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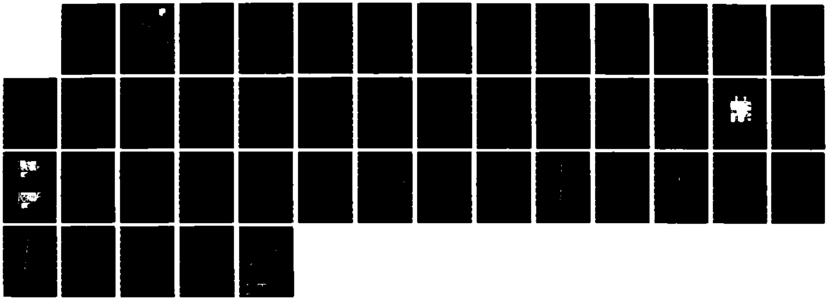

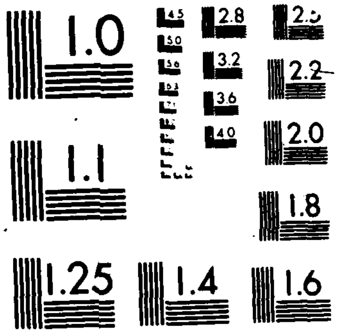
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RADC-TR-85-106
Final Technical Report
July 1986

HIGH PERFORMANCE CRYSTAL OSCILLATOR DEVELOPMENT

Frequency Electronics, Inc.

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Fast Warm-up	RF Amplifier Hybrid
Crystal Oscillator	Colpitts Oscillator Hybrid
Oven Control Hybrid	Pierce Oscillator Hybrid

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

This contract calls for design, development, fabrication and test of a fast warm-up crystal oscillator operating at 5 MHz and 10 MHz. Test results of earlier model oscillators indicated that further reductions of inner oven and oscillator assembly mass was required. In addition, an approved method of coupling heat into the crystal blank was worked on. In order to reduce mass, redesign of the electronic circuitry from discrete circuits to IC and Hybrid designs was accomplished. Four hybridized circuits were designed, fabricated and tested: RF Amplifier Hybrid, Colpitts Oscillator Hybrid, Oven Control Hybrid, Pierce Oscillator Hybrid.

Two different oscillators, each with SC-cut crystals were designed, built and tested, using RF Amplifier Hybrids, Colpitts Oscillator Hybrids, and Oven Control Hybrids. Excellent results were achieved in short and long term stability, low power, "g" sensitivity, as well as reduced volume and weight. The Pierce oscillator was also a hybridized design,

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containing a 5 MHz, 5th overtone crystal. Preliminary test results were also satisfactory.

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1. OBJECTIVE.

The objective of these research activities is to design, develop, fabricate and test an operational preproduction oscillator utilizing a double rotated quartz crystal resonator. Goals for the oscillator require the development of components which will minimize oscillator power consumption via solid state electronic temperature control, ruggedized titanium Dewar enclosure, and thermal isolation material. Electronic components and oscillator circuitry will be optimized to provide maximum stability and spectral purity and at the same time minimize sensitivity to shock, vibration and acceleration.

2. CONTRACT SPECIFICATION GOALS.

1. Stabilization time @ 25°C	$\pm 5\times10^{-9}$ of final value after 2 minutes of turn-on
2. Short term stability	9×10^{-13} in-between 1 and 100 sec averaging time
3. Ageing rate/day	1×10^{-10} after one-day of warm-up
4. Continuous operating power	0.6 watt (-40 to +90°C)
5. Warm-up power	10 watt
6. Temperature stability	2×10^{-10} (-10 to +50°C)
7. Load stability	2×10^{-11} for 10% load change
8. Voltage stability	2×10^{-11} for 5% voltage change
9. Acceleration sensitivity	1×10^{-10}/g along any axis
10. Vibration sensitivity	1×10^{-10}/g without vibration isolators
11. Shock stability	1×10^{-10} after 50g, 11 msec

3. SUMMARY OF PREVIOUS REPORTING PERIOD.

This is a summary of the results presented in the interim test report No. RADC-TR-82-191 (July 1982):

Oscillator Models FE-2188B and FE-2173A were developed during the previous reporting period. FE-2188B is a discrete oscillator with a 5 MHz, 5th overtone, SC bi-convex, 3 point mount crystal in a "C" holder and is insulated in a pyrex flask. FE-2173A is a discrete oscillator with a 10.05+ MHz, 3rd overtone, SC bi-convex, 3 point mount crystal in a TO-8 holder and foam insulated. Table I shows a comparison of the contract specification goals and the parametric performance of the two oscillator designs incorporating low 'g' sensitivity SC crystal resonators. The following paragraphs are the technical considerations as they relate to the performance differences between the two oscillator configurations.

3.1 Stabilization - Warm-up.

The 5 MHz oscillator (FE-2188B) showed the input power for the initial 3 minutes of warm-up to be 20 watts. After booster heater cutoff, the input power was reduced to under 2.0 watts in less than 5 minutes.

The frequency stabilized to within 2×10^{-7} in 5 minutes and 2×10^{-9} in 7 minutes. These results are dramatic improvements over the previous AT cut oscillators with typical warm-up period of 30 minutes to 2 hours to obtain the same stability.

