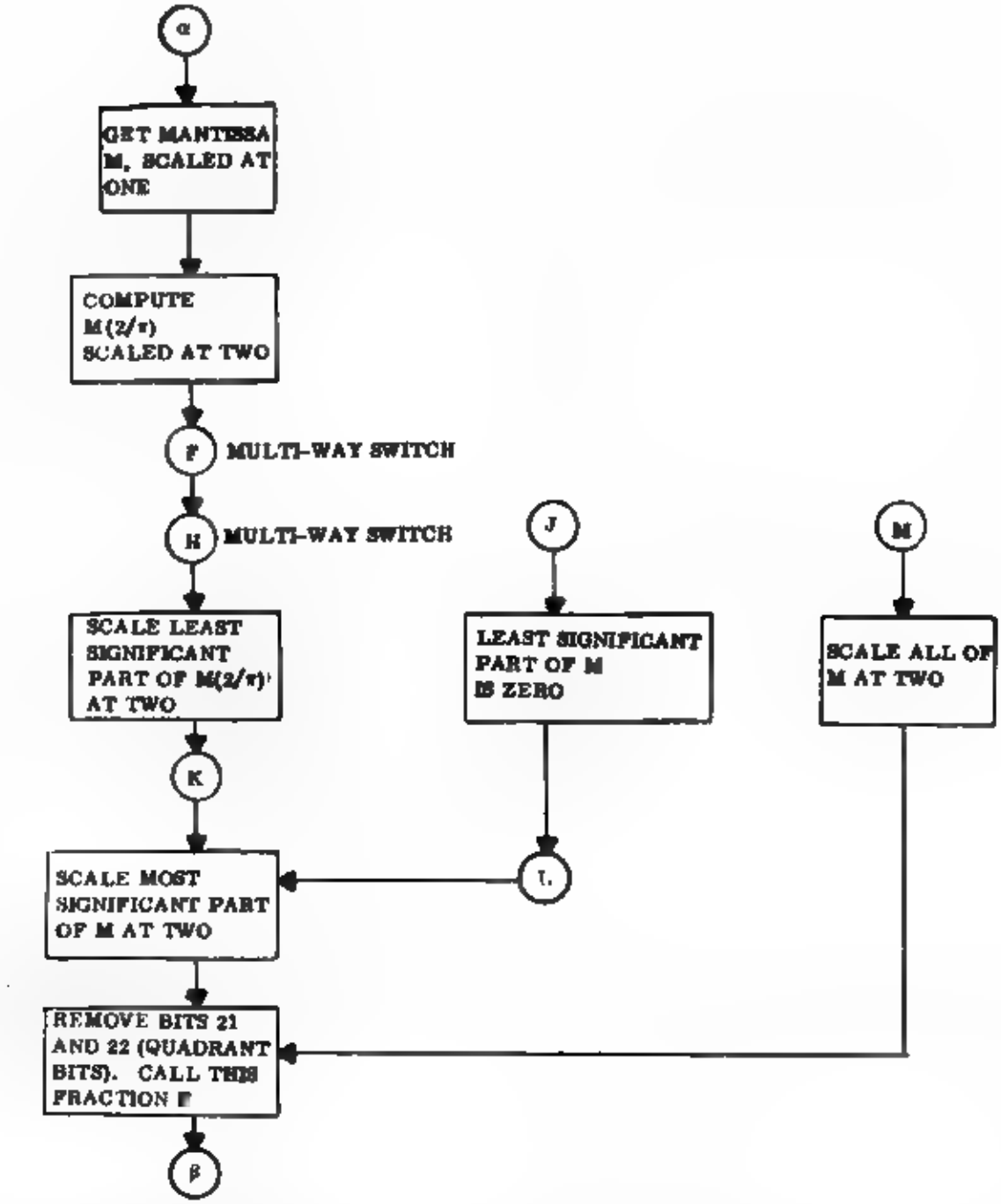
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
XX = ± XXX = ±	A	49671	2186645
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 10

DEL 1263-3A (2/65)

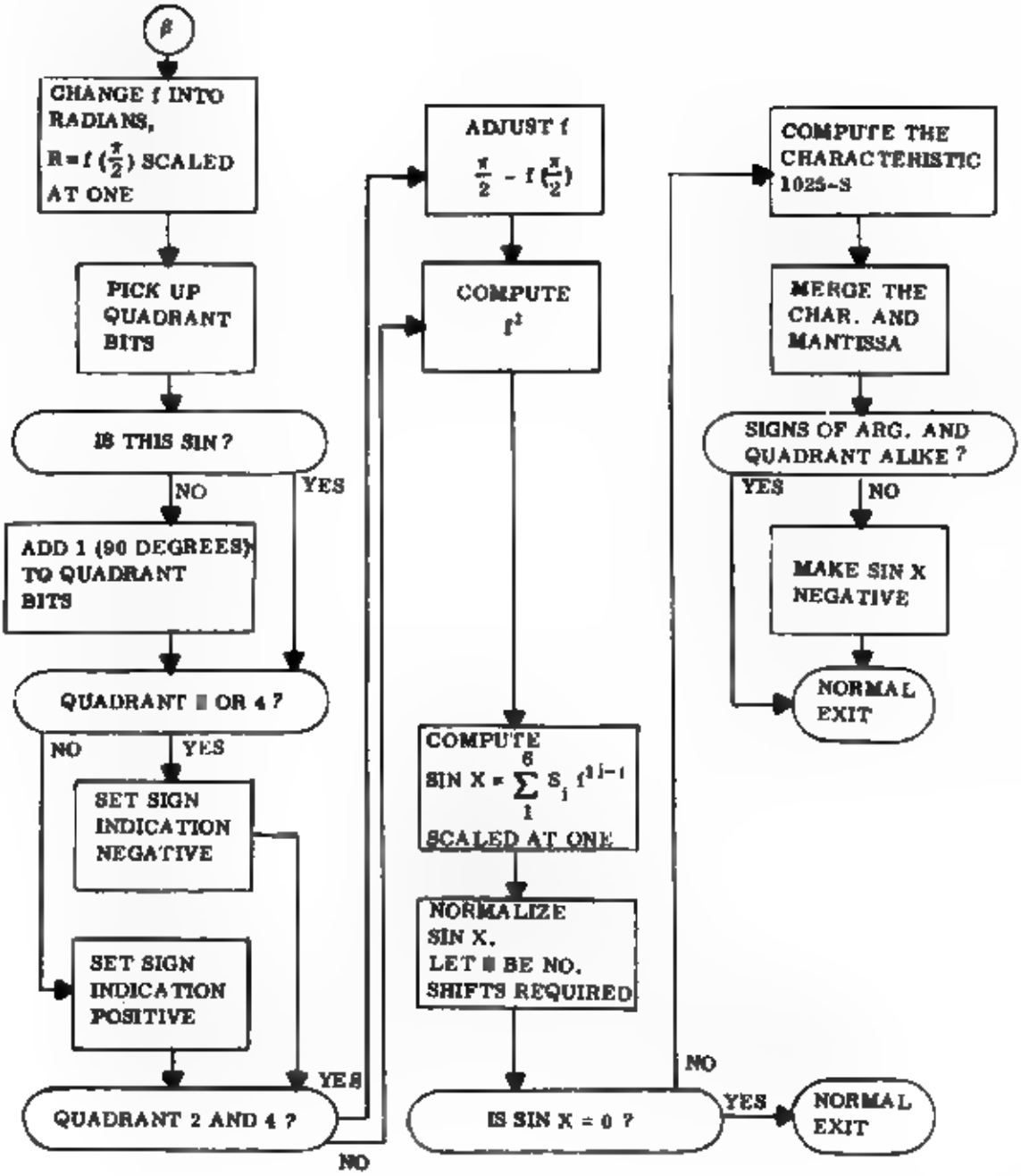


FPS/C2

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186645
	SCALE		SHEET //

DEL 1263-3A (2/65)



FPS/C3

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186645
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 12

DEL 1263-3A (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT SINE OR (COSINE)

PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186645
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 13

DEL 1263-3A (2/65)

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*		FLOATING POINT SIN ■ (CDSIN)	00010
00000	■ 0 00000		$FCS	**5	0	00310
00001	356 0 0003	1		TPZ	*+2 C0S X ENTRANCE	00320
00002	161 0 0000			CMB	SET THE ARGUMENT POSITIVE.	00330
00003	423 0 0313	1		STB	C0M+1 SAVE THE ARGUMENT.	00340
00004	421 0 0312	1		STL	C0M SET THE SIGN OF THE ARGUMENT POSITIVE.	00350
00005	402 0 0000	1		LDR	FCS	00360
00006	422 0 0011	1		STR	FSN	00370
00007	402 0 0251	1		LDR	FSNX SET THE SIN FLAG OFF.	00380
00010	357 0 0017	1		TRA	FSNA	00390
00011	00 0 00000		$FSN	**5	0	00400
00012	421 0 0312	1		STL	C0M SIN X ENTRANCE.	00410
00013	356 0 0015	1		TPZ	*+2 SET THE ARGUMENT POSITIVE.	00420
00014	161 0 0000			CMB		00430
00015	423 0 0313	1		STB	C0M+1 SAVE THE ARGUMENT.	00440
00016	402 0 0252	1		LDR	FSNX+1	00450
00017	422 0 0316	1	FSNA	STR	C0M+4	00460
00020	501 0 0014			SBA	*12 GET THE CHARACTERISTIC.	00470
00021	110 0 0256	1		SUB	FSNX+5 UNBIAS THE CHARACTERISTIC. C.	00480
00022	421 0 0315	1		STL	C0M+3 STORE C AT 23.	00490
00023	351 0 0047	1		TRN	FSNC TRANSFER IF C IS NEGATIVE.	00500
00024	110 0 0257	1		SUB	FSNX+6 IS C GREATER THAN 34	00510
00025	353 0 0030	1		TNZ	*+3 OVERFLOW ERROR. L-REGISTER POSITIVE.	00520
00026	102 0 0306	1		ADDI	FSNY TURN OVERFLOW ON	00530
00027	357 7 0011	1		TRA	FSN,7	00540
00030	401 0 0265	1		LDL	FSNX+12 SET VARIABLE TRANSFER.	00550
00031	421 0 0077	1		STL	FSNF	00560
00032	401 0 0263	1		LDL	FSNX+10 23-C	00570
00033	110 0 0315	1		SUB	C0M+3	00580
00034	351 0 0041	1		TRN	FSNB IS 23-C POSITIVE	00590
00035	150 0 0264	1		L10	FSNX+11 SBA (23-C)	00600
00036	421 0 0101	1		STL	FSNH STORE SHIFT COMMANDS.	00610
00037	421 0 0105	1		STL	FSNK	00620
00040	357 0 0061	1		TRA	FSND	00630
00041	100 0 0263	1	FSNB	ADD	FSNX+10 46-C	00640
00042	150 0 0264	1		L10	FSNX+11 SBA (46-C)	00650
00043	421 0 0111	1		STL	FSNL	00660
00044	401 0 0266	1		LDL	FSNX+13 SET TRANSFER FOR C GREATER THAN 23 CASE.	00670
00045	421 0 0101	1		STL	FSNH	00680
00046	357 0 0061	1		TRA	FSND	00690
00047	100 0 0267	1	FSNC	ADD	FSNX+14 IS C LESS THAN -45	00700
00050	356 0 0053	1		TPZ	*+3	00710

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186945

SCALE

SHEET 14

DEL 1263-3A (2/65)

```
00051  401 0 0267  1          LDL     FSNX+14         SBA 45 IF C LESS THAN -45.                      00720
00052  357 0 0055  1          TRA     *+3                                                             00730
00053  401 0 0315  1          LDL     C@M+3           BUILD SHIFT TO SCALE M (2*PI).                  00740
00054  160 0 0000             CML                                                                     00750
00055  150 0 0264  1          L1@     FSNX+11         SBA (-C)                                        00760
00056  421 0 0116  1          STL     FSNM                                                            00770
00057  401 0 0270  1          LDL     FSNX+15         SET VARIABLE TRANSFER FOR C NEGATIVE            00780
00060  421 0 0077  1          STL     FSNF            CASE IN SCALING M(2*PI).                        00790
00061  403 0 0313  1  FSND    LDB     C@M+1           PICK UP ARGUMENT.                               00800
00062  140 0 0260  1          LAN     FSNX+7          GET MANTISSA.                                   00810
00063  500 0 0044             RBA     +36             M, MANTISSA AT 1.                               00820
00064  423 0 0313  1          STB     C@M+1                                                           00830
00065  120 0 0262  1          MPY     FSNX+9          M(2*PI) AT 2. PARTIAL PRODUCT                   00840
00066  423 0 0317  1          STB     C@M+5                                                           00850
00067  401 0 0313  1          LDL     C@M+1                                                           00860
00070  120 0 0262  1          MPY     FSNX+9          M(2*PI) AT -21. PARTIAL PRODUCT                 00870
00071  423 0 0321  1          STB     C@M+7                                                           00880
00072  401 0 0314  1          LDL     C@M+2                                                           00890
00073  120 0 0261  1          MPY     FSNX+8          M(2*PI) AT -21. PARTIAL PRODUCT                 00900
00074  104 0 0321  1          ADL     C@M+7                                                           00910
00075  501 0 0027             SBA     +23                                                             00920
00076  105 0 0317  1          ALR     C@M+5           M(2*PI) AT 2. FULL PRODUCT                      00930
00077  357 0 0000     FSNF    TRA     **              SCALE M(2*PI) ABSOLUTELY. LDL OR TRA FSNG       00940
00100  402 0 0252  1          LDR     FSNX+1          LEAST SIGNIFICANT M(2*PI) IN L-REG.             00950
00101  357 0 0000     FSNM    TRA     **              VARIABLE COMMAND. SBA OR TRA FSNJ               00960
00102  423 0 0321  1          STB     C@M+7                                                           00970
00103  401 0 0320  1          LDL     C@M+6           MOST SIGNIFICANT PART OF M(2*PI).               00980
00104  402 0 0252  1          LDR     FSNX+1          ZERO IN R-REG.                                  00990
00105  501 0 0000     FSNK    SBA     **              SBA (23-C)                                      01000
00106  357 0 0112  1          TRA     *+4                                                             01010
00107  420 0 0321  1  FSNJ    STZ     C@M+7           C IS GREATER THAN 23 CASE.                      01020
00110  420 0 0322  1          STZ     C@M+8                                                           01030
00111  501 0 0000     FSNL    SBA     **              SBA (46-C)                                      01040
00112  500 0 0027             RBA     +23                                                             01050
00113  402 0 0252  1          LDR     FSNX+1                                                          01060
00114  105 0 0321  1          ALR     C@M+7                                                           01070
00115  357 0 0120  1          TRA     *+3                                                             01080
00116  501 0 0000     FSNM    SBA     **              C IS NEGATIVE CASE.                             01090
00117  423 0 0321  1          STB     C@M+7           M (2*PI) SCALED ABSOLUTELY AT 2.                01100
00120  140 0 0255  1          LAN     FSNX+2          REMOVE QUADRANT BITS.                           01110
00121  500 0 0054             RBA     +44             SCALE F AT ZERO.                                01120
00122  423 0 0317  1          STB     C@M+5           STORE F, THE FRACTIONAL PART OF M(2*PI).        01130
00123  120 0 0271  1          MPY     FSNX+16         CHANGE F TO RADIANS.                            01140
00124  501 0 0001             SBA     1               (PI*2)F AT -22. PARTIAL PRODUCT                 01150
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671

SCALE

SHEET 15

2186945

DEL 1263-3A (2/66)

```
00125  423 0 0313   1              STB     C@M+1                                          01160
00126  401 0 0317   1              LDL     C@M+5                                          01170
00127  120 0 0272   1              MPY     FSNX+17         (P1*2)F AT -22, PARTIAL PRODUCT 01180
00130  501 0 0001                  SBA     1                                              01190
00131  104 0 0313   1              ADL     C@M+1                                          01200
00132  501 0 0026                  SBA     *22                                            01210
00133  423 0 0313   1              STB     C@M+1           (P1*2)F AT 1.                  01220
00134  401 0 0320   1              LDL     C@M+6                                          01230
00135  120 0 0272   1              MPY     FSNX+17                                        01240
00136  105 0 0313   1              ALR     C@M+1           (P1*2)F AT 1, FULL PRODUCT.    01250
00137  401 0 0322   1              LDL     C@M+8           GET QUADRANT BITS.             01260
00140  501 0 0025                  SBA     *21                                            01270
00141  100 0 0316   1              ADD     C@M+4           ADD SIN-COS FLAG.              01280
00142  515 0 0002                  RLL     2                                              01290
00143  421 0 0316   1              STL     C@M+4           DETERMINE SIGN OF SIN, COS.    01300
00144  515 0 0027                  RLL     *23                                            01310
00145  356 0 0150   1              TPZ     *+3             DETERMINE IF IN 2 OR 4 QUADRANT. 01320
00146  403 0 0271   1              LDD     FSNX+16         (P1*2) AT 1.                   01330
00147  115 0 0313   1              SLR     C@M+1           (P1*2)-(P1*2)F AT 1.           01340
00150  401 0 0314   1              LDL     C@M+2           COMPUTE F**2.                  01350
00151  120 0 0313   1              MPY     C@M+1           F**2 AT 2, PARTIAL PRODUCT.    01360
00152  501 0 0026                  SBA     *22                                            01370
00153  423 0 0317   1              STB     C@M+5                                          01380
00154  401 0 0314   1              LDL     C@M+2                                          01390
00155  120 0 0314   1              MPY     C@M+2           F**2 AT 2, PARTIAL PRODUCT     01400
00156  105 0 0317   1              ALR     C@M+5           F**2 AT 2, FULL PRODUCT        01410
00157  405 0 0006                  LDL@    6               SAVE INDEX 6.                  01420
00160  421 0 0323   1              STL     C@M+9                                          01430
00161  401 0 0254   1              LDL     FSNX+3          SET INDEX 7 EQUAL TO 6.        01440
00162  425 0 0006                  STL@    6                                              01450
00163  400 0 0000                  LDZ                     CLEAR BOTH REGISTERS.          01460
00164  513 0 0030                  SBL     *24                                            01470
00165  423 0 0321   1              STB     C@M+7           CLEAR SUM WORD.                01480
00166  104 6 0303   1    FSNN      ADL     FSNX+26,6       ADD AND MULTIPLY LOOP.         01490
00167  356 0 0171   1              TPZ     *+2             IF NEGATIVE, PUT L-REGISTER    01500
00170  100 0 0251   1              ADD     FSNX            IN 2-COMPLEMENT FORM.          01510
00171  423 0 0321   1              STB     C@M+7                                          01520
00172  120 0 0317   1              MPY     C@M+5           SUM TIMES F**2, PARTIAL PRODUCT 01530
00173  501 0 0001                  SBA     1                                              01540
00174  423 0 0324   1              STB     C@M+10                                         01550
00175  401 0 0321   1              LDL     C@M+7                                          01560
00176  120 0 0320   1              MPY     C@M+6           SUM TIMES F**2, PARTIAL PRODUCT 01570
00177  501 0 0001                  SBA     1                                              01580
00200  104 0 0324   1              ADL     C@M+10                                         01590
```

```
00201  501 0 0026                    SBA     *22                                                 01600
00202  423 0 0324   1                STB     C@M+10                                              01610
00203  401 0 0322   1                LDL     C@M+8                                               01620
00204  120 0 0320   1                MPY     C@M+6                                               01630
00205  104 0 0324   1                ADL     C@M+10                                              01640
00206  31 2 6 0166  1                TXD     FSNN,6,2                                            01650
00207  104 0 0305   1                ADL     FSNX+25     SUM=SUM+51 SCALED AT 5.                 01660
00210  425 0 0321   1                STB     C@M+7                                               01670
00211  120 0 0313   1                MPY     C@M+1       (SUM) F AT 1. PARTIAL PR@DUCT           01680
00212  501 0 0001                    SBA     1                                                   01690
00213  425 0 0324   1                STB     C@M+10                                              01700
00214  401 0 0323   1                LDL     C@M+9                                               01710
00215  425 0 0006                    STL@    6           RESTORE INDEX 7.                        01720
00216  401 0 0321   1                LDL     C@M+7                                               01730
00217  120 0 0314   1                MPY     C@M+2       (SUM) F AT 1. PARTIAL PR@DUCT           01740
00220  501 0 0001                    SBA     1                                                   01750
00221  104 0 0324   1                ADL     C@M+10                                              01760
00222  501 0 0026                    SBA     *22                                                 01770
00223  425 0 0324   1                STB     C@M+10                                              01780
00224  401 0 0322   1                LDL     C@M+8                                               01790
00225  120 0 0314   1                MPY     C@M+2                                               01800
00226  104 0 0324   1                ADL     C@M+10      (SUM) F AT 1. FULL PR@DUCT              01810
00227  520 0 0307   1                NRM     FSNX+30     N@RMALIZE                               01820
00230  520 0 0310   1                NRM     FSNX+31                                             01830
00231  501 0 0013                    SBA     *11                                                 01840
00232  421 0 0324   1                STL     C@M+10                                              01850
00233  352 7 0011   1                TRZ     FSN,7       CHECK F@R ZER@ ANSWER.                  01860
00234  401 0 0311   1                LDL     FSNX+32     C@MPUTE THE CHARACTERISTIC.             01870
00235  110 0 0307   1                SUB     FSNX+30                                             01880
00236  110 0 0310   1                SUB     FSNX+31                                             01890
00237  515 0 0014                    RLL     *12                                                 01900
00240  151 0 0324   1                LIR     C@M+10      M@RGE THE CHARACTERISTIC AND            01910
00241  401 0 0312   1                LDL     C@M         MANTISSA T@GETHER.                      01920
00242  170 0 0316   1                LE@     C@M+4       CHECK IF ANSNER SH@ULD BE NEGATIVE.     01930
00243  356 0 0247   1                TPZ     FSNP        EXCLUSIV@ @R T@GETHER ARG. SIGN         01940
00244  401 0 0324   1                LDL     C@M+10      AND QUADRANT INDICATION.                01950
00245  161 0 0000                    CN@                 MAKE ANSWER MINUS.                      01960
00246  357 7 0011   1                TRA     FSN,7       N@RMAL EXIT.                            01970
00247  401 0 0324   1    FSNP        LDL     C@M+10                                              01980
00250  357 7 0011   1                TRA     FSN,7       N@RMAL EXIT.                            01990
00251  00000001     FSNX   NUM      01          C@S PR@GRAM FLAG                                02000
00252  00000000            NUM      00          SIN PR@GRAM FLAG                                02010
00253  07777777            NUM      007777777                                                   02020
00254  00000010            NUM      010         L@@P C@UNT                                      02030
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
.XX = ±
.XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186645 | SCALE | SHEET 17

