(12)

A LEAST SQUARES
INTERPOLATION SCHEME
FOR CRYOGENIC THERMOMETERS
USING A HAND-HELD
PROGRAMMABLE CALCULATOR

See 1473 on back page

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19 SEPTEMBER 1979

APPROVED FOR PUBLIC RELEASE
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New 411470

INTRODUCTION

The following is a description of a program for a hand-held programmable calculator which, in effect, interpolates values of temperature from the calibration table of a silicon diode thermometer over a full 4 to 300K temperature range. When making temperature measurements in the laboratory, the voltage across a forward biased calibrated diode is read from a digital voltmeter. With this program, the voltage reading is keyed into the calculator and the interpolated temperature is calculated quickly and accurately. The computational technique presented here is superior to techniques generally used since the data reduction scheme allows more information to be stored, allows for a simple calculator routine resulting in very short computation times and results in an interpolation having the accuracy of the original data table. The scheme is perfectly general and can be used to interpolate any data table.

GENERAL SCHEME

A common recurring problem in laboratory work is the necessity of interpolation from a table of values. An example is interpolation from a calibration table furnished with a cryogenic silicon diode thermometer where pairs of temperature and voltage values are given.[1] During an experiment, the diode voltage is read from a digital voltmeter, then the corresponding temperature value must be interpolated from the calibration table. It would be very convenient to be able to make this interpolation quickly and with a high degree of accuracy while the experiment is in progress. A hand-held programmable calculator, in our case a Texas Instruments TI-59, can be used to accomplish this.

Before this is done, a number of problems must be overcome. The calibration table supplied with a diode typically may have 90 or more pairs of temperature and voltage values. This would exceed the maximum available memory capacity of the calculator which is about 100 locations. Interpolation can be accomplished by the evaluation of a least square fit polynomial, however the calculator is too slow to do other than the simplest fitting routines in a short period of time. An attempt to fit a polynomial equation to the entire 4 to 300K calibration using a large computer did not result in the desired accuracy. The following procedure was subsequently devised.

The values from the calibration table were divided into overlapping temperature intervals. Then for each interval, a least square polynomial fit was made using a Forsythe fitting method[2] programmed on an IBM 370 computer. Any least square polynomial fit with sufficient accuracy is adequate. The least square polynomial fit program gives an rms error for each polynomial. The temperature intervals were adjusted by trial and error in order to obtain a satisfactory rms error over the full 4 to 300K span. In the case considered here, it was found that 12 polynomials each of 4th order were needed and that the length of the temperature intervals varied over the calibration range. All intervals have a one point overlap with the adjoining intervals. Using the coefficients found to 16 place precision by the IBM 370 computer, the rms error, σ_{370}, of each polynomial fit is given in Table I. The accuracy obtained preserves the accuracy of the calibration table. The full calibration table was thus reduced to 12 sets of polynomial coefficients, a_0, a_1, a_2, a_3, a_4, which could all be stored in the calculator. A relatively simple program could then be used to calculate any temperature, T, between 4 and 300K by evaluating

$T = a_4 V^4 + a_3 V^3 + a_2 V^2 + a_1 V + a_0$, where V is the voltage reading across the silicon diode thermometer. Both the coefficients and the calculator program are stored on magnetic cards and a set of magnetic cards can be used to store the coefficients for several different calibrated temperature sensors.

Table I. The temperature intervals and the corresponding rms errors of the 4th order polynomial fit using coefficients having 16 digit precision on an IBM 370, σ_{370}, and coefficients having 10 digit precision on a TI-59, σ_{59}.

Polynomial #	Temp. Interval (K)	σ_{370} (K°)	σ_{59} (K°)
1	4 - 6.5	1×10^{-3}	1×10^{-3}
2	6.5 - 9.5	2×10^{-3}	2×10^{-3}
3	9.5 - 13	9×10^{-12}	3×10^{-5}
4	13 - 17	6×10^{-12}	1×10^{-5}
5	17 - 21	4×10^{-12}	2×10^{-6}
6	21 - 25	6×10^{-12}	1×10^{-4}
7	25 - 32	7×10^{-3}	7×10^{-3}
8	32 - 55	1×10^{-2}	1×10^{-2}
9	55 - 85	1×10^{-2}	1×10^{-2}
10	85 - 155	8×10^{-3}	9×10^{-3}
11	155 - 245	9×10^{-3}	1×10^{-2}
12	245 - 300	2×10^{-3}	2×10^{-3}

CALCULATOR PROGRAM

The 12 polynomials used each have five coefficients therefore, 60 memory locations are needed for coefficient storage. The program itself uses 13 memory locations for the voltages which define the temperature intervals, 4 locations for accumulation registers and one location for the input voltage. The program itself requires 106 program steps. There are 13 memory locations and 133 program steps not used. The number of memory locations and program steps can be reallocated so that a maximum of fifteen 4th order polynomials can be used if necessary.