DEL 1263-3A (2/65)

```
00255  00000027                    NUM   027          23 AT 23.                                  02040
00256  00002000                    NUM   02000        1024 AT 23.                                02050
00257  00000042                    NUM   042          34 AT 23.                                  02060
00260  00007777                    NUM   000007777    MASK FOR MANTISSA                          02070
00261  33344710                    NUM   033344710    2oPI AT 1. LS PART                         02080
00262  12137140                    NUM   012137140    2oPI=0.6366197723675184                    02090
00263  00000027                    NUM   027          23 AT 23.                                  02100
00264  501 0 0000                  SBA   **           CONSTANT                                   02110
00265  401 0 0317   1             LDL   COM+5        TRANSFER FOR C POSITIVE CASE.              02120
00266  357 0 0107   1             TRA   FSNJ         TRANSFER FOR C GREATER THAN 23 CASE,       02130
00267  00000055                    NUM   055          45 AT 23.                                  02140
00270  357 0 0116   1             TRA   FSNM         TRANSFER FOR C NEGATIVE CASE.              02150
00271  12114132                    NUM   012114132    PIo2 AT 1. LS PART                         02160
00272  31103755                    NUM   031103755    PIo2=1.570796326794896                     02170
00273  76752574                    NUM   076752574    S6 AT -10                                  02180
00274  77777462                    NUM   077777462    S6=-0.000000023868930                      02190
00275  27443114                    NUM   027443114    S5 AT -8                                   02200
00276  00013426                    NUM   000013426    S5=0.000002752401177                       02210
00277  52550474                    NUM   052550474    S4 AT -6.                                  02220
00300  77457750                    NUM   077457750    S4=-0.000198408338222                      02230
00301  26751041                    NUM   026751041    S3 AT -4.                                  02240
00302  04210420                    NUM   004210420    S3=0.008333330730723                       02250
00303  65746400                    NUM   065746400    S2 AT -2.                                  02260
00304  52525252                    NUM   052525252    S2=-0.166666666092171                      02270
00305  37775100                    NUM   037775100    S1 AT 0.                                   02280
00306  37777777           FSNY     NUM   037777777    S1=0.999999999979082                       02290
00307  00000000                    NUM   00           NORMALIZATION COUNT                        02300
00310  00000000                    NUM   00           NORMALIZATION COUNT                        02310
00311  00002001                    NUM   02001        1024 AT 23.                                02320
00312                     COM      BSS   12                                                      02330
                                   END                                                           02340
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186645
	SCALE		SHEET 18

DEL 1263-3A (2/65)

SECTION 14
FLOATING POINT ARCTANGENT

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE ENGINEERING CHANGE NOTICE CLASS II, DCS 642	8 SEP 65 8 SEP 65	[signature]

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN [signature] DATE 31 AUG 65

CHECKED [signature] DATE 8 SEP 65

DESIGN ACTIVITY APPD J.N. Vanderford 8 SEP 65 REL

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
FLOATING POINT ARCTANGENT

SIZE	CODE IDENT NO.	
A	49671	2186646

WEIGHT LB SHEET 1 OF 18

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186646-1	FLOATING POINT ARCTANGENT	
								SYMBOLIC CARD DECK	
				X	5		CDV86646	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT ARCTANGENT	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186646

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT ARCTANGENT

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

RADIO CORPORATION ■ AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186646
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 3

DEL 1263-3A (2/65)

TABLE OF CONTENTS

1.0 Identification

ID: FRT

2.0 Introduction

The purpose of the Floating Point Arctangent is to compute the floating point arctangent of the quotient (X ÷ Y). X and Y are both floating point arguments of the subroutine.

The program conforms to the specifications of the Floating Point System 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86646. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

$X = 2^N \cdot x$ where $1 > |y| \geq .5$

$Y = 2^M \cdot y$ where $1 > |y| \geq .5$

for $N > M$, $Z = \frac{Y}{x}$ and $K = 0$.

$N \leq M$, $Z = \frac{x}{y}$ and $K = 1$.

for $|Z| < (\sqrt{2} - 1)$, $t = Z$ and $L = 0$.

$|Z| \geq (\sqrt{2} - 1)$, $t = \frac{(Z - 1)}{(Z + 1)}$ and $L = 1$.

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UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
.XX = ± .XXX = ±	A	49671	2186646
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 5

DEL 1263-3A (2/65)

3.0 Mathematical Method (Cont'd)

Compute μ,

$$\mu = \left\{ |t| \left[d_0 + t^2 \left(d_1 + \frac{e_i}{t^2 + d_2 + e_2 + (t^2 + d_3)} \right) \right] \right\} (1 - 2K) + K\left(\frac{\pi}{2}\right)$$

$d_0 = 0.999999999996107$

$d_1 = -0.015585371018178$

$d_2 = 2.100554087165198$

$d_3 = 1.621023833634443$

$e_1 = -0.585315135071831$

$e_2 = -0.419003002282544$

Final adjustment is made for which quadrant was specified by X and Y as follows:

for $Y > 0, \quad X > 0, \quad \arctan \frac{Y}{X} = \mu$

$Y > 0, \quad X < 0, \quad \arctan \frac{Y}{X} = \pi - \mu$

$Y < 0, \quad X < 0, \quad \arctan \frac{Y}{X} = \pi + \mu$

$Y < 0, \quad X > 0, \quad \arctan \frac{Y}{X} = 2\pi - \mu$

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program and the associated subroutine (Section 7.0). The SLAP 2 Loader uses the object program card deck, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

Calling Sequence:

With the floating point argument Y in the left (L) and right (R) accumulators:

Location	Operation	Address
a	TSP	FRT (see below)
a + 1	**5	M,T (see below)
a + 2	Return	

FRT - symbolic entrance in the Floating Point Arctangent subroutine.

M is the address of the argument X

T ($0 \leq T \leq 6$) is the index tag modifying M.

5.0 Output Format

Error Return:

An error return is indicated by overflow 'ON'.

Both arguments equal zero X = 0, Y = 0. The L register is zero upon return.

Normal Return:

A normal return is indicated by overflow 'OFF'.

The arctangent of Y ÷ X will be in L and R registers upon return. The arctangent will be in normalized floating point radians. The range of the arctangent is 0 to 2π radians.

6.0 Memory Requirements

6.1 Program: see program listing

6.2 Temporary Space: 14 core memory locations

7.0 Restrictions

This program uses the following floating point subroutine:

Name	ID	Number
Double Precision Divide	DVD	2186650

8.0 Timing

Approximate timing: 49.2 milliseconds maximum.

9.0 Floating Point Arctangent Card Deck

Symbolic source card deck for this program is 2186646-1

10.0 Appendices

10.1 Flow Chart

Flow chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

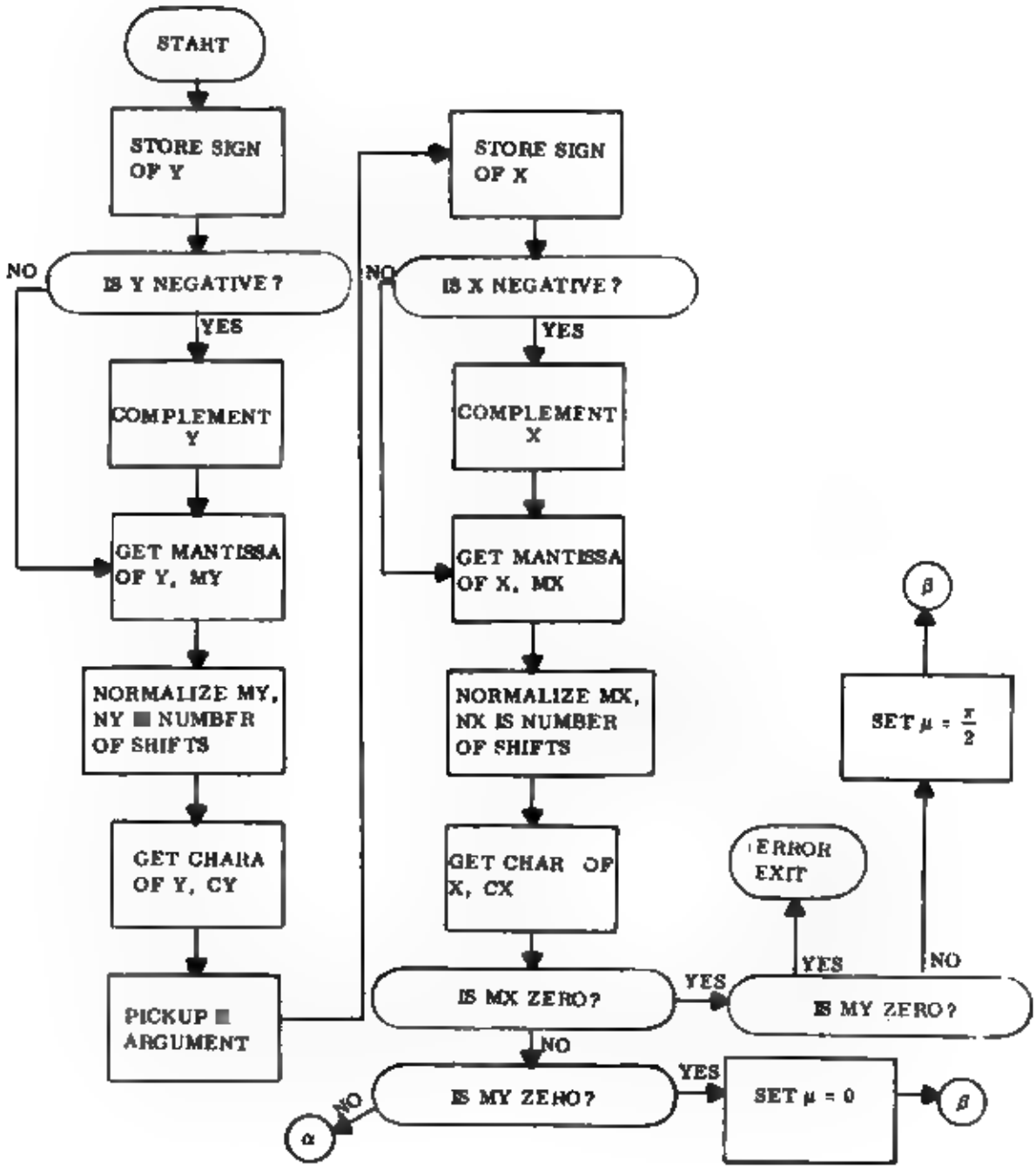
SATURN GROUND COMPUTER SYSTEM

FLOATING POINT ARCTANGENT

FLOW CHART

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186646
	SCALE		SHEET 9



FPA1

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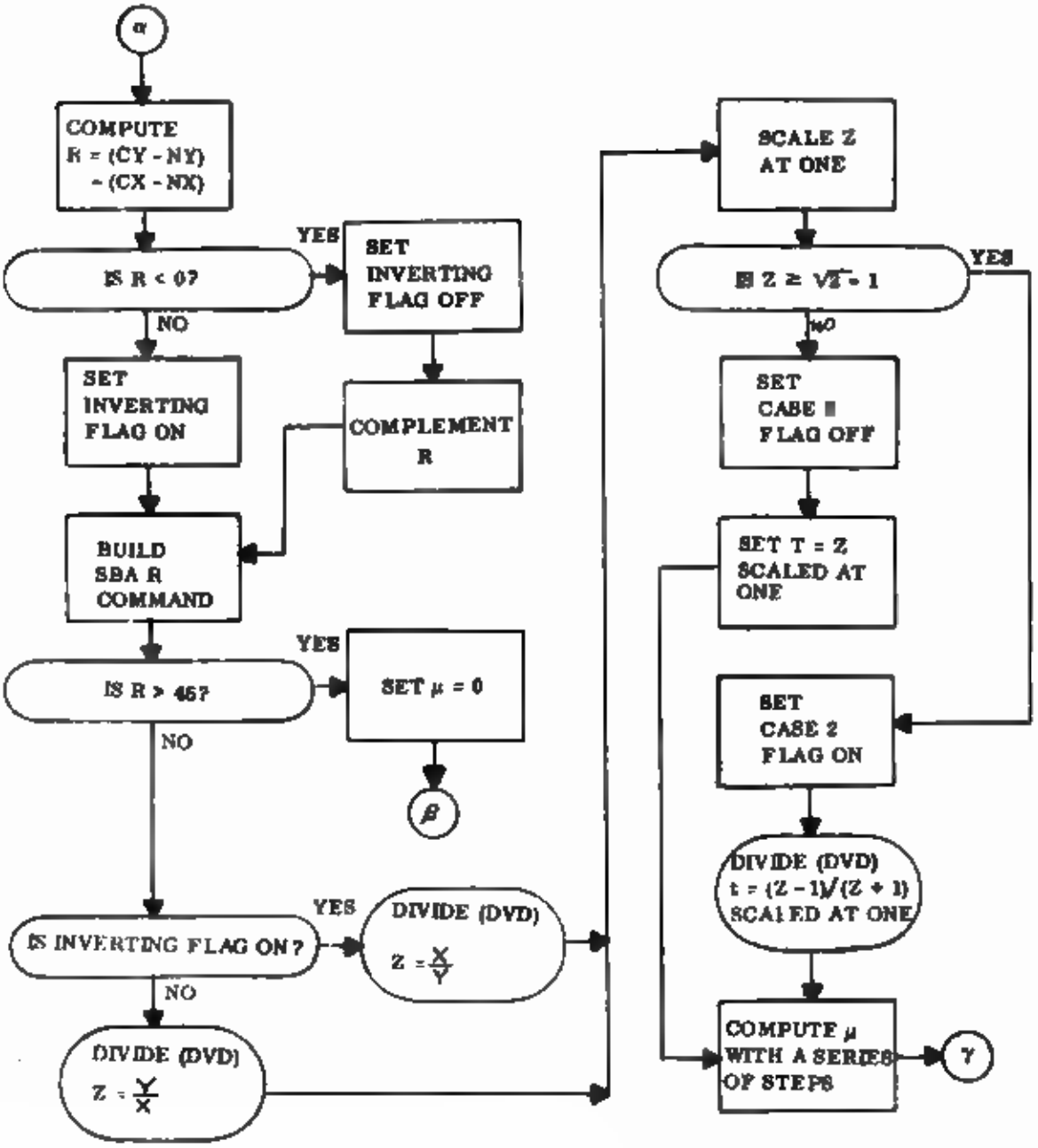
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186646
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 10

DEL 1263-3A (2/65)

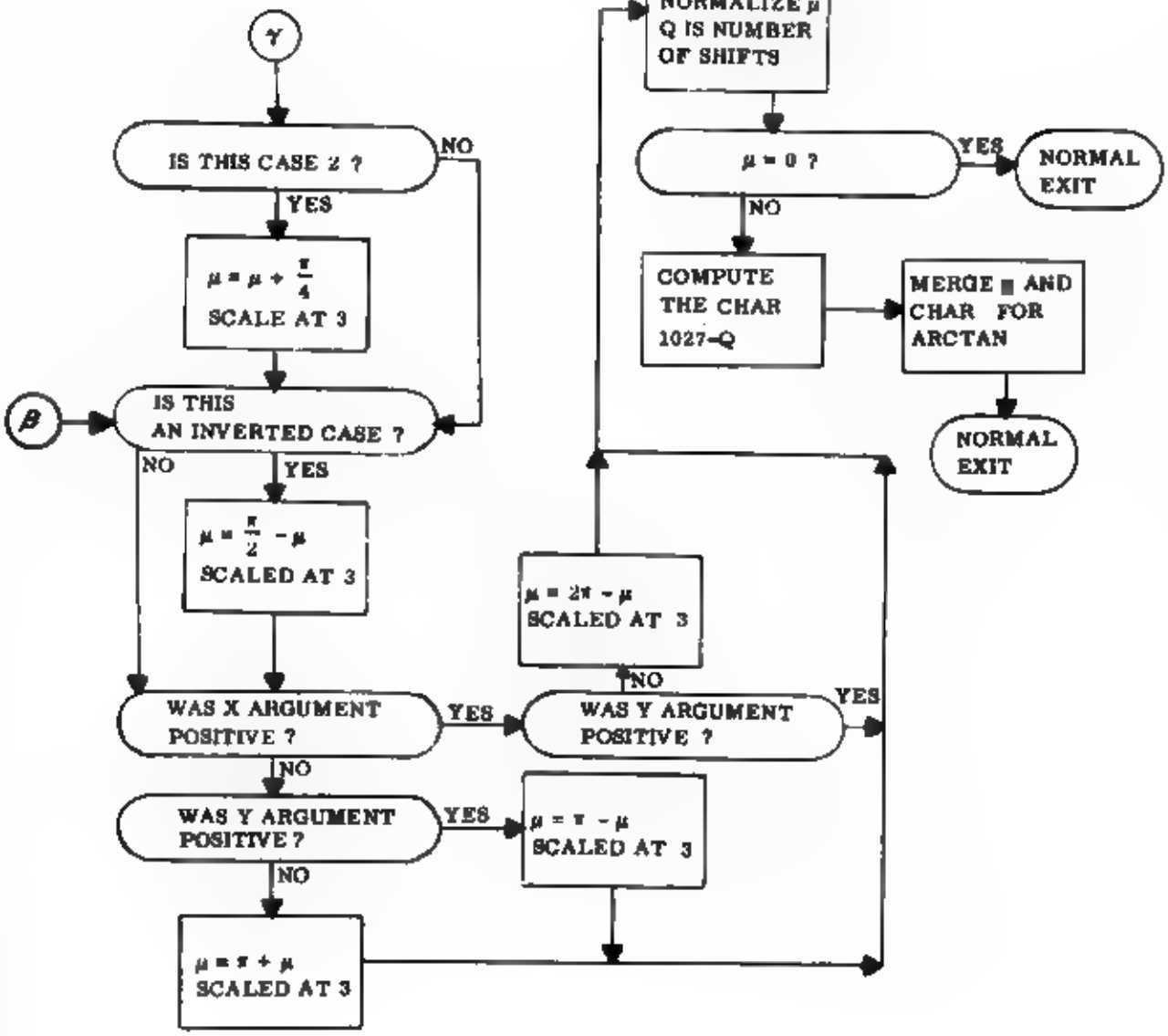


FPA2

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186646
XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET //

DEL 1263-3A (2/65)



FPA3

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
XX = ± XXX = ±	A	49671	2186646
FRACTIONS = ± ANGLES ≈ ± 1/2°	SCALE		SHEET 12

DEL 1263-3A (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT ARCTANGENT

PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186646
	SCALE		SHEET /3

DEL 1263-3A (2/65)

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*		FLOATING POINT ARCTANGENT	00010
00000	00 7 00000		$FRT	B*5	0,7	00310
00001	421 0 0310	1		STL	C@M	ARCTAN ENTRANCE. 00320
00002	356 0 0004	1		TPZ	*+2	C@MPLEMENT Y IF NEGATIVE. 00330
00003	161 0 0000			CMB		00340
00004	421 0 0311	1		STL	C@M+1	00350
00005	140 0 0252	1		LAN	FRTX	GET MANTISSA @F Y, MY. 00360
00006	520 0 0253	1		NRM	FRTX+1	N@RMALIZE MY. 00370
00007	520 0 0254	1		NRM	FRTX+2	NY IS NUMBER @F SHIFTS. 00380
00010	423 0 0312	1		STB	C@M+2	00390
00011	401 0 0311	1		LDL	C@M+1	GET CHARACTERISTIC @F Y, CY. 00400
00012	501 0 0014			SBA	+12	00410
00013	421 0 0311	1		STL	C@M+1	00420
00014	401 0 0000	1		LDL	FRT	00430
00015	100 0 0271	1		ADD	FRTX+15	00440
00016	431 0 0251	1		STE	FRTC	00450
00017	403 7 0000	1		LDB	FRT,7	PICKUP X. 00460
00020	421 0 0314	1		STL	C@M+4	SAVE SIGN @F X. 00470
00021	356 0 0023	1		TPZ	*+2	C@MPLEMENT X IF IT IS NEGATIVE. 00480
00022	161 0 0000			CMB		00490
00023	421 0 0315	1		STL	C@M+5	00500
00024	140 0 0252	1		LAN	FRTX	GET THE MANTISSA @F X, MX. 00510
00025	520 0 0261	1		NRM	FRTX+7	N@RMALIZE X. 00520
00026	520 0 0262	1		NRM	FRTX+8	00530
00027	423 0 0316	1		STB	C@M+6	00540
00030	401 0 0315	1		LDL	C@M+5	GET CHARACTERISTIC @F X, CX. 00550
00031	501 0 0014			SBA	+12	00560
00032	421 0 0315	1		STL	C@M+5	00570
00033	401 0 0317	1		LDL	C@M+7	IS MX ZER@ 00580
00034	355 0 0044	1		TPN	*+8	00590
00035	401 0 0313	1		LDL	C@M+3	IS MY ZER@ ALS@ 00600
00036	255 00042	2		JPN	*+4	00610
00037	401 0 0271	1		LDL	FRTX+15	00620
00040	102 0 0255	1		ADDI	FRTX+3	00630
00041	257 00251	2		JRA	FRTC	00640
00042	403 0 0257	1		LDB	FRTX+5	MX ZER@, MY N@T ZER@ CASE. 00650
00043	357 0 0213	1		TRA	FRTP	00660
00044	403 0 0316	1		LDB	C@M+6	IS MY ZER@ 00670
00045	352 0 0213	1		TRZ	FRTP	00680
00046	401 0 0311	1		LDL	C@M+1	C@MPUTE K=CY+NY-CX-NX 00690
00047	110 0 0253	1		SUB	FRTX+1	00700
00050	110 0 0254	1		SUB	FRTX+2	00710

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2/86646

SCALE | SHEET 14

DEL 1263-3A (2/66)