The program action is as follows:

a) The voltage drop across the silicon diode is keyed in.

b) The program finds the corresponding voltage interval.

c) The polynomial coefficients corresponding to this interval are located.

d) The fourth order polynomial is evaluated using these coefficients and the resulting interpolated temperature is displayed rounded to three decimal places.

e) If a voltage is entered which lies outside of the range of the calibration the display will flash with the value of the voltage which defines that calibration limit.

Using the TI-59 with the coefficients stored to the 10 digit precision of the calculator, the temperatures were calculated at the known voltage calibration points and checked against the given temperatures from the calibration table. This rms error, σ_{59} is given in Table I for comparison. The calculation still preserves the accuracy of the calibration table.

The time required for the calculator to compute the temperature is ten seconds or less. Thus it is possible to take voltage readings and calculate the temperature while an experiment is in progress. A copy of the TI program is given in the Appendix as Program I. Familiarity with programming language and procedures on the TI-59 are assumed.

EXAMPLE

First, the program must be entered into the calculator. The intial step is to partition the calculator's memory. This is accomplished by keying in 9 2nd OP 17. The calculator responds by displaying 239.89 indicating the correct partition. The display is cleared to 0 and the four sides of the two cards are read into the calculator (The display must be cleared to zero before each card is entered). The calculator is now ready.

Assume a voltage reading of 2.0153 volts. This value is keyed into the calculator and the program is run by pressing "A". The calculator then displays the corresponding temperature 9.758 rounded to 3 decimal places. The accuracy of the result depends on the accuracy of the original calibration and the accuracy of the polynomial fit as discussed above. Table II in the Appendix shows the values stored in the memory locations after this example was run. Memory location 00 stores the input voltage reading. Locations 1-13 contain the voltages which define the temperature intervals starting with the lowest temperature interval first. Location 14 accumulates a value which determines which set of coefficients shall be used. Location 20 through 79 contains the ceofficients of the polynomials starting with the lowest temperature interval first and stored in the order; a_0, a_1, a_2, a_3, a_4. Location 82 is a counter which equals the memory location of each coefficient to be used. Location 83 stores the result of the evaluated polynomial and location 84 contains this result rounded to three decimal places which is the value to be displayed.

ANOTHER PROGRAM

The storage capacity limits one to using a maximum of fifteen 4th order polynomials. The data set may be such that the desired accuracy cannot be obtained without exceeding the storage capacity of the calculator. This problem occurred with one of our thermometers and the solution used is presented here.

It was found that in three temperature intervals the fourth order polynomial did not give the desired accuracy. So a fifth order polynomial was calculated for these cases. A program was written for the calculator that selects the appropriate number of coefficients and makes the decision whether to use the 4th or 5th order equation. After selection, the polynomial is evaluated and the temperature displayed. The program, the contents of the memory locations and a flow chart are given in the Appendix under Program II.

It should be noted that this procedure (changing some polynomials to 5th order) was an original attack on the problem. Our present philosophy of attack would be to adjust the range of the polynomials by trial and error with the least square fit program on the IBM 370 to give fits to accepted limits using polynomials all of the same order. Only if this procedure fails should a mixture of orders be used.

SUMMARY

A method has been found to interpolate values from a large table of data using a hand-held programmable calculator. The method uses a series of overlapping least squared polynomial fits, calculated by a large computer, to reduce the information contained in the table to a small set of polynomial

coefficients. The entire set of coefficients can be stored in the calculator. Interpolation is accomplished quickly and accurately by the programmed evaluation of the polynomial. The method is perfectly general and, in particular, is ideally suited to the interpolation of calibration tables in the laboratory while an experiment is in progress.

REFERENCES

1. Also, the raw calibration data is often available from the supplier upon request if a temperature calibration table is ordered.