```
00051  110 0 0315   1          SUB     C@M+5                                    00720
00052  100 0 0261   1          ADD     FRTX+7                                   00730
00053  100 0 0262   1          ADD     FRTX+8                                   00740
00054  421 0 0311   1          STL     C@M+1          STORE K.                  00750
00055  421 0 0315   1          STL     C@M+5     SET INVERTING FLAG, PLUS IS @N, MINUS IS @FF.  00760.
00056  356 0 0060   1          TPZ     *+2                                      00770
00057  160 0 0000              CML                    COMPLEMENT K IF NEGATIVE. 00780
00060  421 0 0311   1          STL     C@M+1                                    00790
00061  430 0 0103   1          STA     FRTA           SET SHIFT @N AN SBA COMMAND.  00800
00062  110 0 0263   1          SUB     FRTX+9         K-45 AT 23.               00810
00063  353 0 0067   1          TNZ     *+4            IF K IS GREATER THAN 45, SET U=0.  00820
00064  400 0 0000              LDZ                                              00830
00065  517 0 0057              RBL     +47                                      00840
00066  357 0 0206   1          TRA     FRTR           GO TO R.                  00850
00067  401 0 0315   1          LDL     C@M+5          IS INVERTING FLAG @@      00860
00070  351 0 0075   1          TRN     *+5                                      00870
00071  403 0 0312   1          LDB     C@M+2          DIVIDE Z=X÷Y              00880
00072  423 0 0321   1          STB     C@M+9                                    00890
00073  403 0 0316   1          LDB     C@M+6                                    00900
00074  357 0 0100   1          TRA     *+4                                      00910
00075  403 0 0316   1          LDB     C@M+6          DIVIDE Z=Y÷X              00920
00076  423 0 0321   1          STB     C@M+9                                    00930
00077  403 0 0312   1          LDB     C@M+2                                    00940
00100  501 0 0001              SBA     1                                        00950
00101  321 7 0326   1          TSP     DVD            GO TO DIVIDE SUBROUTINE.  00960
00102  00 0 00321   2          *+5     C@M+9                                    00970
00103  501 0 0000         FRTA SBA     **             SCALE Z ABSOLUTELY AT 1.  00980
00104  423 0 0321   1          STB     C@M+9                                    00990
00105  114 0 0264   1          SUL     FRTX+10        Z-2**.5+1 AT 1.           01000
00106  421 0 0325   1          STL     C@M+13         SET CASE 2 FLAG, PLUS IS @N, MINUS IS @FF.  01010
00107  353 0 0124   1          TNZ     FRT@           TRANSFER IF CASE 1.       01020
00110  403 0 0321   1          LDB     C@M+9          CASE 2 CLACULATION.       01030
00111  501 0 0001              SBA     1                                        01040
00112  100 0 0270   1          ADD     FRTX+14        Z+1 AT 2.                 01050
00113  423 0 0323   1          STB     C@M+11                                   01060
00114  403 0 0321   1          LDB     C@M+9                                    01070
00115  501 0 0002              SBA     2                                        01080
00116  114 0 0266   1          SUL     FRTX+12        Z-1 AT 3.                 01090
00117  321 7 0326   1          TSP     DVD            GO TO DIVIDE SUBROUTINE.  01100
00120  30 0 00323   2          **5     C@M+11         T=(Z-1)*(Z+1) AT 1.       01110
00121  356 0 0123   1          TPZ     *+2            T AT 1.                   01120
00122  100 0 0271   1          ADD     FRTX+15        PUT L-REGISTER IN 2-COMPLEMENT.  01130
00123  423 0 0321   1          STB     C@M+9                                    01140
00124  401 0 0322   1     FRT@ LDL     C@M+10         COMPUTE T**2.             01150
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

DEL 1263-3A (2/66)

SIZE A | CODE IDENT NO. 49671 | 2186946

SCALE

SHEET 15

```
00125  120  0  0321   1          MPY     C@M+9
00126  501  0  0026              SBA     +22                                    01160
00127  423  0  0323   1          STB     C@M+11                                 01170
00130  401  0  0322   1          LDL     C@M+10                                 01180
00131  120  0  0322   1          MPY     C@M+10                                 01190
00132  105  0  0323   1          ALR     C@M+11      T**2 SCALED AT 2.          01200
00133  104  0  0272   1          ADL     FRTX+16     T**2+D3 SCALED AT 2.       01210
00134  423  0  0312   1          STB     C@M+2                                  01220
00135  403  0  0274   1          LDB     FRTX+18                                01230
00136  321  7  0326   1          TSP     DVD         E2 SCALED AT 4.            01240
00137  00   0  00312  2          **5     C@M+2       TRANSFER T@ DIVIDE SUBR@UTINE. 01250
00140  104  0  0276   1          ADL     FRTX+20     E2*(T**2+D3) AT 2.         01260
00141  104  0  0323   1          ADL     C@M+11      D2+E2(T**2+D3) AT 2.       01270
00142  423  0  0312   1          STB     C@M+2       T**2+D2+E2*(T**2+D3) SCALED AT 2. 01280
00143  403  0  0300   1          LDB     FRTX+22                                01290
00144  321  7  0326   1          TSP     DVD         E1 SCALED AT 0.            01300
00145  00   0  00312  2          **5     C@M+2                                  01310
00146  350  0  0000              NBP                 TRANSFER T@ DIVIDE SUBR@UTINE. 01320
00147  104  0  0302   1          ADL     FRTX+24     E1*(T**2+D2+E2*(T**2+D3)) AT 0. 01330
00150  356  0  0152   1          TPZ     **2         D1+E1*(--) SCALED AT 0.    01340
00151  100  0  0271   1          ADD     FRTX+15                                01350
00152  423  0  0312   1          STB     C@M+2                                  01360
00153  120  0  0323   1          MPY     C@M+11      C@MPUTE T**2(D1+E1(--)) AT 2. 01370
00154  423  0  0316   1          STB     C@M+6                                  01380
00155  401  0  0312   1          LDL     C@M+2                                  01390
00156  120  0  0324   1          MPY     C@M+12                                 01400
00157  104  0  0316   1          ADL     C@M+6                                  01410
00160  501  0  0027              SBA     +23                                    01420
00161  423  0  0316   1          STB     C@M+6                                  01430
00162  401  0  0315   1          LDL     C@M+5                                  01440
00163  120  0  0324   1          MPY     C@M+12                                 01450
00164  104  0  0316   1          ADL     C@M+6       T**2(D1+E1(--)) SCALED AT 2. 01460
00165  104  0  0304   1          ADL     FRTX+26     D0+T**2(D1+E1(--)) SCALED AT 2. 01470
00166  423  0  0316   1          STB     C@M+6                                  01480
00167  120  0  0322   1          MPY     C@M+10      T(D0+T**2(D1+E1())) AT 3.  01490
00170  423  0  0312   1          STB     C@M+2                                  01500
00171  401  0  0316   1          LDL     C@M+6                                  01510
00172  120  0  0322   1          MPY     C@M+10                                 01520
00173  423  0  0323   1          STB     C@M+11                                 01530
00174  401  0  0317   1          LDL     C@M+7                                  01540
00175  120  0  0321   1          MPY     C@M+9                                  01550
00176  104  0  0323   1          ADL     C@M+11                                 01560
00177  501  0  0027              SBA     +23                                    01570
00200  105  0  0312   1          ALR     C@M+2       T(D0+T**2(D1+E1(---))) SCALED AT 3. 01580
                                                                               01590
```

```
00201  401 0 0325   1            LDL     C0M+13      IS CASE 2 FLAG ON                    01600
00202  351 0 0207   1            TRN     FRTR+1                                           01610
00203  403 0 0257   1            LDB     FRTX+5      CASE 2, U=U+(P)e4) AT 3.             01620
00204  501 0 0001                SBA     1                                                01630
00205  104 0 0312   1            ADL     C0M+2                                            01640
00206  423 0 0312   1     FRTR   STB     C0M+2                                            01650
00207  401 0 0315   1            LDL     C0M+5       IS THIS AN INVERTED CASE             01660
00210  351 0 0214   1            TRN     FRTP+1                                           01670
00211  403 0 0257   1            LDB     FRTX+5      INVERTED CASE.                       01680
00212  114 0 0312   1            SUL     C0M+2       U=(P)e2)-U SCALED AT 3.              01690
00213  423 0 0312   1     FRTP   STB     C0M+2                                            01700
00214  401 0 0314   1            LDL     C0M+4       DETERMINE WHICH QUADRANT.            01710
00215  351 0 0226   1            TRN     FRTT        TRANSFER IF X IS NEGATIVE.           01720
00216  401 0 0310   1            LDL     C0M         IS Y POSITIVE                        01730
00217  356 0 0224   1            TPZ     FRTS        X, Y POSITIVE, 1ST QUADRANT.         01740
00220  403 0 0257   1            LDB     FRTX+5      4TH QUADRANT, U=2PI-U                01750
00221  500 0 0054                RBA     +44                                              01760
00222  114 0 0312   1            SUL     C0M+2                                            01770
00223  357 0 0237   1            TRA     FRTF                                             01780
00224  403 0 0312   1     FRTS   LDB     C0M+2       1ST QUADRANT, NO CORRECTION.         01790
00225  357 0 0237   1            TRA     FRTF                                             01800
00226  401 0 0310   1     FRTT   LDL     C0M         IS Y NEGATIVE                        01810
00227  351 0 0234   1            TRN     FRTD                                             01820
00230  403 0 0257   1            LDB     FRTX+5      2ND QUADRANT.                        01830
00231  500 0 0055                RBA     +45                                              01840
00232  114 0 0312   1            SUL     C0M+2       U=PI-U SCALED AT 3.                  01850
00233  357 0 0237   1            TRA     FRTF                                             01860
00234  403 0 0257   1     FRTD   LDB     FRTX+5      3RD QUADRANT.                        01870
00235  500 0 0055                RBA     +45                                              01880
00236  104 0 0312   1            ADL     C0M+2       U=PI+U SCALED AT 3.                  01890
00237  520 0 0306   1     FRTF   NRM     FRTX+28                                          01900
00240  520 0 0307   1            NRM     FRTX+29                                          01910
00241  252 00251    2            JRZ     FRTC        ZERO ANSWER, NORMAL RETURN.          01920
00242  501 0 0013                SBA     +11                                              01930
00243  421 0 0310   1            STL     C0M                                              01940
00244  401 0 0256   1            LDL     FRTX+4      COMPUTE THE CHARACTERISTIC.          01950
00245  110 0 0306   1            SUB     FRTX+28                                          01960
00246  110 0 0307   1            SUB     FRTX+29                                          01970
00247  515 0 0014                RLL     +12                                              01980
00250  150 0 0310   1            LIB     C0M                                              01990
00251  257 00000     FRTC       JRA     0           NORMAL EXIT.                         02000
00252  00007777      FRTX       NUM     00007777    MASK FOR MANTISSA.                   02010
00253  00000000                 NUM     00          NORMALIZING SHIFTS FOR MY,           02020
00254  00000000                 NUM     00          NORMALIZING SHIFT FOR MY.            02030
```

```
00255  37777777                    NUM     037777777   MASK FOR ADDRESS AND INDEX TAG.          02040
00256  00002003                    NUM     02003       1027 AT 23                               02050
00257  12421026                    NUM     012421026   P1o AT 3.                                02060
00260  06220773                    NUM     006220773   P1=*1.570796326799896                    02070
00261  00000000                    NUM     00          NORMALIZING SHIFTS FOR MX.               02080
00262  00000000                    NUM     00          SAME                                     02090
00263  00000055                    NUM     055         45 AT 23.                                02100
00264  23177167                    NUM     023177167   2**.5-1 SCALED AT 1.                     02110
00265  06501171                    NUM     006501171   2**.5-1=0.414213562373095                02120
00266  00000000                    NUM     00          1 AT 3. (ZERO)                           02130
00267  04000000                    NUM     004000000   1 AT 3.                                  02140
00270  10000000                    NUM     010000000   1 AT 2.                                  02150
00271  00000001                    NUM     01          1 AT 23.                                 02160
00272  13773761                    NUM     013773761   D3 SCALED AT 2.                          02170
00273  14757555                    NUM     014757555   D3=1.621023833634443                     02180
00274  70100425                    NUM     070100425   E2 AT 2.                                 02190
00275  77122741                    NUM     077122741   E2=-0.419003002282544                    02200
00276  06436650                    NUM     006436650   D2 SCALED AT 2.                          02210
00277  20633675                    NUM     020633675   D2=2.100554087165198                     02220
00300  54327445                    NUM     054327445   E1 AT 2.                                 02230
00301  73242435                    NUM     073242435   E1=-0.585315135071031                    02240
00302  55645625                    NUM     055645625   D1 SCALED AT 0.                          02250
00303  77400514                    NUM     077400514   D1=-0.015585371018178                    02260
00304  37777673                    NUM     037777673   D0 SCALED AT 2.                          02270
00305  07777777                    NUM     007777777   D0=0.999999999996107                     02280
00306  00000000                    NUM     00          NORMALIZING COUNT FOR U.                 02290
00307  00000000                    NUM     00          NORMALIZING COUNT FOR U.                 02300
00310                        CBM    BSS     14                                                   02310
                                    END                                                          02320
00320  00 0 00000     DVD
```

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET 18

2/86646

DEL 1263-3A (2/65)

SECTION 15

FLOATING POINT COMMON LOGARITHM OR (NATURAL LOGARITHM)

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

DRAWN DATE
31 AUG 65

CHECKED DATE
W. A. L. Sturman 3 SEP 65

DESIGN ACTIVITY APPD REL
J. W. Vanderpool 3 SEPT 65 (R)

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM MATHEMATICAL ROUTINE FLOATING POINT COMMON LOGARITHM OR (NATURAL LOGARITHM)

SIZE	CODE IDENT NO.	
A	49671	2186647

WEIGHT LB | SHEET 1 OF 18

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186647-1	FLOATING POINT COMMON LOGARITHM	
								OR (NATURAL LOGARITHM)	
								SYMBOLIC CARD DECK	
				X	5		CDV86647	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT COMMON LOGARITHM	
								OR (NATURAL LOGARITHM)	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186647

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT COMMON LOGARITHM

OR (NATURAL LOGARITHM)

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186647
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 3

DEL I263-3A (2/65)

TABLE OF CONTENTS

1.0 Identification

ID: FLG or (FLN)

2.0 Introduction

The purpose of the Floating Point Common Logarithm or (Natural Logarithm) is to compute the floating point common log or (natural log) of a number X which is in floating point format.

The program conforms to the specifications of the Floating Point System 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86647. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

The argument X is reduced as follows to yield the natural log of X.

$$X = 2^N \cdot F \text{ where } 1/2 \leq F < 1$$

$$\ln x = N \ln 2 + \ln F$$

$$\ln F = \ln \sqrt{1/2} + \ln \left(\frac{1 + T}{1 - T}\right) \text{ where } T = \left(\frac{F - \sqrt{1/2}}{F + \sqrt{1/2}}\right)$$

$$\ln\left(\frac{1 + T}{1 - T}\right) = T \left[A + T^2 \left(B + \frac{C}{(D + T^2)} \right) \right]$$

$A = 1.999999999491255$

$B = 0.109078890502997$

$C = -0.777314001005492$

$D = -1.394065145176107$

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UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186647
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 5

DEL 1263-3A (2/65)

3.0 Mathematical Method (Cont'd)

To compute the common log, the following relationship is used:

$$\log X = \log e \ln X$$

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program and the associated subroutine (Section 7.0). The SLAP 2 Loader uses the object program card deck, a product of the SLAP 2 Assembly, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

Calling Sequence:

With the floating point argument X in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	FLG or (FLN) (see below)
a + 1	Return	

FLG - symbolic entrance in the Floating Point common logarithm subroutine

FLN - symbolic entrance in the Floating Point natural logarithm subroutine

5.0 Output Format

Error Return:

An error return is indicated by overflow 'ON'.

a. The argument X is zero. The L register contains (40000000) and the R register contains (40000001) upon return.

b. The argument X is negative. The L and R registers contain the log of the absolute value of X. The log is in floating point format.

Normal Return:

A normal return is indicated by overflow 'OFF'.

The common logarithm or (natural logarithm) of the argument X is the L and R registers upon return. The log will be in floating point format.