2. Louis G. Kelly, "Handbook of Numerical Methods and Applications", Addison-Wesley Publishing Co. 1967, pg. 68.

APPENDIX

TITLE Program I Silicon Diode Thermometer #9343 PAGE 1 OF 2

TI Programmable Program Record

PROGRAMMER Carl G. Gardner DATE 23 April 79

Partitioning (Op 17) 2 3 9 8 9 Library Module ______ Printer ______ Cards ______

PROGRAM DESCRIPTION

This silicon diode thermometer interpolation program is designed to calculate the temperature (in deg. Kelvin) corresponding to a given voltage. The calculator performs a search routine to find the correct coefficients, then calculates T using the predetermined coefficients of a least square polynomial fit.

$$T = a_4 V^4 + a_3 V^3 + a_2 V^2 + a_1 V^1 + a_0$$

Range of validity 4.0 to 300K.

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
1	Partitioning	9	2nd	OP	17	239.89
2	Enter program and coefficients from cards		CLR			0
	Enter sides 1, 2, 3, and 4 (not necessary					
	to be in that order) clear display to 0					
	before each entry.					
3	Enter Voltage (V)	V				V
4	Calculate Temperature (T)		A			T*
	*If a voltage is entered which lies outside					
	of the range of the calibration, the					
	display will flash with the value of the					
	voltage which defines the calibration					
	limit.					

USER DEFINED KEYS: A, B, C, D, E, A', B', C', D', E'

DATA REGISTERS: 0–9, 0–9

LABELS (Op 08)

FLAGS 0 1 2 3 4 5 6 7 8 9

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Program I

TITLE Silicon Diode Thermometer #9343 PAGE 2 OF 2

PROGRAMMER Carl G. Gardner DATE 23 April 79

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
000	76	LBL	
001	11	A	
002	42	STO	STORE V
003	00	00	
004	32	X:T	LOAD T
005	43	RCL	CHECK
006	01	01	LOWER
007	22	INV	LIMIT
008	77	GE	
009	12	B	
010	43	RCL	CHECK
011	13	13	UPPER
012	77	GE	LIMIT
013	12	B	
014	01	1	INITIALIZE
015	42	STO	COUNTER
016	14	14	
017	73	RC*	FIND
018	14	14	INTERVAL
019	22	INV	
020	77	GE	
021	00	00	
022	29	29	
023	01	1	
024	44	SUM	
025	14	14	
026	61	GTO	
027	00	00	
028	17	17	
029	43	RCL	CALCULATE
030	14	14	LOCATION
031	65	×	OF
032	05	5	COEFFICIENTS
033	85	+	
034	01	1	
035	00	0	
036	95	=	
037	42	STO	
038	82	82	
039	73	RC*	RECALL
040	82	82	a_0
041	42	STO	
042	83	83	
043	01	1	
044	44	SUM	
045	82	82	
046	73	RC*	RECALL
047	82	82	a_1
048	65	×	
049	43	RCL	
050	00	00	
051	95	=	$a_1 V^1$
052	44	SUM	
053	83	83	
054	01	1	

LOC	CODE	KEY	COMMENTS
055	44	SUM	
056	82	82	
057	73	RC*	RECALL
058	82	82	a_2
059	65	×	
060	43	RCL	
061	00	00	
062	33	X^2	
063	95	=	$a_2 V^2$
064	44	SUM	
065	83	83	
066	01	1	
067	44	SUM	
068	82	82	
069	73	RC*	RECALL
070	82	82	a_3
071	65	×	
072	43	RCL	
073	00	00	
074	45	Y^X	
075	03	3	
076	95	=	$a_3 V^3$
077	44	SUM	
078	83	83	
079	01	1	
080	44	SUM	
081	82	82	
082	73	RC*	RECALL
083	82	82	a_4
084	65	×	
085	43	RCL	
086	00	00	
087	45	Y^X	
088	04	4	
089	95	=	$a_4 V^4$
090	44	SUM	
091	83	83	
092	29	CP	CLEAR T
093	43	RCL	
094	83	83	
095	58	FIX	ROUND OFF
096	03	03	
097	52	EE	
098	22	INV	
099	52	EE	
100	42	STO	
101	84	84	
102	22	INV	
103	58	FIX	
104	43	RCL	INTERPOLATED
105	84	84	TEMPERATURE
106	91	R/S	