6.0 Memory Requirements

6.1 Program: see program listing

6.2 Temporary Space: 13 core memory locations

7.0 Restrictions

This program uses the following floating point subroutine:

Name	ID	Number
Double Precision Divide	DVD	2186650

8.0 Timing

Approximate Timing:

FLN - 32.6 milliseconds
FLG - 36.0 milliseconds

9.0 Floating Point Common Logarithm or (Natural Logarithm) Card Deck

Symbolic source card deck for this program is 2186647-1

10.0 Appendices

10.1 Flow Chart

Flow chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

A listing of this program showing memory locations (relative to zero), octal representation and source card contents (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT COMMON LOGARITHM

OR (NATURAL LOGARITHM)

FLOW CHART

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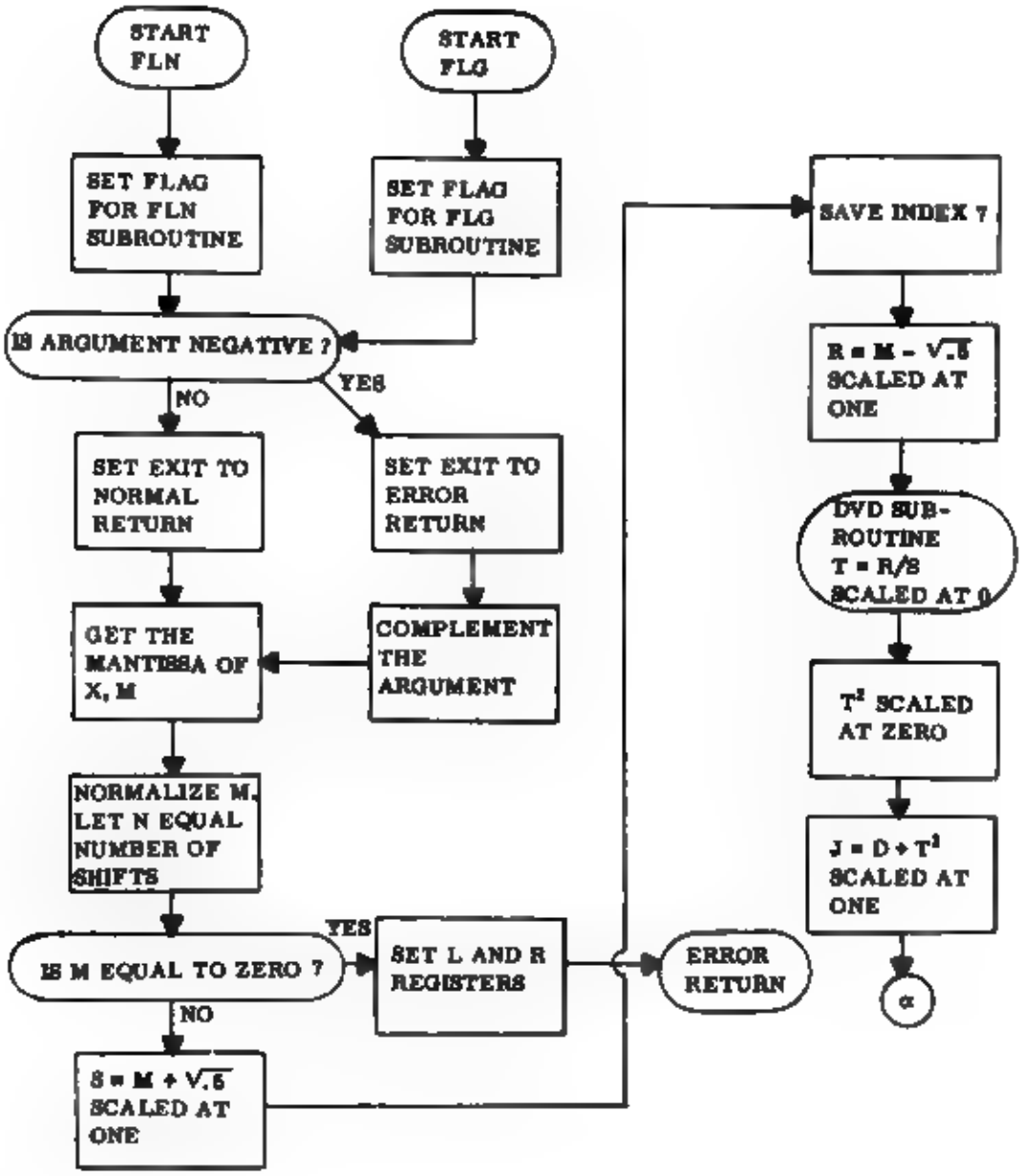
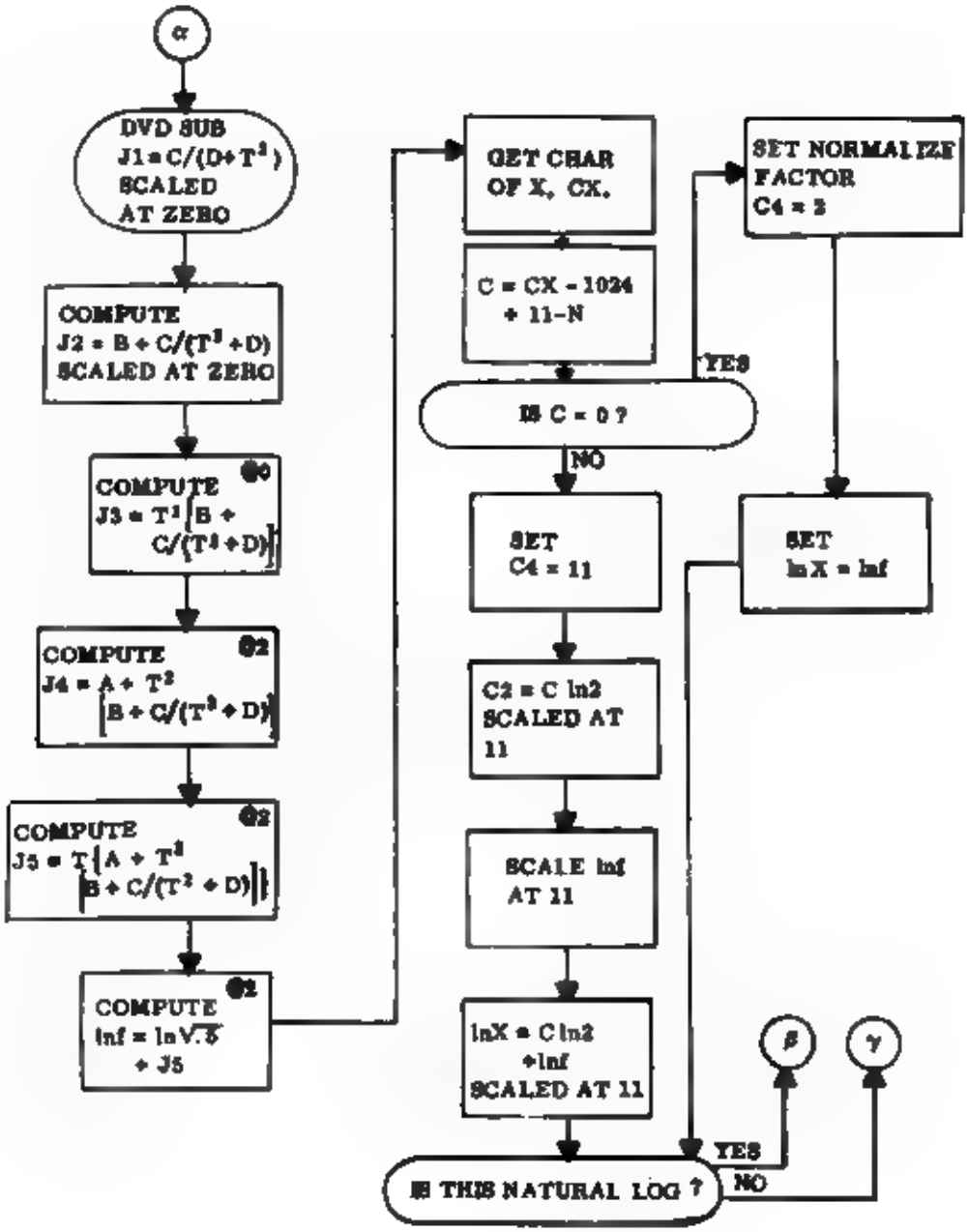
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 9



RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186647
XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET 10

DEL 1263-3A (2/65)

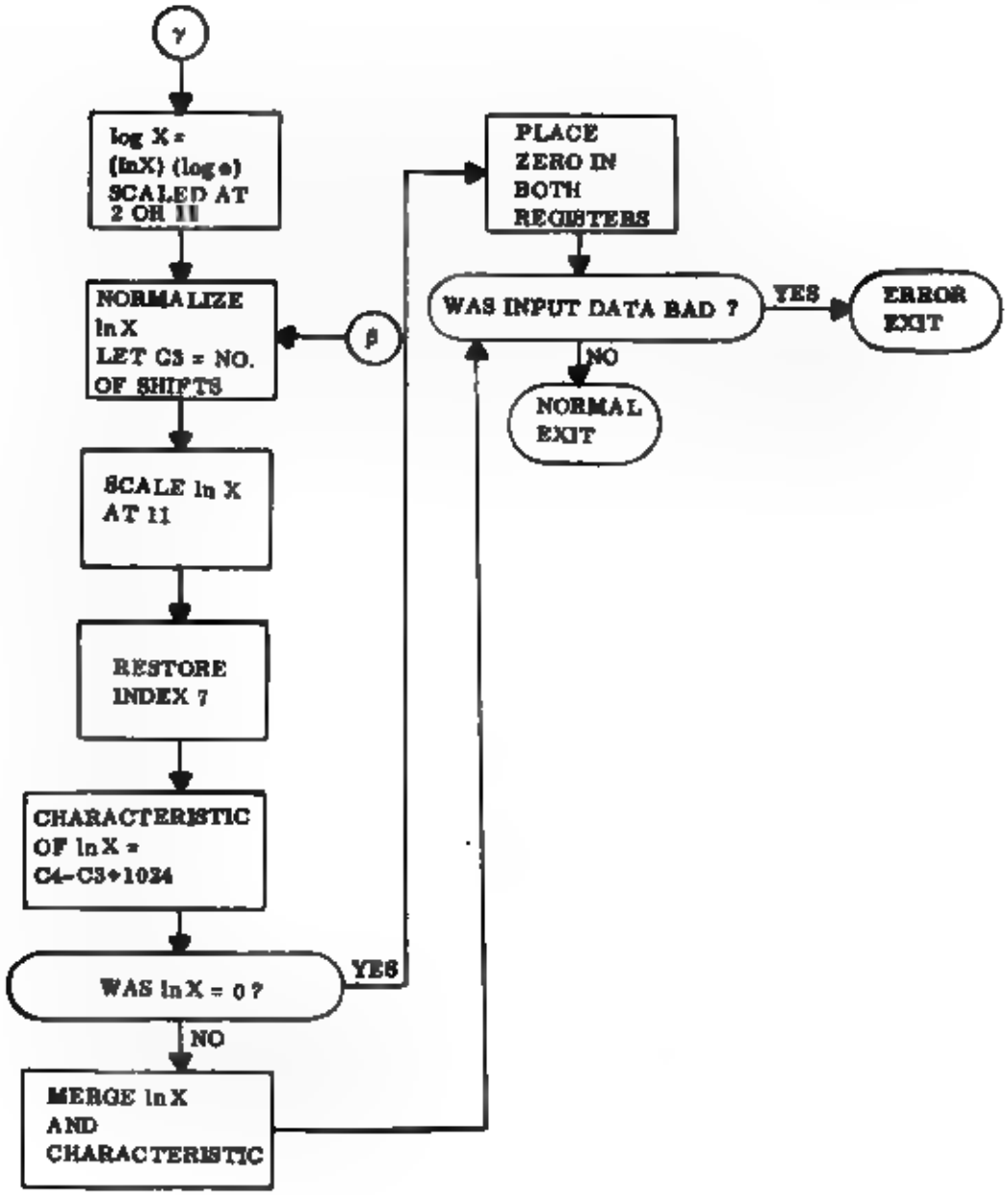


FPCL/NL2

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186647
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET //

DEL 1263-3A (2/65)



FPCL/NL3

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XX = ± XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET /2

DEL 1263-3A (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT COMMON LOGARITHM

OR (NATURAL LOGARITHM)

PROGRAM LISTING

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE	SYMBOLIC CARD CONTENT			CARD NO.
			*		FLOATING POINT COMMON LOGARITHM OR (NATURAL LOGARITHM)	00310
00000	00 0 00000		SFLN	**5	0	00320
00001	423 0 0256	1		STB	COM NATURAL LOG ENTRY.	00330
00002	402 0 0000	1		LDR	FLN	00340
00003	422 0 0006	1		STR	FLG	00350
00004	402 0 0216	1		LDR	FLNX SET NATURAL LOG EXIT.	00360
00005	397 0 0011	1		TRA	FLNA	00370
00006	00 0 00000		SFLG	**5	0	00380
00007	423 0 0256	1		STB	COM COMMON LOG ENTRY	00390
00010	402 0 0217	1		LDR	FLNX+1 SET COMMON LOG EXIT	00400
00011	422 0 0145	1	FLNA	STR	FLNF STORE EXITS	00410
00012	391 0 0015	1		TRN	FLNB CHECK FOR NEGATIVE ARGUMENT	00420
00013	402 0 0220	1		LDR	FLNX+2 SET NORMAL NORMAL RETURN.	00430
00014	357 0 0016	1		TRA	*+2	00440
00015	402 0 0221	1	FLNB	LDR	FLNX+3 SET ERROR EXIT	00450
00016	422 0 0175	1		STR	FLNK STORE EXITS	00460
00017	402 0 0256	1		LDR	COM	00470
00020	356 0 0023	1		TPZ	*+3 CHECK FOR NEGATIVE ARGUMENT.	00480
00021	161 0 0000			CMB	COMPLEMENT A NEGATIVE ARGUMENT.	00490
00022	421 0 0257	1		STL	COM+1	00500
00023	140 0 0222	1		LAN	FLNX+4 GET MANTISSA.	00510
00024	520 0 0223	1		NRM	FLNX+5	00520
00025	520 0 0224	1		NRN	FLNX+6 NORMALIZE THE MANTISSA.	00530
00026	355 0 0032	1		TPN	FLNC CHECK FOR ZERO MANTISSA.	00540
00027	403 0 0225	1		LDB	FLNX+7 ZERO MANTISSA. PLACE LARGEST NEGATIVE	00550
00030	102 0 0226	1		ADDI	FLNX+8	00560
00031	397 7 0006	1		TRA	FLG,7 NUMBER IN REGISTER AND USE ERROR RETURN.	00570
00032	501 0 0001		FLNC	SBA	1 SCALE MANTISSA AT 1.	00580
00033	423 0 0260	1		STB	COM+2	00590
00034	104 0 0227	1		ADL	FLNX+9 S=M+(.5**(.5)	00600
00035	423 0 0262	1		STB	COM+4 STORE S AT 1	00610
00036	403 0 0260	1		LDB	COM+2 R=M-(.5)**(.5) SCALED AT 1.	00620
00037	114 0 0227	1		SUL	FLNX+9	00630
00040	321 7 0273	1		TSP	DVD T=R0S SCALED AT 0	00640
00041	00 0 00262	2		**5	COM+4	00650
00042	350 0 0000			NOP		00660
00043	356 0 0045	1		TPZ	*+2 IF T IS NEGATIVE, ADD ONE T	00670
00044	100 0 0255	1		ADD	FLNX+31 TO MS PART TO GET 2-COMPLEMENT.	00680
00045	423 0 0264	1		STB	COM+6 STORE T SCALED AT 0	00690
00046	120 0 0264	1		MPY	COM+6 COMPUTE T**2.	00700
00047	501 0 0026			SBA	+22	00710
00050	423 0 0266			STB	COM+8	

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XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET /4

2189947

DEL 1263-3A (2/65)

```
00051  401 0 0265   1          LDL     C@M+7                                          00720
00052  120 0 0265   1          MPY     C@M+7                                          00730
00053  105 0 0266   1          ALR     C@M+8       STORE T**2 SCALED AT 0.            00740
00054  501 0 0001              SBA     1                                              00750
00055  104 0 0231   1          ADL     FLNX+11     T**2+D SCALED AT 1.                00760
00056  423 0 0270   1          STB     C@M+10      STORE J=T**2+D AT 1.               00770
00057  403 0 0233   1          LDB     FLNX+13     DIVIDE                             00780
00060  321 7 0273   1          TSP     DVD         TRANSFER TO DIVIDE SUBROUTINE.     00790
00061  00 0 00270   2          **5     C@M+10      J1=C+(D+T**2) SCALED AT 0.         00800
00062  104 0 0235   1          ADL     FLNX+15     J2=B+J1                            00810
00063  423 0 0270   1          STB     C@M+10      J2=B+J1 SCALED AT 0.               00820
00064  120 0 0266   1          MPY     C@M+8       J3=T**2(J2) SCALED AT 0.           00830
00065  501 0 0027              SBA     +23                                            00840
00066  423 0 0262   1          STB     C@M+4       J+ SCALED AT 0. (LS) (MS)          00850
00067  401 0 0270   1          LDL     C@M+10      J2 (LS PART)                       00860
00070  120 0 0267   1          MPY     C@M+9       T**2(J2) SCALED AT 0. (MS) (LS)    00870
00071  501 0 0027              SBA     +23                                            00880
00072  105 0 0262   1          ALR     C@M+4                                          00890
00073  401 0 0271   1          LDL     C@M+11      J2 SCALED AT +. (MS PART)          00900
00074  120 0 0267   1          MPY     C@M+9       T**2(J2) (MS) (MS)                 00910
00075  104 0 0262   1          ADL     C@M+4       J3 =T**2(J2)                       00920
00076  501 0 0002              SBA     2           SCALED J3 AT 2.                    00930
00077  104 0 0237   1          ADL     FLNX+17     J2=A+J3 SCALED AT 2.               00940
00100  423 0 0270   1          STB     C@M+10      STORE J4                           00950
00101  120 0 0264   1          MPY     C@M+6       COMPUTE J5                         00960
00102  501 0 0027              SBA     +23         T(J4) SCALED AT 2.                 00970
00103  423 0 0262   1          STB     C@M+4       STORE T (J4) SCALED AT 2. (LS) (MS)00980
00104  401 0 0270   1          LDL     C@M+10      J4, (LS) PART                      00990
00105  120 0 0265   1          MPY     C@M+7       T(J4) SCALED AT 2. (MS) (LS)       01000
00106  501 0 0027              SBA     +23                                            01010
00107  105 0 0262   1          ALR     C@M+4                                          01020
00110  401 0 0271   1          LDL     C@M+11      J4, (MS) PART                      01030
00111  120 0 0265   1          MPY     C@M+7       T(J4) SCALED AT 2. (MS) (MS)       01040
00112  104 0 0262   1          ADL     C@M+4       J5=T(J4) SCALED AT 2.              01050
00113  104 0 0241   1          ADL     FLNX+19     LN F+LN(.5)**(.5)+J5 SCALED 2      01060
00114  423 0 0262   1          STB     C@M+4       STORE LN F SCALED AT 2.            01070
00115  401 0 0257   1          LDL     C@M+1       GET THE CHARACTERISTIC OF THE ARGUMENT 01080
00116  501 0 0014              SBA     +12         CX.                                01090
00117  110 0 0243   1          SUB     FLNX+21     CX-1024+11                         01100
00120  110 0 0223   1          SUB     FLNX+5      CX-1013-N                          01110
00121  110 0 0224   1          SUB     FLNX+6      C=CX-1013-N SCALED AT 23.          01120
00122  352 0 0142   1          TRZ     FLND        CHECK IF C IS ZERO. USE SPECIAL SCALING. 01130
00123  402 0 0246   1          LDR     FLNX+24     SET C4 EQUAL TO 11.                01140
00124  422 0 0257   1          STR     C@M+1                                          01150
```

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XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET 15

2189647

DEL 1263-3A (2/60)

```
00125  402 0 0222   1          LDR     FLNX+4          PLACE ZERO IN RIGHT REGISTER.                   01160
00126  517 0 0044              RBL     +36             SCALE C AT 11                                   01170
00127  421 0 0256   1          STL     C@M             STORE C AT 11.                                  01180
00130  120 0 0244   1          MPY     FLNX+22         @ LN2 SCALED AT 11. (MS) (LS)                   01190
00131  501 0 0027              SBA     +23                                                             01200
00132  423 0 0270   1          STB     C@M+10                                                          01210
00133  401 0 0256   1          LDL     C@M             C SCALED AT 11.                                 01220
00134  120 0 0245   1          MPY     FLNX+23         C LN2 SCALED AT 11 (MS) (MS)                    01230
00135  105 0 0270   1          ALR     C@M+10          C LN2 SCALED AT 11.                             01240
00136  403 0 0262   1          LDB     C@M+4           PICK UP LN F SCALED AT 2.                       01250
00137  501 0 0011              SBA     +9              RESCALE LN F T@ 11.                             01260
00140  104 0 0270   1          ADL     C@M+10          LNX =C LN 2 +LN F SCALED AT 11.                 01270
00141  357 0 0145   1          TRA     FLNF                                                            01280
00142  401 0 0247   1  FLND    LDL     FLNX+25         C IS ZER@, SET C4 EQUAL T@ 2.                   01290
00143  421 0 0257   1          STL     C@M+1                                                           01300
00144  403 0 0262   1          LDB     C@M+4           PLACE LN X IN REGISTERS                         01310
00145  357 0 0000      FLNF    TRA     **              NATURAL L@G TRANSFER C@MMAND                    01320
00146  356 0 0150   1          TPZ     *+2             IF LN X IS NEGATIVE, ADD @NE                    01330
00147  100 0 0255   1          ADD     FLNX+31         T@ PUT MS PART IN 2C@MPLEMENT.                  01340
00150  423 0 0270   1          STB     C@M+10                                                          01350
00151  120 0 0250   1          MPY     FLNX+26         C@MM@N L@G. LN X IS IN C@M+10.                  01360
00152  501 0 0001              SBA     1               (LN X) (L@G E) SCALED AT 11 @R 2.               01370
00153  423 0 0262   1          STB     C@M+4           STORE (LN X) (L@G E), (MS) ((LS) PART           01380
00154  401 0 0270   1          LDL     C@M+10          LN X, THE LS PART.                              01390
00155  120 0 0251   1          MPY     FLNX+27         LN X) (L@G E), (LS) (MS) PART.                  01400
00156  501 0 0001              SBA     1                                                               01410
00157  104 0 0262   1          ADL     C@M+4                                                           01420
00160  501 0 0026              SBA     +22                                                             01430
00161  423 0 0262   1          STB     C@M+4                                                           01440
00162  401 0 0271   1          LDL     C@M+11          LN X, THE MS PART                               01450
00163  120 0 0251   1          MPY     FLNX+27         LN X L@G E, (MS) (MS) PART                      01460
00164  104 0 0262   1          ADL     C@M+4           L@G X SCALED AT 2 @R 11                         01470
00165  421 0 0266   1  FLNG    STL     C@M+8           MAKE THE MANTISSA PLUS.                         01480
00166  356 0 0170   1          TPZ     *+2                                                             01490
00167  161 0 0000              CMB                                                                     01500
00170  520 0 0223   1          NRM     FLNX+5          N@RMALIZE LN X.                                 01510
00171  520 0 0224   1          NRM     FLNX+6                                                          01520
00172  501 0 0013              SBA     +11             SCALE LN X AT 11                                01530
00173  140 0 0232   1          LAN     FLNX+28                                                         01540
00174  423 0 0262   1          STB     C@M+4           LN X SCALED AT 11                               01550
00175  357 0 0000      FLNK    TRA     **                                                              01560
00176  102 0 0226   1          ADDI    FLNX+8                                                          01570
00177  401 0 0253   1  FLNJ    LDL     FLNX+29                                                         01580
00200  110 0 0223   1          SUB     FLNX+5          GET CHARACTERISTIC @F L@GX.                     01590
```

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XX = ± XXX = ±
FRACTIONS = ± ANGLES = ±1/2°

DEL 1263-3A (2/65)

SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET 16

2186647

```
00201  112 0 0224   1              SUBI    FLNX+6          CHECK IF LOG X IS ZERO                          01600
00202  352 0 0215   1              TRZ     FLNN            LOG X IS ZERO. EXIT WITH ZERO IN REGISTER       01610
00203  102 0 0254   1              ADDI    FLNX+30                                                         01620
00204  102 0 0257   1              ADDI    C0M+1           CHARACTERISTIC =C4-C3+1024                      01630
00205  515 0 0014                  RLL     +12                                                             01640
00206  151 0 0263   1              LIR     C0M+5           MERGE CHARACTERISTIC AND MANTISSA.              01650
00207  401 0 0266   1              LDL     C0M+8           CHECK IF MANTISSA HAS NEGATIVE.                 01660
00210  356 0 0214   1              TPZ     *+4                                                             01670
00211  401 0 0263   1              LDL     C0M+5                                                           01680
00212  161 0 0000                  CMB                     RESTORE NEGATIVE MANTISSA.                      01690
00213  357 0 0215   1              TRA     FLNN                                                            01700
00214  401 0 0263   1              LDL     C0M+5                                                           01710
00215  357 7 0006   1       FLNN   TRA     FLG,7           NORMAL RETURN OR ERROR RETURN.                  01720
00216  357 0 0165   1       FLNX   TRA     FLNG            NATURAL LOG EXIT                                01730
00217  350 0 0000                  NOP                     COMMON LOG EXIT.                                01740
00220  257 00177    2              JRA     FLNJ            NORMAL RETURN                                   01750
00221  401 0 0226   1              LDL     FLNX+8          ERROR RETURN                                    01760
00222  00007777                    NUM     000007777       MANTISSA MASK.                                  01770
00223  00000000                    NUM     00              NORMALIZING SHIFTS FOR MANTISSA OR ANS.         01780
00224  00000000                    NUM     00              NORMALIZING SHIFTS FOR MANTISSA OR ANS.         01790
00225  40000001                    NUM     040000001       LARGEST NEGATIVE NUMBER.                        01800
00226  40000000                    NUM     040000000                                                       01810
00227  31477473                    NUM     031477473       (.5)**.5 SCALED AT 1. (LS PART)                 01820
00230  13240474                    NUM     013240474       (.5)**.5 SCALED AT 1. (MS PART)                 01830
00231  77417464                    NUM     077417464       D SCALED AT 1. (LS PART)                        01840
00232  51543642                    NUM     051543642       D SCALED AT 1. (MS PART)                        01850
00233  70657254                    NUM     070657254       C SCALED AT 1. (LS PART)                        01860
00234  63440174                    NUM     063440174       C SCALED AT 1. (MS PART)                        01870
00235  01554474                    NUM     001554474       B SCALED AT 0. (LS PART)                        01880
00236  03373114                    NUM     003373114       B SCALED AT 0. (MS PART)                        01890
00237  37756412                    NUM     037756412       A SCALED AT 2. (LS PART)                        01900
00240  17777777                    NUM     017777777       A SCALED AT 2. (MS PART)                        01910
00241  60040561                    NUM     060040561       LN(.5)**(.5) SCALED AT 2. (LS PART)             01920
00242  75164336                    NUM     075164336       LN (.5)**(.5) SCALED AT 2. (MS PART)            01930
00243  00001765                    NUM     01765           U013 AT 23                                      01940
00244  37372163                    NUM     037372163       LN 2 AT 0. (LS PART)                            01950
00245  26134413                    NUM     026134413       LN2 AT 0. (MS PART)                             01960
00246  00000013                    NUM     013             SCALING OF LN X                                 01970
00247  00000002                    NUM     02              SCALING OF LN X                                 01980
00250  05223344                    NUM     005223344       LOG E SCALED AT 0. (LS PART)                    01990
00251  15713366                    NUM     015713366       LOG E     SCALED AT 0. (MS PART)                02000
00252  40007777                    NUM     040007777                                                       02010
00253  00000056                    NUM     056             46 AT 23                                        02020
00254  00001722                    NUM     01722           978 AT 23                                       02030
```

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XX = ± XXX = ±
FRACTIONS = ± ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186647

SCALE | SHEET 17

DEL 1263-3A (2/60)

```
02040
02050
02060

                1 AT 23.


                NUM   01
                BSS   13
                END


          CBM


00255  00000001
00256
00273  00 0 00000    DVD
```

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.XX = ± .XXX = ±	A	49671	2186647
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 18

DEL 1263-3A (2/65)

SECTION 16

FLOATING POINT EXPONENTIAL E^x

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	A	SEE ENGINEERING CHANGE NOTICE CLASS II, DCS 642	4 FEB 66 4 FEB 66	

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN	DATE
E.M. Stanzel	2 SEP 65
CHECKED	DATE
H.A. Stillman	8 SEP 65
DESIGN ACTIVITY APPD	REL
J.W. Vanderford	8 SEPT 65

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
FLOATING POINT EXPONENTIAL E^X

SIZE	CODE IDENT NO.	
A	49671	2186648

WEIGHT LB

SHEET 1 OF 16

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186648-1	FLOATING POINT EXPONTIAL E^X	
								SYMBOLIC CARD DECK	
				X	5		CDV 86648	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT EXPONENTIAL E^X	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186648

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT EXPONENTIAL E^x

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
.XX = ± .XXX = ±	A	49671	2186648
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 3

TABLE OF CONTENTS

1.0 Identification

ID: FEX

2.0 Introduction

The purpose of the Floating Point Exponential, E^X, program is to compute the floating point exponential E^x of a floating point argument, X.

The program conforms to the specifications of the Floating Point System 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86648. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

To compute E^X, the argument ■ is first reduced to a fixed point number.

$$X = 2^C \cdot M$$

$X = M_1$ where M_1 is a fixed point number.

Change the exponent of E to an exponent of 2

$$E^X = 2^{M_1\left(\frac{1}{\ln 2}\right)}$$

$$= 2^{M_2 + M_3} \quad \text{where } M_2 \text{ is an integer and } |M_3| < 1.$$

$$E^X = 2^{M_2} \cdot E^{M_3(\ln 2)}$$

3.0 Mathematical Method (Cont'd)

Let $f = |M_3| \ln 2$

Then $E^x = 2^{M_2} \cdot E^f$ where $E^f < \ln 2$

Evaluating E^f,

$$E^f = 1 + \frac{2f}{(P - f)} \text{ and } P = A + f^2 \left[B + \frac{C}{(D + f^2)} \right]$$

A = 2.000000000000575924

B = 0.049962489136450764

C = 4.903154798968682648

D = 42.013532895041661680

For positive X,

$$E^x = 2^{M_2} \cdot E^f$$

For negative X,

$$E^x = 2^{M_2} \cdot \left(\frac{1}{E^f} \right)$$

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program and the associated subroutine (section 7.0). The SLAP 2 Loader uses the object program card deck, a product of the SLAP 2 assembly, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

With the floating point argument X in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	FEX (see below)
a + 1	Return	

FEX - Symbolic entrance in the Floating Point Exponential, E^X, subroutine

5.0 Output Format

Error return:

An error return is indicated by overflow 'ON'.

X> 709.98 = (1023) ln 2. The L register will contain (37777777) upon return.

Normal return:

A normal return is indicated by overflow 'OFF'.

The exponential of the argument X will be in the L and R registers upon return. The exponential will be in normalized floating point format.

6.0 Memory Requirements

6.1 Program: see program listing

6.2 Temporary Space: None

7.0 Restrictions

This program uses the following floating point subroutine:

Name	ID	Number
Double Precision Divide	DVD	2186650

8.0 Timing

Approximate timing: 41.4 milliseconds maximum

9.0 Floating Point Exponential, E^X, Card Deck

Symbolic source card deck for this program is 2186648-1.

10.0 Appendices

10.1 Flow Chart

Flow chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

A listing of this program showing memory locations (relative to zero), octal representation and source card content (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

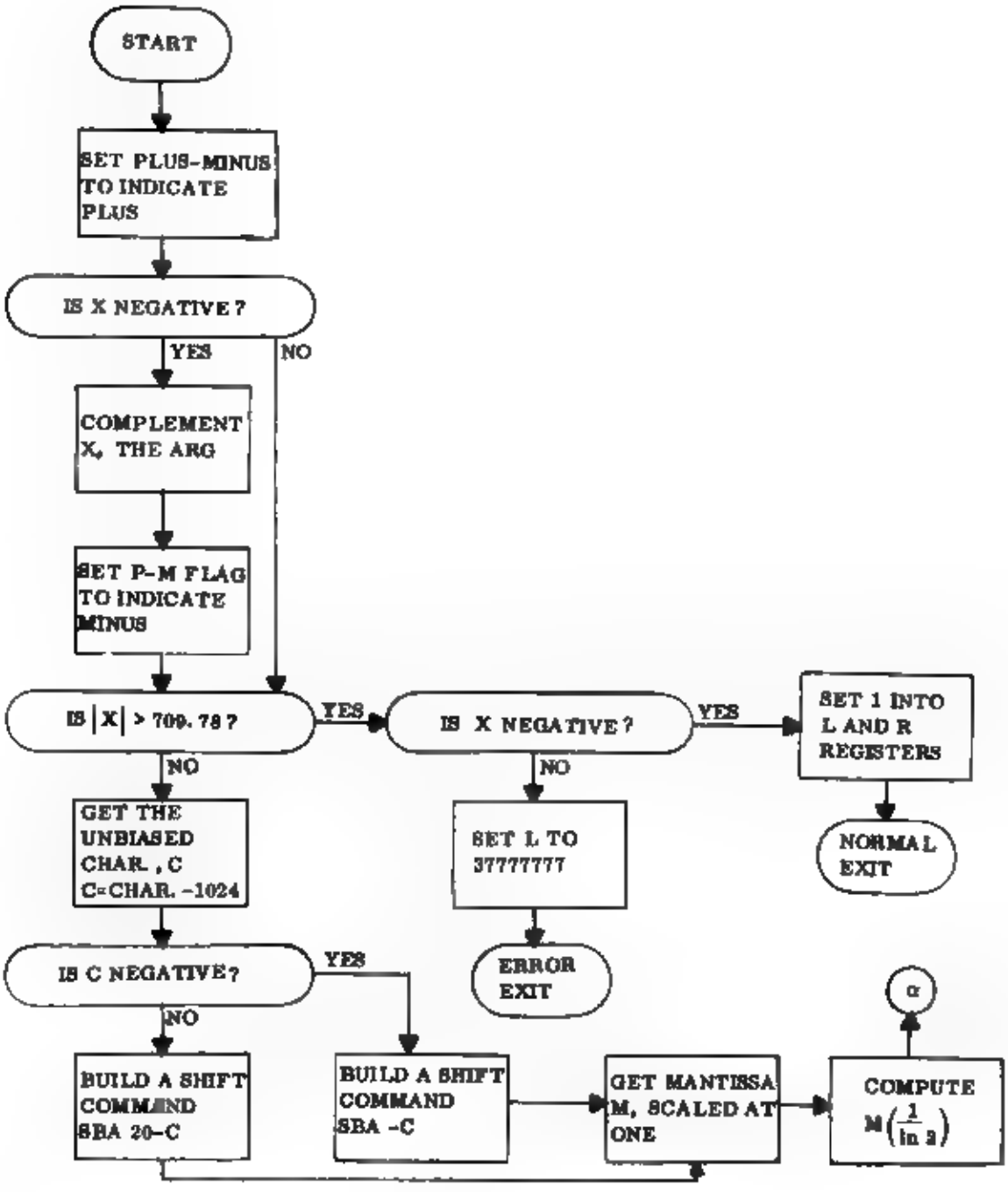
FLOATING POINT EXPONENTIAL E^X

FLOW CHART

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186648
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 9

DEL 1263-3A (2/65)



FPE1

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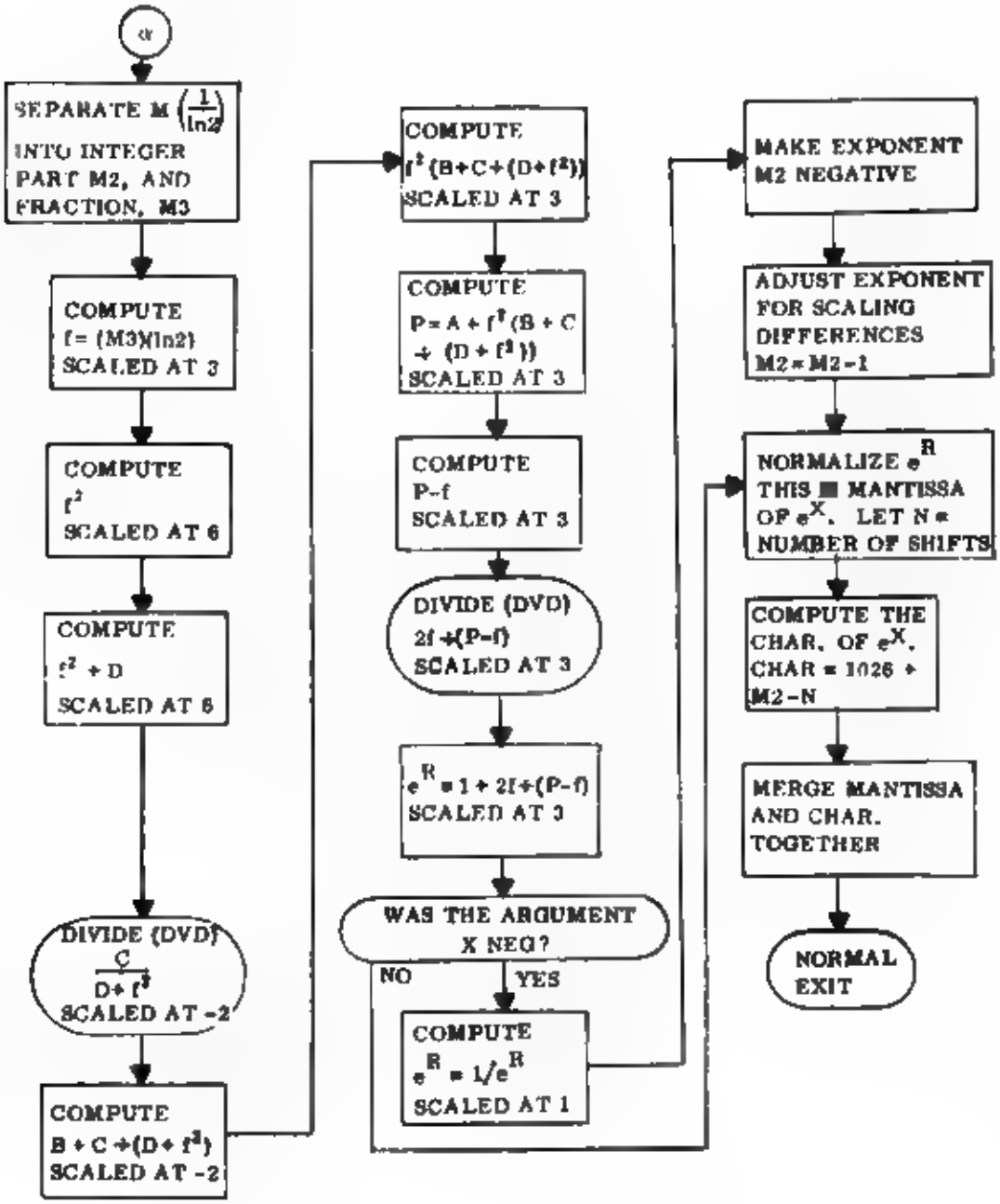
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186648
	SCALE		SHEET 10

DEL 1263-3 (2/65)



FPE2

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.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET //

DEL 1263-3 (2/65)

TABLE 1

SATURN GROUND COMPUTER SYSTEM

FLOATING POINT EXPONENTIAL E^X

PROGRAM LISTING

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			•		FLOATING POINT EXPONENTIAL, **	00310
			SFEX	••5	0	00310
00000	00 0 00000					
00001	420 0 0246	1		STZ	FEXY ENTRANCE TO EXPONENTIAL SUBROUTINE	00320
00002	356 0 0005	1		YPZ	FEXA CHECK SIGN OF ARGUMENT	00330
00003	161 0 0000			CNB	COMPLEMENT ARGUMENT IF NEGATIVE	00340
00004	421 0 0246	1		STL	FEXY INDICATE NEGATIVE ARGUMENT	00350
00005	423 0 0247	1	FEXA	STB	FEXY+1 STORE THE ARGUMENT	00360
00006	114 0 0207	1		SUL	FEXX IS X GREATER 709.78 IF YES, THERE EXISTS AN	00370
00007	351 0 0022	1		TRN	FEXB OVERFLOW CONDITION	00380
00010	401 0 0246	1		LDL	FEXY	00390
00011	352 0 0016	1		TAZ	FEXC	00400
00012	403 0 0014	1		LDB	FEXH UNDERFLOW .E••0 IS ONE.	00410
00013	357 7 0000	1		TRA	FEX,7 NORMAL EXIT.	00420
00014	00000000		FEXH	NUH	000000000 FLOATING ONE	00430
00015	20014000			NUH	020014000	00440
00016	401 0 0211	1	FEXC	LDL	FEXX+2	00450
00017	102 0 0211	1		ADDI	FEXX+2	00460
00020	401 0 0211	1		LDL	FEXX+2	00470
00021	357 7 0000	1		TRA	FEX,7 OVERFLOW (37777777---L REG.) ERROR EXIT	00480
00022	401 0 0250	1	FEXB	LDL	FEXY+2	00490
00023	501 0 0014			SBA	+12 CHARACTERISTIC, C, AT 23.	00500
00024	110 0 0213	1		SUB	FEXX+4	00510
00025	421 0 0251	1		STL	FEXY+3 C= (CHARACTERISTIC-1024)	00520
00026	351 0 0171	1		TRN	FEX1	00530
00027	401 0 0217	1		LDL	FEXX+8 BUILD SBA COMMAND	00540
00030	110 0 0251	1		SUB	FEXY+3 NUMBER OF SHIFTS =(20-C)	00550
00031	421 0 0053	1		STL	FEXE	00560
00032	421 0 0056	1		STL	FEXF	00570
00033	403 0 0247	1	FEXD	LDB	FEXY+1	00580
00034	140 0 0220	1		LAN	FEXX+9 MANTISSA, M AT 1.	00590
00035	500 0 0044			NBA	+36	00600
00036	423 0 0247	1		STB	FEXY+1	00610
00037	120 0 0221	1		MPY	FEXX+10 MULTIPLY MANTISSA BY (1•LN2)	00620
00040	423 0 0252	1		STB	FEXY+4 M(1•LN2) AT -20, (MS) (LS)	00630
00041	401 0 0247	1		LDL	FEXY+1	00640
00042	120 0 0222	1		MPY	FEXX+11 M (1•LN2) AT -20 (LS) (MS)	00650
00043	104 0 0252	1		ADL	FEXY+4	00660
00044	501 0 0027			SBA	+23	00670
00045	423 0 0252	1		STB	FEXY+4 M(1•LN2) AT 3, (LS) (MS)+(MS) (LS)	00680
00046	401 0 0250	1		LDL	FEXY+2	00690
00047	120 0 0222	1		MPY	FEXX+11 M(1•LN2) AT 3, (MS) (MS)	00700
00050	104 0 0252	1		ADL	FEXY+4	00710

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SIZE A | CODE IDENT NO. 49671 | SCALE | SHEET 13