MERGED CODES

62 Pgm Ind	72 STO Ind	83 GTO Ind
63 Exc Ind	73 RCL Ind	84 Op Ind
64 Prd Ind	74 SUM Ind	92 INV SBR

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COMMENTS ON PROGRAM I

STEPS	
00 to 13	Pressing Label A starts program, stores voltage, V_1 for which temperature is to be calculated into Memory Location 00 and makes comparison to insure V is within correct range (in this case $2.3822 \geq V \geq .38345$).
14 to 28	Locates correct voltage range by comparing V to high value of voltage in each of 12 ranges. (These values are stored in Memory Locations 01 to 13). Locator Register (Memory Location 14) is initially set equal to 1.
29 - 38	Calculates the starting Memory Location of the coefficients of the polynomial selected. Stores starting location in Memory Location 82.
39 - 91	Evaluates the 4th order polynomial equation. The value corresponding to the location of the first polynomial coefficient, a_0, is in Memory Location 82. The next coefficient, a_1, is found by incrementing Memory Location 82 by 1. As the values of the terms of the polynomial are calculated, they are summed into Memory Location 83: When finished evaluating Memory Location 83 holds the answer.
92 to 106	Rounds the value in Memory Location 83 to 3 decimal places, stores the rounded value in Memory Location 84, clears the fixing condition back to full size and displays the rounded value from Memory Location 84.

Table II - Memory Locations for Program I after an Interpolation calculation for 2.0153 volts.

MEMORY LOCATION	VALUE	MEMORY LOCATION	VALUE
00	2.0153	45	2074.966811
01	2.3822	46	-6208.586484
02	2.2021	47	7116.287458
03	2.0267	48	-3654.244386
04	1.8835	49	707.3400023
05	1.6675	50	404993.1391
06	1.3913	51	-1396680.632
07	1.1763	52	1806751.599
08	1.0989	53	-1038958.009
09	1.0422	54	224076.8687
10	0.96836	55	609130.855
11	0.78067	56	-2308606.087
12	0.53053	57	3282707.07
13	0.38344	58	-2075035.347
14	4.	59	491881.7346
15	0.	60	-48117.4103
16	0.	61	192689.0092
17	0.	62	-287998.5369
18	0.	63	191092.9626
19	0.	64	-47593.42425
20	-1094.283324	65	254.7583636
21	2326.797748	66	526.5869284
22	-1765.698376	67	-1641.674924
23	579.7823942	68	1371.790555
24	-70.25141099	69	-438.8594261
25	34369.50004	70	747.8762571
26	-64464.60945	71	-2133.334189
27	45368.40195	72	3728.40793
28	-14192.15918	73	-3440.120102
29	1664.598503	74	1176.630273
30	73424.10279	75	590.4916319
31	-150454.1826	76	-1878.955702
32	115633.4704	77	5571.079202
33	-39493.42567	78	-8891.861835
34	5056.745188	79	5188.952836
35	-11225.81177	80	0.
36	25626.06727	81	0.
37	-21868.0481	82	34.
38	8284.919676	83	9.75758829
39	-1176.614927	84	9.758
40	2323.379797	85	0.
41	-5943.230288	86	0.
42	5756.394635	87	0.
43	-2475.625587	88	0.
44	397.9060207	89	0.

Program II

TITLE Silicon Diode Thermometer Interpolation PAGE 1 OF 3

TI Programmable Program Record

PROGRAMMER Ellen Fyffe DATE 10-6-78

Partitioning (Op 17) 2 3 9 8 9 Library Module ____ Printer ____ Cards ____

PROGRAM DESCRIPTION

This silicon diode temperature sensor interpolation program is designed to calculate the temperature (in degrees Kelvin) corresponding to a given voltage. The calculator performs a search routine to find the correct coefficients, then calculates T using the predetermined coefficients of a least square polynomial fit.

$$T = a_4 V^4 + a_3 V^3 + a_2 V^2 + a_1 V + a_0$$

NOTE: Not valid for voltages greater than 2.33785 volts, (1.9K). Range of validity 1.9° - 300°K.