2186648

DEL 1263-3A (2/65)

```
00051  423 0 0252   1              STB     FEXY+4      M(1@LN2) AT 8, FULL PR@DUCT,                    00720
00052  402 0 0223   1              LDR     FEXX+12     SEPERATE INTEFER AND FRACTI@NAL PART            00730
00053  501 0 0000          FEXE    SBA     **          @F M(1/N2). SHIFT (20-C) PLACES IF C            00740
00054  423 0 0254   1              STB     FEXY+6      IS P@SITIVE, IF C IS NEGATIVE, TRANSFER         00750
00055  401 0 0252   1              LDL     FEXY+4      L@AD LEAST SIGNIFICANT PART @F M(1/LN2)         00760
00056  501 0 0000          FEXF    SBA     **          AND SCALE AT 0, SHIFT (20-C) PLACES.            00770
00057  100 0 0254   1              ADD     FEXY+6    MERGE THE LS AND MS FRACTI@N PARTS T@GETHER.      00780
00060  501 0 0003                  SBA     3           FRACTI@NAL PART @F M (1@LN2) AT 3               00790
00061  423 0 0256   1      FEXG    STB     FEXY+8                                                      00800
00062  120 0 0225   1              MPY     FEXX+14   COMPUTE M4=M3 (LN2)                              00810
00063  423 0 0252   1              STB     FEXY+4      (LN2) M3 AT 3 (LS) (MS)                         00820
00064  401 0 0256   1              LDL     FEXY+8                                                      00830
00065  120 0 0226   1              MPY     FEXX+15   (LN2) M3 AT -20, (MS) (LS)                      00840
00066  104 0 0252   1              ADL     FEXY+4      (LN2)M3 (LS) (MS)+(MS) (LS)                     00850
00067  501 0 0027                  SBA     +23         (LN2) (M3) AT 3                                 00860
00070  423 0 0252   1              STB     FEXY+4                                                      00870
00071  401 0 0257   1              LDL     FEXY+9                                                      00880
00072  120 0 0226   1              MPY     FEXX+15   (LN2)M3 AT 3 (MS) (MS)                          00890
00073  105 0 0252   1              ALR     FEXY+4      F=(LN2) [redacted] AT 3                         00900
00074  120 0 0253   1              MPY     FEXY+5      F**2 AT 6, (MS) (MS)                            00910
00075  423 0 0256   1              STB     FEXY+8                                                      00920
00076  401 0 0252   1              LDL     FEXY+4                                                      00930
00077  120 0 0253   1              MPY     FEXY+5      F**2 AT -17 (LS) (MS)                           00940
00100  501 0 0026                  SBA     +22         F**2 AT 6 2 (LS) (MS)                           00950
00101  105 0 0256   1              ALR     FEXY+8      F**2 AT 6                                       00960
00102  104 0 0227   1              ADL     FEXX+16   B+F**2 AT 6,                                     00970
00103  423 0 0260   1              STB     FEXY+10                                                     00980
00104  403 0 0231   1              LDB     FEXX+18   PICK UP C AT 3                                    00990
00105  321 7 0267   1              TSP     DVD-        DIVIDE, Co(D+F**2) AT 3                         01000
00106  00 0 00260   8              **5     FEXY+10                                                     01010
00107  501 0 0001                  SBA     1         Co(D+F**2) AT -2,                                 01020
00110  423 0 0262   1              STB     FEXY+12                                                     01030
00111  403 0 0256   1              LDB     FEXY+8    RESCALE F**2 AT 5,                                01040
00112  500 0 0055                  RBA     +45                                                         01050
00113  423 0 0256   1              STB     FEXY+8                                                      01060
00114  403 0 0236   1              LDB     FEXX+23   PICK UP B AT -2                                   01070
00115  105 0 0262   1              ALR     FEXY+12   B+Co(D+F**2) AT -2, (MS PART)                     01080
00116  120 0 0256   1              MPY     FEXY+8    F**2(B+Co(D+F**2) AT -20, (LS) (MS)               01090
00117  501 0 0001                  SBA     1                                                           01100
00120  423 0 0264   1              STB     FEXY+14                                                     01110
00121  401 0 0262   1              LDL     FEXY+12   PICK UP B+Co(D+F**2) AT -25, (LS PART)           01120
00122  120 0 0257   1              MPY     FEXY+9    F**2(B+Co(D+F**2) AT -20, (MS) (LS)               01130
00123  501 0 0001                  SBA     1                                                           01140
00124  104 0 0264   1              ADL     FEXY+14                                                     01150
```

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.XX = ±
.XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

DEL 1263-3A (2/66)

SIZE A | CODE IDENT NO. 49671 | 2186648 | SCALE | SHEET 14

```
00125  501 0 0026                SBA     +22         RESCALE AT 3.                          01160
00126  423 0 0264   1            STB     FEXY+14                                            01170
00127  401 0 0263   1            LDL     FEXY+13                                            01180
00130  120 0 0257   1            MPY     FEXY+9      F**2(B+C*(D+F**2)) AT 3 (NS) (NS)      01190
00131  104 0 0264   1            ADL     FEXY+14                                            01200
00132  104 0 0240   1            ADL     FEXX+25     P*A+F**2(B+C*(D+F**2)) AT 3.           01210
00133  114 0 0252   1            SUL     FEXY+4      P-F AT 3                               01220
00134  423 0 0260   1            STB     FEXY+10                                            01230
00135  403 0 0252   1            LDB     FEXY+4      2F AT 4.                               01240
00136  501 0 0002                SBA     2           2F AT 6.                               01250
00137  321 7 0267   1            TSP     DVD         2F*(P-F)SCALED AT 3.                   01260
00140   00 0 00260  2            **5     FEXY+10                                            01270
00141  100 0 0224   1            ADD     FEXX+13     1+2F*(P-F) SCALED AT 3.                01280
00142  500 0 0055                RBA     +45         E**R=1+2F*(P-F) SCALED AT 2.           01290
00143  423 0 0252   1            STB     FEXY+4                                             01300
00144  401 0 0246   1            LDL     FEXY        CHECK IF X WAS NEGATIVE. YES           01310
00145  352 0 0156   1            TRZ     FEXP        IF NON-ZERO.                           01320
00146  403 0 0223   1            LDB     FEXX+12     X WAS NEGATIVE. GET RECIPROCAL OF (**R.01330
00147  321 7 0267   1            TSP     DVD         GO TO DIVIDE SUBROUTINE                01340
00150   00 0 00252  2            **5     FEXY+4                                             01350
00151  421 0 0253   1            STL     FEXY+5      1**R AT 1.                             01360
00152  401 0 0255   1            LDL     FEXY+7      COMPLEMENT THE EXPONENT                01370
00153  160 0 0000                CML                                                        01380
00154  110 0 0244   1            SUB     FEXX+29  SUBTRACT ONE FROM THE EXPONENT TO ADJUST FOR 01390
00155  421 0 0255   1            STL     FEXY+7      SCALING DIFFERENCE.                    01400
00156  401 0 0253   1       FEXP LDL     FEXY+5      NORMALIZE E**R.                        01410
00157  520 0 0233   1            NRM     FEXX+20                                            01420
00160  501 0 0013                SBA     +11                                                01430
00161  421 0 0253   1            STL     FEXY+5                                             01440
00162  401 0 0255   1            LDL     FEXY+7      COMPUTE THE CHARACTERISTIC OF E**X.    01450
00163  110 0 0233   1            SUB     FEXX+20     ADJUST FOR NORMALIZING SHIFTS.         01460
00164  100 0 0243   1            ADD     FEXX+28     ADD BIAS PLUS 2 BECAUSE OF SCALING     01470
00165  515 0 0014                RLL     +12                                                01480
00166  140 0 0245   1            LAN     FEXX+30     PACK FLOATING POINT RESULT.            01490
00167  150 0 0253   1            LIB     FEXY+5                                             01500
00170  357 7 0000   1            TRA     FEX,7       NORMAL RETURN                          01510
00171  100 0 0216   1       FEX1 ADD     FEXX+7      BUILD A SHIFT INSTRUCTION WHICH        01520
00172  351 0 0176   1            TRN     FEX2        SHIFTS C PLACES.                       01530
00173  401 0 0214   1            LDL     FEXX+5      C IS LESS THAN 46.                     01540
00174  110 0 0251   1            SUB     FEXY+3      SHIFT COMMAND OF -C PLACES.            01550
00175  357 0 0177   1            TRA     FEX3                                               01560
00176  401 0 0242   1       FEX2 LDL     FEXX+27     GET SHIFT COMMAND OF 45 PLACES.        01570
00177  421 0 0205   1       FEX3 STL     FEX5                                               01580
00200  401 0 0215   1            LDL     FEXX+6      SET EXIT FOR NEGATIVE CHARACTERISTIC   01590
```

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XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE: A | CODE IDENT NO. 49671 | 2186648

SCALE

SHEET 15

DEL 1263-3A (2/60)

```
00201  421 0 0053   1              STL     FEXE        CASE.                                          01600
00202  357 0 0033   1              TRA     FEXD                                                       01610
00203  422 0 0255   1       FEX4   STR     FEXY+7      SET INTEGER PART OF N(1*LN2)=0.                01620
00204  403 0 0252   1              LDQ     FEXY+4                                                     01630
00205  501 0 0000           FEX5   SBA     **          SHIFT N (1*LN2) C PLACES RIGHT.                01640
00206  357 0 0061   1              TRA     FEXG                                                       01650
00207  04137400             FEXX   NUM     004137400   709,782712 IN FLOATING POINT.                  01660
00210  20125427                    NUM     020125427   709.78                                         01670
00211  37777777                    NUM     037777777   OVERFLOW CONDITION FLAG                        01680
00212  77770000                    NUM     077770000   MASK FOR CHARACTERISTIC.                       01690
00213  00002000                    NUM     000002000   1024 AT 23.                                    01700
00214  501 0 0000                  SBA     **          SBA COMMAND                                    01710
00215  357 0 0203   1              TRA     FEX4                                                       01720
00216  00000055                    NUM     055         45 AT 23.                                      01730
00217  501 0 0024                  SBA     *20         SBA COMMAND OF 20.                             01740
00220  00007777                    NUM     000007777   MASK FOR MANTISSA.                             01750
00221  31225603                    NUM     031225603   1*LN2 AT 2 (LS PART)                           01760
00222  13425216                    NUM     013425216   1*LN2=1,442,695,040,888,964                    01770
00223  00000000                    NUM     00          ZERO                                           01780
00224  04000000                    NUM     004000000   1 AT 3                                         01790
00225  37372163                    NUM     037372163   LN2 AT 0. (LS PART)                            01800
00226  26134413                    NUM     026134413   LN2=0,693,147,180,559,945                      01810
00227  31046637                    NUM     031046637   D AT 6. (LS PART)                              01820
00230  25003355                    NUM     025003355   D=42,013,532,895,041,661,680                   01830
00231  16223136                    NUM     016223136   C AT 3 (LS PART)                               01840
00232  23471522                    NUM     023471522   C=4,903,154,798,968,682,648                    01850
00233  00000000                    NUM     00          NUMBER OF SHIFTS TO NORMALIZE T.               01860
00234  00000000                    NUM     00          NUMBER OF SHIFTS TO NORMALIZE R.               01870
00235  501 0 0026                  SBA     *22                                                        01880
00236  36157050                    NUM     036157050   B AT -2                                        01890
00237  06312256                    NUM     006312256   B=0,049,962,489,136,450,760                    01900
00240  00000005                    NUM     000000005   A AT 3.                                        01910
00241  10000000                    NUM     010000000   A=2.000,000,000,000,575,924                    01920
00242  513 0 0057                  SBL     *47                                                        01930
00243  00002002                    NUM     02002       1026 AT 23.                                    01940
00244  00000001                    NUM     01          1 AT 23.                                       01950
00245  37770000                    NUM     037770000   MASK                                           01960
00246                      FEXY   BSS     *17         RESERVE BLOCK FOR TEMPORARY STORAGE            01970
                                  END                                                                01980

00267  ## 0 00000      DVD
```

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XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

DEL 1263-3A (2/66)

SIZE A | CODE IDENT NO. 49671 | 2186648

SCALE

SHEET 16

SECTION 17
FLOATING POINT TANGENT
OR (COTANGENT)

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR	USED ON
NEXT ASSY	110A

CONTRACT NO.
NAS 8-13007

DRAWN DATE
Tirai 31 AUG 65

CHECKED DATE
W. A. Lattiman 3 SEP 65

DESIGN ACTIVITY APPD REL
J. W. Vanderford 3 SEPT 65 (R)

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

SATURN GROUND COMPUTER SYSTEM MATHEMATICAL ROUTINE FLOATING POINT TANGENT OR (COTANGENT)

SIZE	CODE IDENT NO.	
A	49671	2186649

WEIGHT LB SHEET 1 OF 19

DEL 1263-1 (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186649-1	FLOATING POINT TANGENT	
								OR (COTANGENT)	
								SYMBOLIC CARD DECK	
				X	5		CDV86649	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								FLOATING POINT TANGENT	
								OR (COTANGENT)	

LTR

SIZE A | CODE IDENT NO. 49671 | 2186649

SHEET 2

RADIO CORPORATION OF AMERICA

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

FLOATING POINT TANGENT

OR (COTANGENT)

PREPARED UNDER CONTRACT NAS 8-13007
FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

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	SCALE		SHEET 3

TABLE OF CONTENTS

1.0 Identification

ID: FTN or (FCT)

2.0 Introduction

The purpose of the Floating Point Tangent or (Cotangent) program is to compute the floating point tangent or (cotangent) of a floating point radian argument, X.

The program conforms to the specifications of the Floating Point System 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86649. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

To evaluate tan X, the following procedure is followed:

$X\left(\frac{2}{\pi}\right) = 2I + K + Z$ where $|Z| < 0$

$|K| = 0$ or 1

I is an integer

for $|Z| < .5$, set $S = 0$ and $W = |Z|$

$|Z| \geq .5$, set $S = 1$ and $W = (1 - |Z|)$

for $X < 0$, $K = 1$ set $J = 1$

$X \geq 0$, $K = 0$ set $J = 1$

$X < 0$, $K = 0$ set $J = -1$

$X \geq 0$, $K = 1$ set $J = -1$

for $S = 1$, $K = 1$ or $S = 0$, $K = 0$

$\tan X = W/S\ (W^2)\ .\ J$

for $S = 1$, $K = 0$ or $S = 0$, $K = 1$

$\tan X = S(W^2)/W.J$

Where

$$S\ (W^2) = a + W^2 \left\{ b + \frac{c}{d + W^2 + \frac{e}{f + W^2}} \right\}$$

$a = 0.636619772367597$

$b = -0.07319486991705$

$c = 3.885605722768290$

$d = -14.870268625197861$

$e = -57.818691387368667$

$f = -9.32191895364603$

Cotangent is evaluated by the following relationship.

Cotangent X = 1/tangent X

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	SCALE		SHEET 6

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program and the associated subroutine (Section 7.0). The SLAP 2 Loader uses the object program card deck, a product of the SLAP 2 assembly, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

With the floating point radian argument, X, in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	FTN or (FCT) (see below)
a + 1	Return	

FTN - Symbolic entrance in the Floating Point Tangent subroutine

FCT - Symbolic entrance in the Floating Point Cotangent subroutine

5.0 Output Format

Error Return:

An error return is indicated by overflow 'ON'.

a. The $|X| > 2^{46}$ radians. The L register will be positive upon return.

b. If $|X| < 2^{-44}$ while attempting to evaluate cotan, an error return is given. The L register will be negative upon return.

c. If $|X| = N. \pi/2$, where N is odd, while evaluating tan X, an error return will be given. The L register will be negative upon return.

d. If $|X| = N. \pi/2$, where N is even, while evaluating cotan X, an error return will be given. The L register will be negative upon return.

Normal Return:

A normal return is indicated by overflow 'OFF'.

The tangent or (cotangent) of the argument X will be in the L and R registers upon return. The tangent or (cotangent) will be in normalized floating point format.

6.0 Memory Requirements

6.1 Program: see program listing

6.2 Temporary Space: 13 core memory locations

7.0 Restrictions

This program uses the following floating point subroutine:

Name	ID	Number
Double Precision Divide	DVD	2186650

8.0 Timing

Approximate timing: 41.2 milliseconds

9.0 Floating Point Tangent or (Cotangent) Card Deck

Symbolic source card deck for this program is 2186649-1.

10.0 Appendices

10.1 Flow Chart

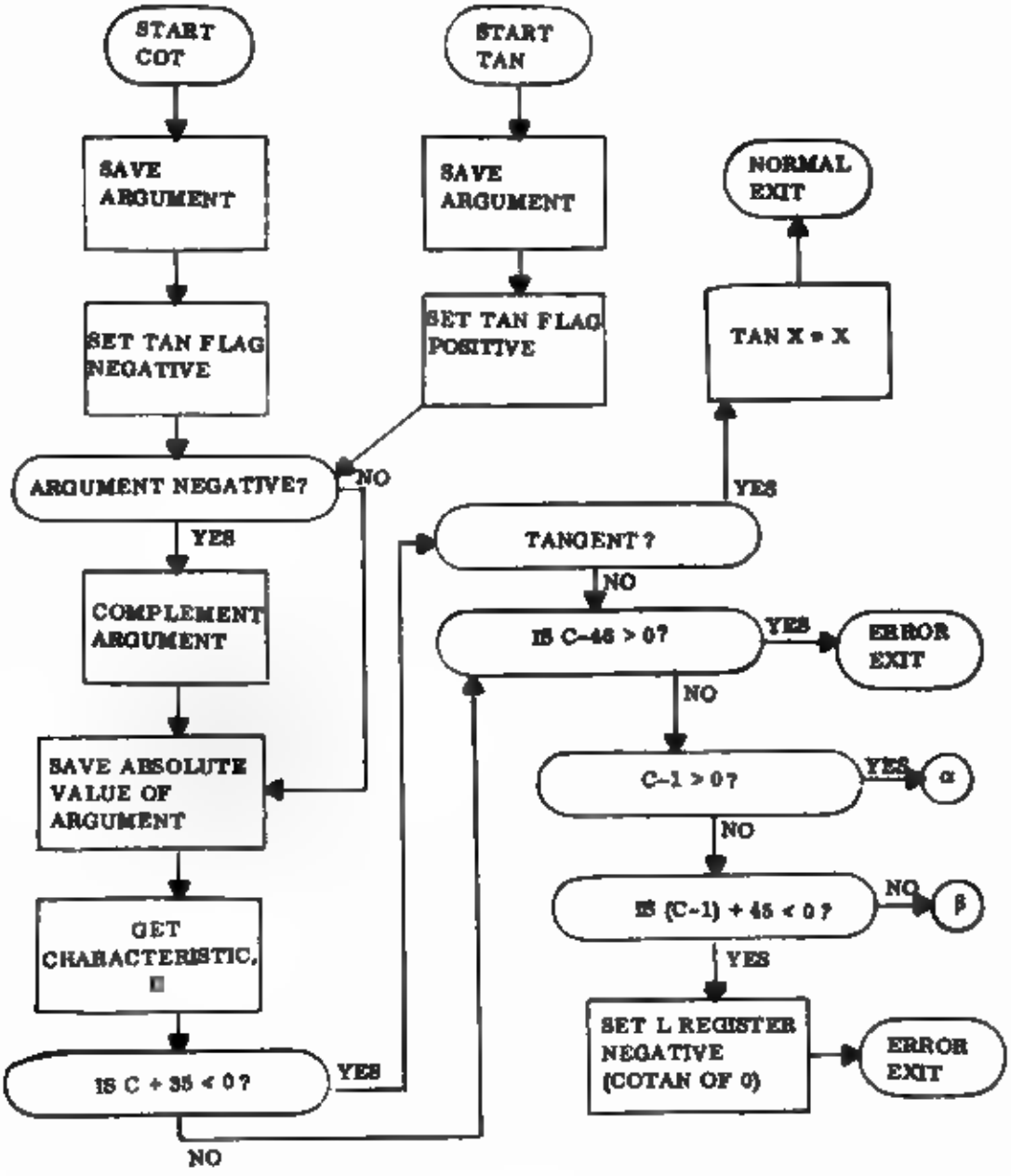
Flow chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

A listing of this program showing memory locations (relative to zero), octal representation and source card content (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A
SATURN GROUND COMPUTER SYSTEM
FLOATING POINT TANGENT OR (COTANGENT)
FLOW CHART