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS			DISPLAY
1	Partitioning	9	2nd	OP	17	239.89
2	Enter voltage (V)	V				V
3	Calculate temperature (T)		A			T

USER DEFINED KEYS	DATA REGISTERS		LABELS (Op 08)
A	0	0	
B	1	1	
C	2	2	
D	3	3	
E	4	4	
A'	5	5	
B'	6	6	
C'	7	7	
D'	8	8	
E'	9	9	

FLAGS	0	1	2	3	4	5	6	7	8	9

TITLE Program II Silicon Diode Thermometer Interpolation PAGE 2 OF 3

PROGRAMMER Ellen M. Fyffe DATE 10-6-78

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
000	76	LBL		055	65	×		110	73	RC*	
001	11	A		056	05	5		111	82	82	
002	42	STO		057	85	+		112	65	×	
003	00	00		058	01	1		113	43	RCL	
004	32	X:T		059	01	1		114	00	00	
005	01	1		060	95	=		115	33	X²	
006	42	STO		061	42	STO		116	95	=	
007	14	14		062	82	82		117	44	SUM	
008	73	RC*		063	29	CP		118	83	83	
009	14	14		064	06	6		119	01	1	
010	22	INV		065	32	X:T		120	44	SUM	
011	77	GE		066	43	RCL		121	82	82	
012	00	00		067	14	14		122	73	RC*	
013	20	20		068	67	EQ		123	82	82	
014	01	1		069	01	01		124	65	×	
015	44	SUM		070	49	49		125	43	RCL	
016	14	14		071	61	GTO		126	00	00	
017	61	GTO		072	00	00		127	45	Y^x	
018	00	00		073	92	92		128	03	3	
019	08	08		074	43	RCL		129	95	=	
020	07	7		075	14	14		130	44	SUM	
021	32	X:T		076	65	×		131	83	83	
022	43	RCL		077	05	5		132	01	1	
023	14	14		078	85	+		133	44	SUM	
024	77	GE		079	01	1		134	82	82	
025	00	00		080	00	0		135	73	RC*	
026	30	30		081	95	=		136	82	82	
027	61	GTO		082	42	STO		137	65	×	
028	00	00		083	82	82		138	43	RCL	
029	43	43		084	29	CP		139	00	00	
030	43	RCL		085	04	4		140	45	Y^x	
031	14	14		086	32	X:T		141	04	4	
032	65	×		087	43	RCL		142	95	=	
033	05	5		088	14	14		143	44	SUM	
034	85	+		089	67	EQ		144	83	83	
035	01	1		090	01	01		145	29	CP	
036	02	2		091	49	49		146	43	RCL	
037	95	=		092	73	RC*		147	83	83	
038	42	STO		093	82	82		148	91	R/S	
039	82	82		094	42	STO		149	73	RC*	
040	61	GTO		095	83	83		150	82	82	
041	00	00		096	01	1		151	42	STO	
042	92	92		097	44	SUM		152	83	83	
043	05	5		098	82	82		153	01	1	
044	32	X:T		099	73	RC*		154	44	SUM	
045	43	RCL		100	82	82		155	82	82	
046	14	14		101	65	×		156	73	RC*	
047	77	GE		102	43	RCL		157	82	82	
048	00	00		103	00	00		158	65	×	
049	53	53		104	95	=		159	43	RCL	
050	61	GTO		105	44	SUM					
051	00	00		106	83	83					
052	74	74		107	01	1					
053	43	RCL		108	44	SUM					
054	14	14		109	82	82					

MERGED CODES

62 Pgm Ind · 63 Exc Ind · 64 Prd Ind · 72 STO Ind · 73 RCL Ind · 74 SUM Ind · 83 GTO Ind · 84 Op Ind · 92 INV SBR

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Program II

TITLE Silicon Diode Thermometer Interpolation PAGE 3 OF 3

PROGRAMMER Ellen M. Fyffe DATE 10-6-78

TI Programmable Coding Form

LOC	CODE	KEY	COMMENTS
160	00	00	
161	95	=	
162	44	SUM	
163	83	83	
164	01	1	
165	44	SUM	
166	82	82	
167	73	RC*	
168	82	82	
169	65	×	
170	43	RCL	
171	00	00	
172	33	X²	
173	95	=	
174	44	SUM	
175	83	83	
176	01	1	
177	44	SUM	
178	82	82	
179	73	RC*	
180	82	82	
181	65	×	
182	43	RCL	
183	00	00	
184	45	Y^X	
185	03	3	
186	95	=	
187	44	SUM	
188	83	83	
189	01	1	
190	44	SUM	
191	82	82	
192	73	RC*	
193	82	82	
194	65	×	
195	43	RCL	
196	00	00	
197	45	Y^X	
198	04	4	
199	95	=	
200	44	SUM	
201	83	83	
202	01	1	
203	44	SUM	
204	82	82	
205	73	RC*	
206	82	82	
207	65	×	
208	43	RCL	
209	00	00	
210	45	Y^X	
211	05	5	
212	95	=	
213	44	SUM	
214	83	83	
215	29	CP	
216	43	RCL	
217	83	83	
218	91	R/S	
219	00	0	