FPT/C1

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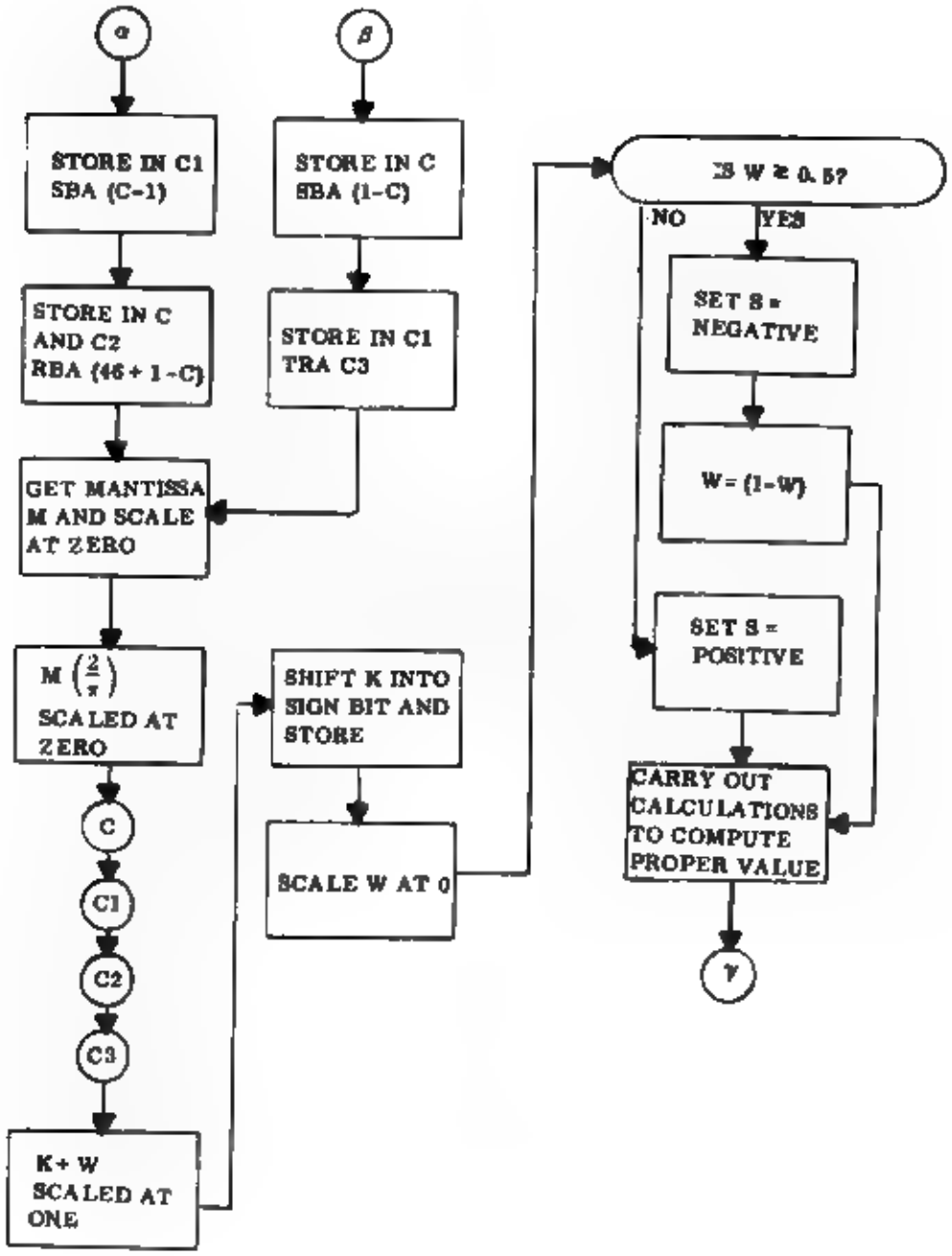
.XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	A	49671	
	SCALE		SHEET //

DEL 1263-3A (2/65)



FPT/C2

RADIO CORPORATION OF AMERICA

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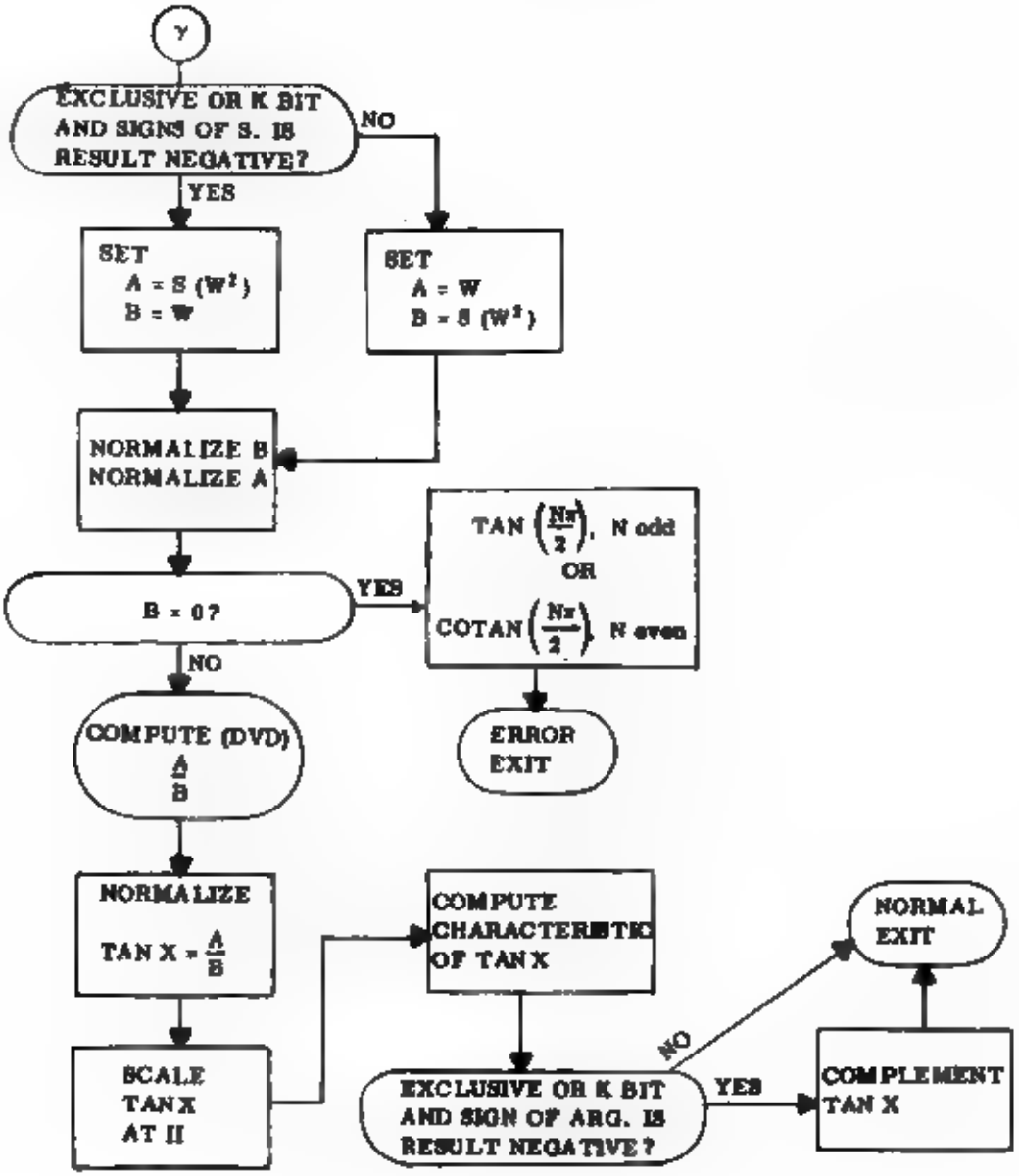
.XX = ± .XXX = ±	A	49671	2186649
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 12

DEL 1263-3A (2/65)



FPT/C3

RADIO CORPORATION OF AMERICA

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	SCALE		SHEET 13

DEL 1263-3A (2/65)

TABLE I
SATURN GROUND COMPUTER SYSTEM
FLOATING POINT TANGENT OR (COTANGENT)
PROGRAM LISTING

RADIO CORPORATION OF AMERICA

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	SCALE		SHEET 14

INST. LOC. OCTAL	MEMORY OCTAL	REL. TYPE			SYMBOLIC CARD CONTENT	CARD NO.
			*		FLOATING POINT TANGENT OR (COTANGENT)	00010
00000	■ 0 00000		SFCT	●+5	0	00310
00001	423 0 0305	1		STB	C0M	COTANGENT SUBROUTINE ENTRANCE.SAVE ARG.	00320
00002	401 0 0243	1		LDL	FTNX+1	SET TANGENT FLAG OFF.	00330
00003	421 0 0307	1		STL	C0M+2		00340
00004	401 0 0000	1		LDL	FCT		00350
00005	421 0 0010	1		STL	FTN		00360
00006	401 0 0306	1		LDL	C0M+1	RESTORE THE ARGUMENT TO THE R REGISTER	00370
00007	357 0 0013	1		TRA	FTNA	TRANSFER TO TANGENT SUBROUTINE	00380
00010	00 0 00000		SFTN	●+5	0	00390
00011	423 0 0305	1		STB	C0M	TANGENT SUBROUTINE ENTRANCE. SAVE ARG.	00400
00012	420 0 0307	1		STZ	C0M+2	SET TANGENT FLAG ON.	00410
00013	356 0 0015	1	FTNA	TPZ	●+2		00420
00014	161 0 0000			CMB		COMPLEMENT ARGUMENT IF NEGATIVE	00430
00015	423 0 0310	1		STB	C0M+3	STORE ABSOLUTE VALUE OF ARGUMENT	00440
00016	501 0 0014			SBA	+12	BIASED CHARACTERISTIC AT 23.	00450
00017	110 0 0244	1		SUB	FTNX+2	SUBTRACT 1024-35	00460
00020	356 0 0027	1		TPZ	FTNB+1	CHECK IF CHARACTERISTIC IS -35 OR LESS.	00470
00021	421 0 0312	1		STL	C0M+5	ARGUMENT TOO SMALL	00480
00022	401 0 0307	1		LDL	C0M+2	CHECK IF ■IS IS TANGENT CASE.	00490
00023	351 0 0026	1		TRN	FTNB	TRANSFER IF COTANGENT.	00500
00024	403 0 0305	1		LDQ	C0M	TANGENT CASE.	00510
00025	357 0 0240	1		TRA	FTNM	EXIT WITH TAN X●X. NORMAL RETURN	00520
00026	401 0 0312	1	FTNB	LDL	C0M+5	RESTORE THE CHARACTERISTIC PLUS 35.	00530
00027	110 0 0245	1		SUB	FTNX+3	SUBTRACT 46 FROM CHARACTERISTIC	00540
00030	353 0 0033	1		TNZ	●+3	ERROR IF CHARACTERISTIC GREATER THAN 46.	00550
						ERROR RETURN	00560
00031	102 0 0304	1		ADD1	FTNY		00570
00032	357 7 0010	1		TRA	FTN,7		00580
00033	100 0 0246	1		ADD	FTNX+4	COMPUTE CHARACTERISTIC LESS 1.	00590
00034	354 0 0050	1		TRP	FTND	CHECK IF C-1 IS GREATER THAN ZERO	00600
00035	100 0 0246	1		ADD	FTNX+4	ADD 45	00610
00036	356 0 0041	1		TPZ	●+3	CHECK IF (C-1) IS LESS THAN -45. ERROR RETURN	00620
00037	102 0 0243	1		ADD1	FTNX+1		00630
00040	357 7 0010	1		TRA	FTN,7		00640
00041	110 0 0246	1		SUB	FTNX+4		00650
00042	160 0 0000			CML		COMPLEMENT (C-1)..	00660
00043	150 0 0247	1		LIB	FTNX+5		00670
00044	421 0 0075	1		STL	FTNC	SET SBA SHIFT COUNT	00680
00045	401 0 0250	1		LDL	FTNX+6	SET TRA C3 AT C1	00690
00046	421 0 0076	1		STL	FTNC+1		00700
00047	357 0 0057	1		TRA	FTNF		00710

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XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186649

SCALE

SHEET 15

DEL 1263-3A (2/66)

```
00050  150 0 0247   1        FTND    LJ0     FTNX+5          SET SBA SHIFT C0UNT                             00720
00051  421 0 0076   1                STL     FTNC+1                                                          00730
00052  160 0 0000                    CML                     C0MPLEMENT (C-1)                                00740
00053  100 0 0251   1                ADD     FTNX+7          BUILD R0A 46-(C-1) C0MMAND                      00750
00054  430 0 0077   1                STA     FTNC+2                                                          00760
00055  401 0 0077   1                LDL     FTNC+2          ST0RE R0A IN C                                  00770
00056  421 0 0075   1                STL     FTNC            ST0RE R0A IN C2                                 00780
00057  403 0 0310   1        FTNF    LD0     C0M+3           GET THE MANTISSA SCALED AT 0.                   00790
00060  140 0 0253   1                LAN     FTNX+9                                                          00800
00061  500 0 0043                    R0A     +35                                                             00810
00062  423 0 0310   1                ST0     C0M+3                                                           00820
00063  120 0 0254   1                MPY     FTNX+10         M(2**P) SCALED AT -23. (MS) (LS)                00830
00064  501 0 0027                    SBA     +23                                                             00840
00065  423 0 0312   1                ST0     C0M+5                                                           00850
00066  401 0 0310   1                LDL     C0M+3           LS PART 0F M                                    00860
00067  120 0 0255   1                MPY     FTNX+11         M (2**P) SCALED AT -23. (LS) (MS)               00870
00070  501 0 0027                    SBA     +23                                                             00880
00071  105 0 0312   1                ALR     C0M+5                                                           00890
00072  401 0 0311   1                LDL     C0M+4           MS PART 00 M.                                   00900
00073  120 0 0255   1                MPY     FTNX+11         M(2**P) SCALED AT 0                             00910
00074  104 0 0312   1                ADL     C0M+5           FULL PR0DUCT 00 M(2**P) AT 0                    00920
00075  350 0 0000            FTNC    N0P     **                                                              00930
00076  350 0 0000                    N0P     **                                                              00940
00077  500 0 0000                    R0A     **              K + W SCALED AT 1                               00950
00100  421 0 0314   1                STL     C0M+7           SAVE K BIT IN BIT P0SITI0N 22                   00960
00101  140 0 0252   1                LAN     FTNX+8          REM0VE K BIT                                    00970
00102  500 0 0055                    R0A     +45             W SCALED AT 0                                   00980
00103  423 0 0312   1                ST0     C0M+5           W                                               00990
00104  403 0 0256   1                LD0     FTNX+12                                                         01000
00105  114 0 0312   1                SUL     C0M+5           (.5-W)                                          01010
00106  421 0 0305   1                STL     C0M             SET THE S INDICAT0R                             01020
00107  356 0 0112   1                TPZ     **+3            CHECK IF (.5-W) IS NEGATIVE                     01030
00110  104 0 0256   1                ADL     FTNX+12         W=(1-W) SCALED AT 0                             01040
00111  423 0 0312   1                ST0     C0M+5                                                           01050
00112  403 0 0312   1                LD0     C0M+5           W SCALED AT 0                                   01060
00113  120 0 0312   1                MPY     C0M+5           W**2 SCALED AT -23 (MS) (LS)                    01070
00114  501 0 0026                    SBA     +22                                                             01080
00115  423 0 0310   1                ST0     C0M+3                                                           01090
00116  401 0 0313   1                LDL     C0M+6           W SCALED AT 0 (MS) PART                         01100
00117  120 0 0313   1                MPY     C0M+6           W**2 SCALED AT 0                                01110
00120  105 0 0310   1                ALR     C0M+3           W**2 AT 0. FULL PR0DUCT                         01120
00121  501 0 0003                    SBA     3               W**2 AT 3.                                      01130
00122  423 0 0320   1                ST0     C0M+11                                                          01140
00123  501 0 0001                    SBA     1               W**2 AT 4                                       01150
```

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XX = ±
FRACTIONS = ±
ANGLES = ±1/2°
XXX = ±

SIZE A | CODE IDENT NO. 49671 | 2186649 | SCALE | SHEET 16

DEL 1263-3A (2/60)

```
00124  104 0 0260   1                ADL     FTNX+14         F+W**2 AT 4                                     01160
00125  423 0 0315   1                STB     C@M+8                                                           01170
00126  403 0 0262   1                LDB     FTNX+16         E AT 7                                          01180
00127  321 7 0322   1                TSP     DVD             TRANSFER T@ DIVIDE SUBR@UTINE                   01190
00130  00 0 00315   2                **5     C@M+8           GET E (F+W**2)                                  01200
00131  104 0 0320   1                ADL     C@M+11          W**2+E@(F+W**2) AT 3                            01210
00132  501 0 0001                    SBA     1                                                               01220
00133  104 0 0264   1                ADL     FTNX+18         D+W**2+E(F+W**2) AT 4                           01230
00134  423 0 0315   1                STB     C@M+8                                                           01240
00135  403 0 0266   1                LDB     FTNX+20         C AT 4                                          01250
00136  321 7 0322   1                TSP     DVD             TRANSFER T@ DIVIDE SUBR@UTINE                   01260
00137  00 0 00315   2                **5     C@M+8           C@MPUTE C@(D+W**2+E@(F+W**2))                   01270
00140  104 0 0270   1                ADL     FTNX+22         B+C@(D+W**2+E(F+W**2)) AT 0                     01280
00141  356 0 0143   1                TPZ     *+2             MAKE L-REGISTER 2-C@MPLEMENT.                   01290
00142  100 0 0303   1                ADD     FTNX+33                                                         01300
00143  423 0 0315   1                STB     C@M+8           C@MPUTE THE F@LL@W!NG                           01310
00144  120 0 0310   1                MPY     C@M+3           W**2(B+C@(D+W**2+E@(F+W**2)) AT 0                01320
00145  501 0 0027                    SBA     +23                                                             01330
00146  423 0 0320   1                STB     C@M+11          ST@RE THE PARTIAL PR@DUCT (LS) (MS)             01340
00147  401 0 0315   1                LDL     C@M+8                                                           01350
00150  120 0 0311   1                MPY     C@M+4                                                           01360
00151  501 0 0027                    SBA     +23                                                             01370
00152  105 0 0320   1                ALR     C@M+11    ST@RE THE PARTIAL PR@DUCT (LS) (MS)+(MS) (LS)        01380
00153  401 0 0316   1                LDL     C@M+9                                                           01390
00154  120 0 0311   1                MPY     C@M+4           THE MS PART @F PR@DUCT.                         01400
00155  104 0 0320   1                ADL     C@M+11          W**2(B+C@(D+W**2+E@(F+W**2))                    01410
00156  104 0 0272   1                ADL     FTNX+24         ADD A. THIS IS S(W**2) SCALED AT 0.             01420
00157  423 0 0320   1                STB     C@M+11          ST@RE S (W**2) AT 0.                            01430
00160  401 0 0314   1                LDL     C@M+7                                                           01440
00161  515 0 0027                    RLL     +23             L@GICALLY ADD THE K BIT, THE S IND.,            01450
00162  170 0 0305   1                LE@     C@M             AND THE TANGENT INDICAT@R.                      01460
00163  170 0 0307   1                LE@     C@M+2                                                           01470
00164  356 0 0171   1                TPZ     FTN@                                                            01480
00165  403 0 0320   1                LDB     C@M+11          SET A EQUAL T@ S (W**2) SCALED AT 0             01490
00166  423 0 0315   1                STB     C@M+8                                                           01500
00167  403 0 0312   1                LDB     C@M+5           SET B EQUAL T@ W SCALED AT 0                    01510
00170  357 0 0174   1                TRA     FTNH                                                            01520
00171  403 0 0312   1        FTNG    LDB     C@M+5           SET A EQUAL T@ W SCALED AT 0                    01530
00172  423 0 0315   1                STB     C@M+8                                                           01540
00173  403 0 0320   1                LDB     C@M+11          SET B EQUAL T@ S(W**2) AT 0.                    01550
00174  520 0 0274   1        FTNH    NRM     FTNX+26         N@RMALIZE B. N IS NUMBER @F SHIFTS              01560
00175  520 0 0275   1                NRM     FTNX+27         T@ N@RMALIZE                                    01570
00176  355 0 0202   1                TPN     FTNJ                                                            01580
00177  401 0 0243   1                LDL     FTNX+1          B EQUALS ZER@. ERR@R. SET REGISTER MINUS        01590
```

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XX = ± FRACTIONS = ± ANGLES = ±1/2°
XXX = ±

SIZE A | CODE IDENT NO. 49671 | 2186949

SCALE | SHEET 17

DEL 1263-3A (2/69)

```
00200  102 0 0243   1            ADDI   FTNX+1                                  01600
00201  357 7 0010   1            TRA    FTN,7          ERROR RETURN             01610
00202  423 0 0320   1      FTNJ  STB    COM+11                                  01620
00203  403 0 0315   1            LDB    COM+8          PICK UP A                01630
00204  520 0 0276   1            NRM    FTNX+28        NORMALIZE A, L IS NUMBER OF SHIFTS  01640
00205  520 0 0277   1            NRM    FTNX+29        TO NORMALIZE             01650
00206  501 0 0001                SBA    1                                       01660
00207  321 7 0322   1            TSP    DVD            TRANSFER TO DIVIDE.      01670
00210  00 0 00320   2            **5    COM+11                                  01680
00211  520 0 0300   1            NRM    FTNX+30        NORMALIZE AoB, M IS NUMBER  01690
00212  520 0 0301   1            NRM    FTNX+31        OF SHIFTS TO NORMALIZE.  01700
00213  352 0 0227   1            TRZ    FTNK                                    01710
00214  501 0 0013                SBA    +11                                     01720
00215  421 0 0320   1            STL    COM+11                                  01730
00216  401 0 0302   1            LDL    FTNX+32        COMPUTE THE CHARACTERISTIC  01740
00217  110 0 0276   1            SUB    FTNX+28        1025-6                   01750
00220  110 0 0277   1            SUB    FTNX+29                                 01760
00221  110 0 0300   1            SUB    FTNX+30        1025-L-M                 01770
00222  110 0 0301   1            SUB    FTNX+31                                 01780
00223  100 0 0274   1            ADD    FTNX+26        1025-L-M+N               01790
00224  100 0 0275   1            ADD    FTNX+27        BIASED CHARACTERISTIC    01800
00225  515 0 0014                RLL    +12            SCALE CHARACTERISTIC AT 11  01810
00226  150 0 0320   1            LIB    COM+11                                  01820
00227  421 0 0320   1      FTNK  STL    COM+11         MERGE TOGETHER THE CHARACTERISTICS AND  01830
                                                       MANTISSA                 01840
00230  401 0 0314   1            LDL    COM+7          LOGICALLY EXCLUSIVE OR THE  01850
00231  515 0 0027                RLL    +23            K BIT AND THE SIGN OF ARGUMENT.  01860
00232  170 0 0306   1            LEB    COM+1          THIS DETERMINES SIGN OF ARG.  01870
00233  351 0 0236   1            TRN    *+3            COMPLEMENT TAN X IF NEGATIVE  01880
00234  401 0 0320   1            LDL    COM+11         PICK UP TAN X.           01890
00235  357 0 0240   1            TRA    FTNM           NORMAL RETURN            01900
00236  401 0 0320   1            LDL    COM+11         PICK UP TAN X            01910
00237  161 0 0000                CNB                   COMPLEMENT TAN X         01920
00240  250 00241    2      FTNM  JOF    *+1                                     01930
00241  357 7 0010   1            TRA    FTN,7          NORMAL RETURN            01940
00242  00002056           FTNX  NUM    02056          1070 AT 23               01950
00243  40000000                 NUM    040000000      MINUS NUMBER             01960
00244  00001735                 NUM    01735          989 AT 23                01970
00245  00000121                 NUM    0121           81 AT 23                 01980
00246  00000055                 NUM    055            45 AT 23                 01990
00247  501 0 0000                SBA    **             CONSTANT                 02000
00250  357 0 0100   1            TRA    FTNC+3         CONSTANT                 02010
00251  00000056                 NUM    056            46 AT 23                 02020
00252  57777777                 NUM    057777777      REMOVE BIT 22            02030
```