MERGED CODES

TEXAS INSTRUMENTS INCORPORATED

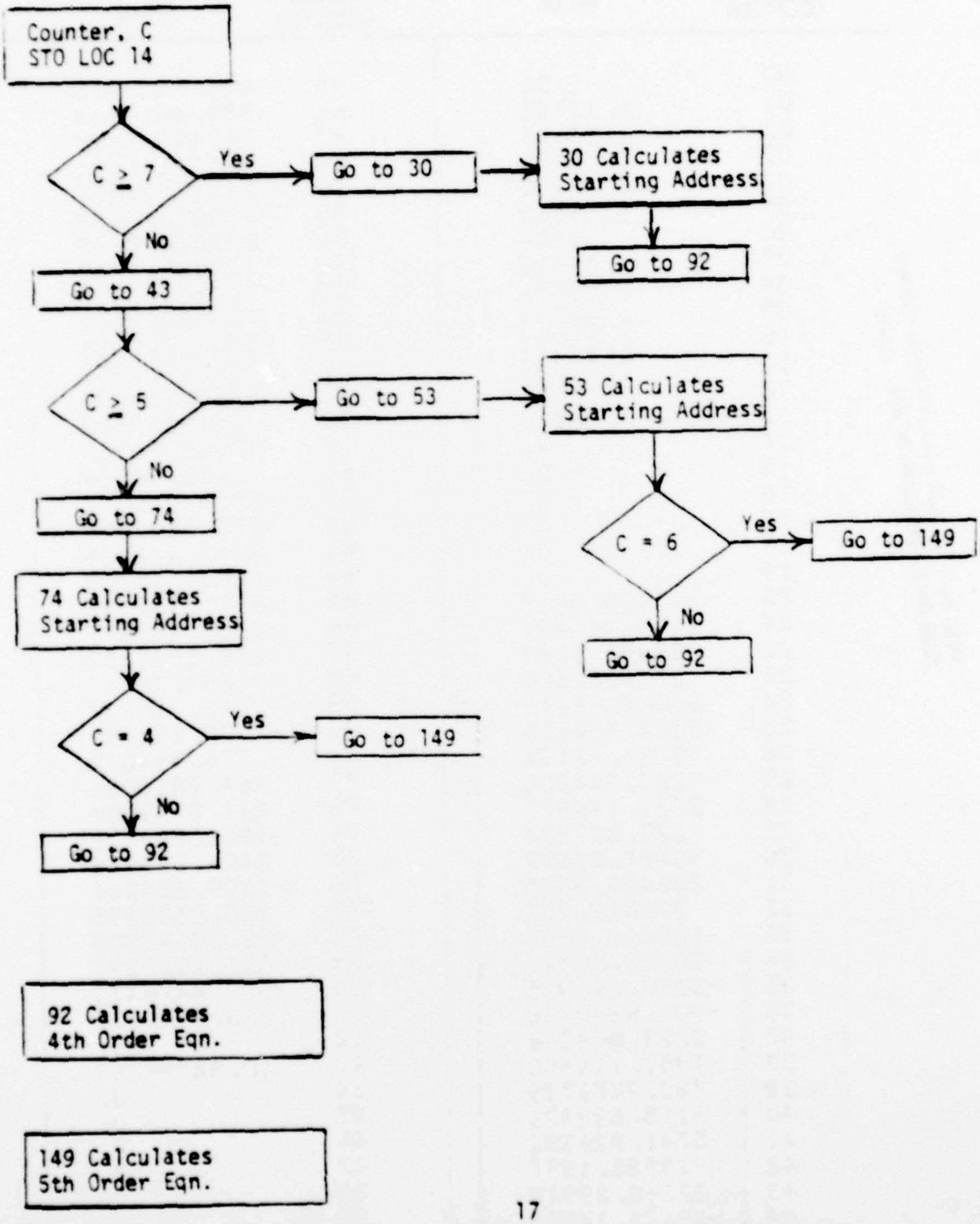
COMMENTS

PROGRAM STEPS	
00 - 19	Search routine for finding correct voltage-coefficient group.
20 - 42	Determining memory location for a_0 coefficient if counter $\geq$ 7 (counter = storage 14).
43 - 62	Determining memory location for a_0 coefficient if counter $\geq$ 5 but <7.
63 - 73	If counter = 6, go to 149 to determine T because need 5th-order polynomial
74 - 83	Determining memory location for a_0 coefficient if counter <5.
84 - 91	If counter = 4, go to 149 to determine T because need 5th-order polynomial.
92 - 148	Calculating T using 4th-order polynomial; storage 82 contains location of first (a_0) coefficient; must increment 82 to get coefficients of v^1, v^2, v^3, v^4, everything summed into storage 83.
149 - 218	Calculating T using 5th-order polynomial storage 82 contains location of first (a_0) coefficient, must increment 82 to get coefficients of v^1, v^2, v^3, v^4, v^5, everything summed into storage 83.

In steps 63, 84, 145, 215, "2nd CP" is used to clear the T-register.

The memory locations are organized essentially the same as in Program I.

Figure 1. Flow Chart for Program II



Memory Locations for Program II

MEMORY LOCATION	VALUE	MEMORY LOCATION	VALUE
00	1.96	45	6817.470413
01	2.33785	46	-954.4819164
02	2.29616	47	363495.9699
03	2.10788	48	-1253411.081
04	1.87985	49	1621291.977
05	1.56563	50	-932274.3518
06	1.1834	51	201066.7865
07	1.09916	52	123069.3687
08	1.05251	53	-507532.1238
09	0.98394	54	780390.7268
10	0.84011	55	-530112.7351
11	0.67056	56	134249.7353
12	0.5025	57	-6862.314076
13	0.36534	58	29835.7513
14	4.	59	-47005.16934
15	0.	60	32622.66764
16	0.	61	-8519.715677
17	0.	62	-975.8603595
18	0.	63	6013.442909
19	0.	64	-10829.45235
20	-845428.3417	65	8191.263795
21	1468446.453	66	-2328.162177
22	-956496.6397	67	672.6761252
23	276915.608	68	-1697.78714
24	-30065.66472	69	2712.316235
25	-5388.554485	70	-2390.568791
26	10326.62134	71	776.494045