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XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186649

SCALE

SHEET 18

DEL 1263-3A (2/66)

```
00293  00007777                        NUM     000007777       MASK FOR MANTISSA                       02040
00294  26711620                        NUM     026711620       2oPI SCALED AT 0. LS PART.              02050
00295  24276301                        NUM     024276301       2oPI=0.636,619,772,367,281,4            02060
00296  00000000                        NUM     00              .5 AT 0. (ZERO)                         02070
00297  20000000                        NUM     020000000       .5 AT 0.                                02080
00260  70134203                        NUM     070134203       F AT 4. LS PART                         02090
00261  55266265                        NUM     055266265       F AT 4.=-9,+32,918,953,646.03           02100
00262  44560336                        NUM     044560336       E AT 7. LS PART                         02110
00263  61427152                        NUM     061427152       E AT 7. = -57,818,691,387,368,867       02120
00264  63230051                        NUM     063230051       D AT 4. LS PART                         02130
00265  42204660                        NUM     042204660       D AT 4.=-14,870,268,625,197,861         02140
00266  16400703                        NUM     016400703       C AT 4. LS PART                         02150
00267  07612670                        NUM     007612670       C AT 4. =3,705,334,164,007,026          02160
00270  53123640                        NUM     053123640       B AT 0. LS PART                         02170
00271  75455756                        NUM     075455756       B AT 0. =-0.075,319,486,991,705         02180
00272  26711622                        NUM     026711622       A SCALED AT 0. LS PART                  02190
00273  24276301                        NUM     024276301       A AT 0 = 0.636,619,772,367,597          02200
00274  00000000                        NUM     00              SHIFTS TO NORMALIZE B.                  02210
00275  00000000                        NUM     00              SHIFTS TO NORMALIZE B.                  02220
00276  00000000                        NUM     00              SHIFTS TO NORMALIZE A                   02230
00277  00000000                        NUM     00              SHIFTS TO NORMALIZE A                   02240
00300  00000000                        NUM     00              SHIFTS TO NORMALIZE AoB                 02250
00301  00000000                        NUM     00              SHIFTS TO NORMALIZE AoB                 02260
00302  00002001                        NUM     02001           1025 AT 23.                             02270
00303  00000001                        NUM     01                                                      02280
00304  37777777                FTNY    NUM     037777777                                               02290
00305                          COM     BSS     13                                                      02300
                                       END                                                             02310

00322  00 0 00000      DVD
```

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XX = ±
XXX = ±
FRACTIONS = ±
ANGLES = ±1/2°

DEL 1263-3A (2/60)

SIZE	CODE IDENT NO.	
A	49671	2/86649
SCALE		SHEET 19

SECTION 18
DOUBLE PRECISION DIVIDE

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIRST MADE FOR | USED ON 110A | NEXT ASSY

CONTRACT NO.
NAS 8-13007

RADIO CORPORATION OF AMERICA
NEW YORK, NY — VAN NUYS PLANT

DRAWN E. M. Stanger DATE 3 SEP 65

CHECKED W. A. Peterman DATE 8 SEP 65

DESIGN ACTIVITY APPD J. W. Vanderpool 8 SEPT 65 REL

SATURN GROUND COMPUTER SYSTEM
MATHEMATICAL ROUTINE
DOUBLE PRECISION DIVIDE

SIZE A | CODE IDENT NO. 49671 | 2186650

WEIGHT LB | SHEET 1 OF 13

DEL 1263-1A (2-65)

LIST OF MATERIALS OR PARTS LIST

QTY REQD 505	504	503	502	501	ITEM NO.	CODE IDENT	PART OR IDENTIFYING NO.	* VENDOR ITEM — SEE SOURCE CONTROL OR SPEC CONTROL DWG NOMENCLATURE OR DESCRIPTION	SPECIFICATION
				X	1		2186653	SATURN GROUND COMPUTER SYSTEM	
								SPECIFICATION FOR SATURN V	
								COMPUTER PROGRAM	
				X	2		2186654	SATURN GROUND COMPUTER SYSTEM	
								MATHEMATICAL ROUTINE	
								FLOATING POINT SYSTEM	
				X	3		2186651	SATURN GROUND COMPUTER SYSTEM	
								SLAP-2 SYSTEM	
				1	4		2186650-1	DOUBLE PRECISION DIVIDE	
								SYMBOLIC CARD DECK	
				X	5		CDV 86650	CEI DETAIL SPECIFICATION	
								MATHEMATICAL ROUTINE	
								DOUBLE PRECISION DIVIDE	

LTR

RADIO CORPORATION OF AMERICA

SIZE	CODE IDENT NO.	
A	49671	2186650

SHEET 2

DEL 1263—2A

SATURN GROUND COMPUTER SYSTEM

MATHEMATICAL ROUTINE

DOUBLE PRECISION DIVIDE

Prepared Under Contract NAS 8-13007
for
National Aeronautics and Space Administration
Marshall Space Flight Center
Huntsville, Alabama

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	
.XX = ± .XXX = ±	A	49671	2186650
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 3

TABLE OF CONTENTS

1.0 Identification

ID: DVD

2.0 Introduction

The purpose of the Double Precision Divide program is to compute the double quotient of the double precision dividend R and the double precision divisor S.

The program conforms to the specifications of the Floating Point System 2186654.

This mathematical routine has been prepared to fulfill the requirements of Specification Number CDV 86650. This drawing, together with the reference documents, describes the procedures for preparing program card decks and the method of utilizing same.

The program flow chart shown in Appendix A describes the logic used to develop the program.

3.0 Mathematical Method

For ease of notation, let M designate the most significant part and L the least significant part of the divisor S.

$$\frac{R}{S} \approx \frac{R}{M}\left[1 - \left(\frac{L}{M}\right) + \left(\frac{L}{M}\right)^2\right]$$

4.0 Program Operation

4.1 Program Assembly and Loader

This program is assembled by the SLAP 2 System (2186651) using the symbolic card deck for this program. The SLAP 2 Loader uses the object program card deck, a product of the SLAP II Assembly, to load the program into core memory.

4.2 Program Control

This program is used as a subroutine by a control program.

4.2.1 Control Program

With the dividend R in the left (L) and right (R) accumulators,

Location	Operation	Address
a	TSP	DVD (see below)
a + 1	**5	M,T (see below)
a + 2	Return	

DVD - symbolic entrance in the Double Precision Divide

M is the double precision divisor S

T ($0 \leq T \leq 6$) is the index tag modifying M

5.0 Output Format

Error Return:

An error return is indicated by overflow 'ON'.

The dividend is larger than, or equal to the divisor. The difference, (S - R), is the L and R registers upon return.

Normal Return:

A normal return is indicated by overflow 'OFF'.

The quotient, (R ÷ S), is in the L and R registers upon return. The quotient is scaled at (J - K) where J is the original scaling of the dividend and K is the original scaling of the divisor.

6.0 Memory Requirements

6.1 Program: see program listing

6.2 Temporary space: none

7.0 Restrictions

The absolute value of the dividend must be smaller than that of the divisor.

8.0 Timing

Approximate Timing: 7.9 milliseconds

9.0 Double Precision Divide Card Deck

Symbolic source card deck for this program is 2186650-1

10.0 Appendices

10.1 Flow Chart

Flow chart for this program is in Appendix A.

11.0 Tables

11.1 Program Listing

A listing of this program showing memory locations (relative to zero), octal representation and source card content (in symbolic language format) for each memory location used by the program is in Table 1.

APPENDIX A

SATURN GROUND COMPUTER SYSTEM

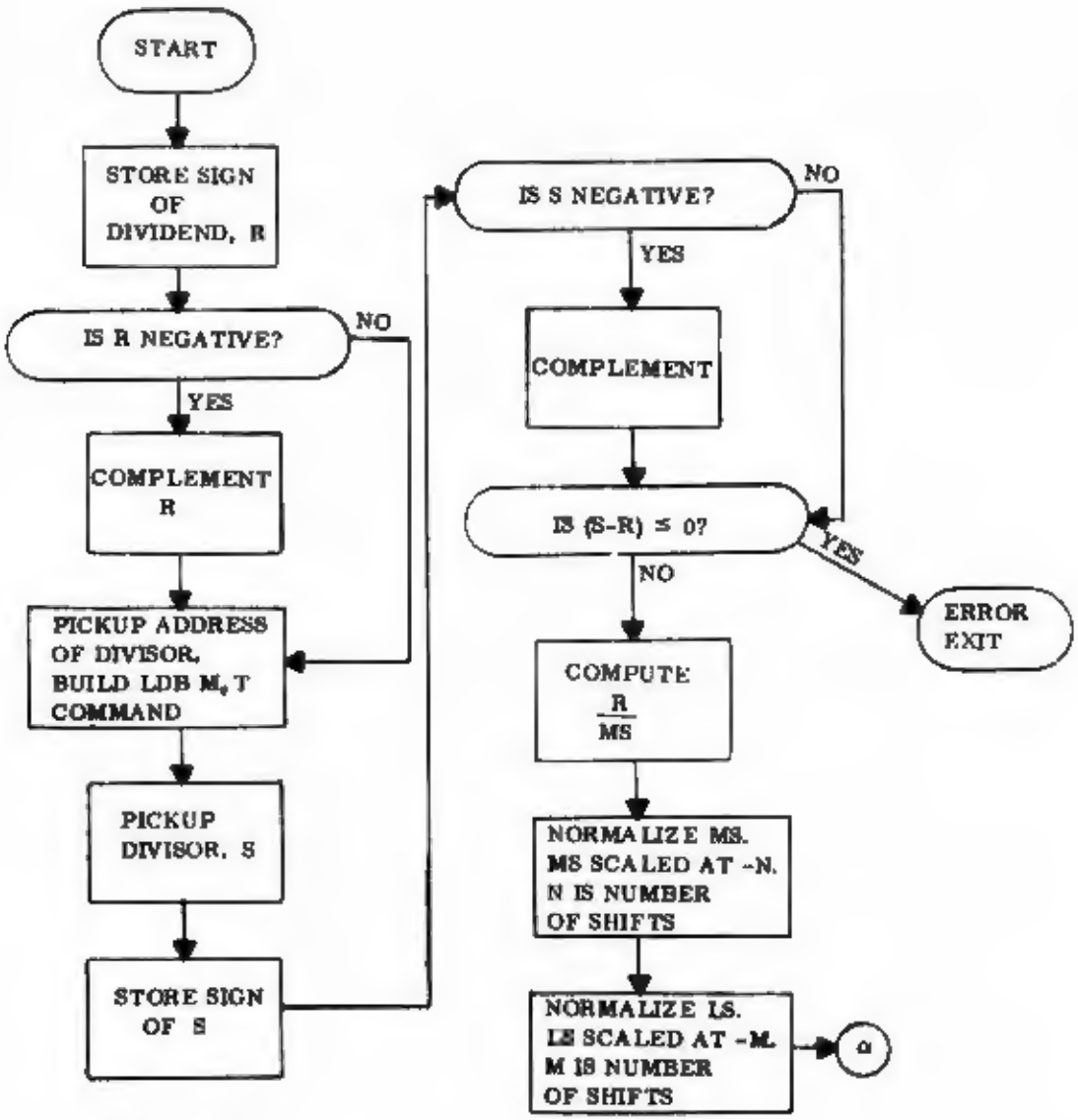
DOUBLE PRECISION DIVIDE

FLOW CHART

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186650
	SCALE		SHEET 8

DEL 1263-3A (2/65)



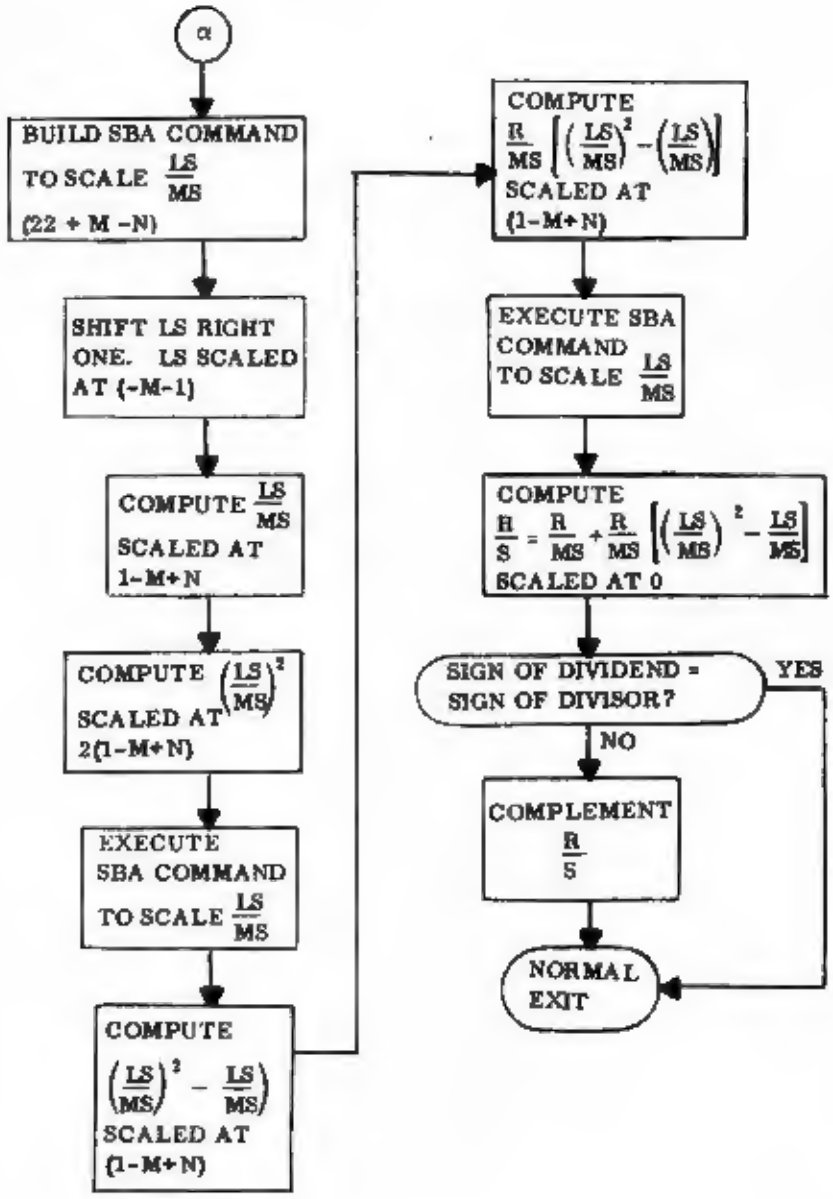
N. B:
Let MS denote most significant part of S; LS, least significant part.

DPD1

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186650
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET 9

DEL 1263-3 (2/65)



DPD2

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE: .XX = ± .XXX = ± FRACTIONS = ± ANGLES = ± 1/2°	SIZE A	CODE IDENT NO. 49671	2186650
	SCALE		SHEET 10

TABLE 1

SATURN GROUND COMPUTER SYSTEM

DOUBLE PRECISION DIVIDE

PROGRAM LISTING

RADIO CORPORATION OF AMERICA

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:	SIZE	CODE IDENT NO.	2186650
.XX = ± .XXX = ±	A	49671	
FRACTIONS = ± ANGLES = ± 1/2°	SCALE		SHEET //

DEL 1263-3A (2/65)

INST. LOC. OCTAL	MEMORY OCTAL	REL TYPE		SYMBOLIC CARD CONTENT		CARD NO.
			*	FLOATING POINT DIVIDE DOUBLE PRECISION		00010
00000	00 7 00000		$DVD	*+5	0,7	00310
00001	421 0 0071	1		STL	DVDX	STORE THE SIGN OF DIVIDEND 00320
00002	356 0 0004	1		TPZ	*+2	00330
00003	161 0 0000			CMB		COMPLEMENT THE DIVIDEND IF NEGATIVE 00340
00004	423 0 0072	1		STB	DVDX+1	STORE ABSOLUTE VALUE OF DIVIDEND, A 00350
00005	401 0 0000	1		LDL	DVD	00360
00006	100 0 0103	1		ADD	DVDX+10	00370
00007	431 0 0065	1		STE	DVDD	00380
00010	403 7 0000	1		LDB	DVD,7	LOAD THE DIVISOR 00390
00011	421 0 0074	1		STL	DVDX+3	STORE THE SIGN OF THE DIVISOR 00400
00012	356 0 0014	1		TPZ	*+2	COMPLEMENT THE DIVISOR IF NEGATIVE 00410
00013	161 0 0000			CMB		00420
00014	423 0 0075	1		STB	DVDX+4	STORE THE ABSOLUTE VALUE OF THE DIVISOR 00430
00015	114 0 0072	1		SUL	DVDX+1	CHECK IF DIVIDEND IS LARGER THAN DIVISOR 00440
00016	354 0 0022	1		TRP	*+4	DIVIDEND TOO LARGE, ERROR RETURN. 00450
00017	401 0 0017	1		LDL	*	00460
00020	102 0 0017	1		ADDI	*-1	SET OVERFLOW 00470
00021	257 00065	2		JMA	DVDD	00480
00022	403 0 0072	1		LDB	DVDX+1	COMPUTE R+MS 00490
00023	130 0 0076	1		DVD	DVDX+5	00500
00024	421 0 0073	1		STL	DVDX+2	STORE R+MS, THE MOST SIGNIFICANT. 00510
00025	400 0 0000			LDZ		00520
00026	500 0 0027			RBA	+23	00530
00027	130 0 0076	1		DVD	DVDX+5	00540
00030	421 0 0072	1		STL	DVDX+1	STORE R+MS, THE LEAST SIGNIFICANT. 00550
00031	402 0 0077	1		LDA	DVDX+6	PLACE ZERO IN THE R-REGISTER 00560
00032	401 0 0076	1		LDL	DVDX+5	NORMALIZE THE MOST SIGNIFICANT PART 00570
00033	520 0 0100	1		NRM	DVDX+7	OF THE DIVISOR. N IS NUMBER OF SHIFTS. 00580
00034	421 0 0076	1		STL	DVDX+5	00590
00035	401 0 0075	1		LDL	DVDX+4	NORMALIZE THE LEAST SIGNIFICANT PART OF 00600
00036	520 0 0101	1		NRM	DVDX+8	THE DIVISOR. M EQUALS NUMBER OF SHIFTS. 00610
00037	421 0 0075	1		STL	DVDX+4	00620
00040	401 0 0102	1		LDL	DVDX+9	BUILD SBA INSTRUCTION TO PROPERLY 00630
00041	100 0 0101	1		ADD	DVDX+8	SCALE LS+MS. 00640
00042	110 0 0100	1		SUB	DVDX+7	00650
00043	421 0 0052	1		STL	DVDA	SBA (22+7-N) 00660
00044	421 0 0057	1		STL	DVDB	00670
00045	401 0 0075	1		LDL	DVDX+4	PICK UP LEAST SIGNIFICANT PART OF S, LS, 00680
00046	501 0 0001			SBA	1	00690
00047	130 0 0076	1		DVD	DVDX+5	DIVIDE BY MOST SIGNIFICANT PART OF S,MS. 00700
00050	421 0 0076	1		STL	DVDX+5	LS+MS SCALED AT 1-M+N. 00710

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES AND INCLUDE THICKNESS OF PLATING. TOLERANCES ARE:
XX = ±
FRACTIONS = ±
XXX = ±
ANGLES = ±1/2°

SIZE A | CODE IDENT NO. 49671 | 2186650

SCALE | SHEET 12

DEL 1263-3A (2/65)