27	-7360.744205	72	364.2819086
28	2321.146973	73	241.8742004
29	-273.827634	74	-1862.869172
30	93497.01597	75	2406.223958
31	-236489.3375	76	-1109.634264
32	239012.757	77	380.2568295
33	-120613.0086	78	-82.93142305
34	30386.86466	79	-321.8337297
35	-3057.666505	80	-372.4476473
36	-906.6640266	81	626.3486177
37	2223.804286	82	35.
38	-1981.118808	83	10.92755787
39	780.3879739	84	0.
40	-115.629971	85	0.
41	5741.926382	86	0.
42	-19938.1997	87	0.
43	27860.29918	88	0.
44	-19486.14265	89	0.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: S-220,604
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): A LEAST SQUARES INTERPOLATION SCHEME FOR CRYOGENIC THERMOMETERS USING A HAND-HELD PROGRAMMABLE CALCULATOR
5. TYPE OF REPORT & PERIOD COVERED:
6. PERFORMING ORG. REPORT NUMBER: R55-006-79
7. AUTHOR(s): CARL G. GARDNER, ELLEN M. FYFFE, JOHN J. HUDAK
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Department of Defense, 9800 Savage Road (R553), Fort George G. Meade, Maryland 20755
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 13004
11. CONTROLLING OFFICE NAME AND ADDRESS: Department of Defense, 9800 Savage Road (R553), Fort George G. Meade, Maryland 20755
12. REPORT DATE: 19 Sept[redacted]79
13. NUMBER OF PAGES: 24
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report):

Approved for public release; Distribution Unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

Interpolation
Cryogenics
Data Handling
Computational Techniques
Thermometry

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A method has been found to interpolate values from a large table of data quickly and accurately using a hand-held programmable calculator. Interpolation is accomplished by evaluation of polynomials which have previously been fit to the large data table. The method is perfectly general and in particular, is ideally suited to the interpolation of calibration tables in the laboratory while an experiment is in progress.

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