TABLE I - TEST DATA SUMMARY (PREVIOUS REPORT PERIOD)

	SPECIFICATION REQUIREMENT	FE-2188B OSCILLATOR	FE-2173A OSCILLATOR
ITEM	5/10 MHz	5 MHz - 5th OVERTONE, C HOLDER SC BI-CONVEX 3 POINT MOUNT	10.05+ MHz - 3rd OVERTONE SC TO-8, 3 POINT MOUNT
STABILIZATION TIME AT 25°C	5×10^{-9} OF FINAL VALUE AFTER 2 MINUTES TURN-ON	5 MINUTES: 2×10^{-7} 7 MINUTES: 2×10^{-9}	2 MINUTES: $<2 \times 10^{-7}$ 5 MINUTES: $<2 \times 10^{-9}$
SHORT TERM STABILITY	9×10^{-13} AVERAGE FROM 1 TO 100 SECONDS	1 SECOND: 1.5×10^{-12}	1 SECOND 5×10^{-11}
AGING RATE PER DAY	1×10^{-10} AFTER ONE DAY OF WARM-UP	* AFTER 4 DAYS WARM-UP 5×10^{-11}/DAY AVG OVER NEXT 10 DAYS	* AFTER 15 DAYS WARM-UP 5×10^{-10}/DAY
PEAK WARM-UP POWER	10 WATTS	20 WATTS	18 WATTS
CONTINOUS OPERATING POWER @ 25°C	0.6 WATTS	2 WATTS AFTER 5 MINUTES	2 WATTS AFTER 5 MINUTES
TEMPERATURE STABILITY (-10°C TO +50°C)	2×10^{-10}	$<2 \times 10^{-10}$ PYREX FLASK	$<2 \times 10^{-9}$ FOAM INSULATION
PHASE NOISE (1Hz BW)	5 MHz | 10 MHz 10 Hz: -130 dB | -124 dB 100 Hz: -155 dB | -149 dB 10 kHz: -164 dB | -159 dB	10 Hz: -132 dB 100 Hz: -143 dB 1 kHz: -154 dB	10 Hz: -115 dB 100 Hz: -122 dB 1 kHz: -138 dB
"g" SENSITIVITY	1×10^{-10}/g	$< 3 \times 10^{-10}$/g IN WORST AXIS	$<5 \times 10^{-10}$/g IN WORST AXIS
WEIGHT	5 OZ.	14.8 OZ.	13 OZ.
VOLUME	10 IN^3	20 IN^3	20.68 IN^3

* NOTE: AGING CHARACTERISTICS DIFFER FOR EACH CRYSTAL.

For the 10 MHz oscillator (FE-2173A), the warm-up time was under 2 minutes to reach 1×10^{-7}, and less than 5 minutes to stabilize to 1×10^{-9}.

The difference in warmup time between the 5 MHz (FE-2188B) and the 10 MHz oscillator (FE-2173A) can be mainly attributed to the physical package. The 5 MHz oscillator used a 5th overtone crystal in a "C" size crystal holder and the size of the inner oven package was almost three times that of the 10 MHz oscillator, which uses a TO-8 crystal holder. The heater hybrid delivers a constant power input which results in a longer warmup time for the FE-2188B. It was obvious, therefore, that the 5 MHz oscillator (FE-2188B) inner oven assembly, and thermal path to the crystal, must be reduced in order to improve the warm-up time.

3.2 Aging - Long Term Stability.

The long term stability results of one 5 MHz oscillator (FE-2188B) was encouraging. After a 4 day warm-up period, the aging rate over the next 10 days was 5×10^{-11}/day and reduced to 5×10^{-12}/day over another 15 days. The long term stability of the second 5 MHz oscillator was considerably poorer than the first. After the 4 days of warm-up, the aging rate was 4×10^{-10}/day. After 15 days of operation, the aging rate was reduced to 2×10^{-10}/day. These results indicated that further enhancements of the design and fabrication processes associated with the SC-cut crystals were necessary to achieve consistently good aging results. Presently manufactured SC-cut, high bakeout, 5th overtone resonators achieve aging rates of $1 - 2 \times 10^{-11}$/day after 4 days stabilization.

The long term stability of the 10 MHz oscillator (FE-2173A) was 5 x 10^{-10}/day after a warm-up of 15 days. Presently manufactured SC-cut 10 MHz, 3rd overtone resonators achieve 5 - 8 x 10^{-11}/day after 15 days.

3.3 Temperature Stability.

Frequency stability over the temperature range of -10°C to +50°C, for both 5 MHz oscillators (FE-2188B) was about 2 x 10^{-10}. For the two 10 MHz oscillators (FE-2173A) the frequency stability over the same temperature range was 2 x 10^{-9} and 2.2 x 10^{-9}.

3.4 "g" Sensitivity.

FEI obtained reasonable yields in low "g" sensitivity SC-cut crystals. For the two 5 MHz oscillators (FE-2188B) tested, the sensitivities were approximately 4 x 10^{-10}/g and 3 x 10^{-10}/g. This compared to a typical AT-cut crystal sensitivity of 1-2 x 10^{-9}/g, indicating a significant improvement. The "g" sensitivity results for two 10 MHz oscillators (FE-2173A) were 5 x 10^{-10}/g and 5 x 10^{-10}/g.

Comparison of the "g" sensitivity results showed the 5 MHz oscillator to be better than the 10 MHz oscillator by about a factor of two. This can be understood by relating back to the basic crystal design and fabrication process particularly in the area of the crystal support structure. Better integrity can be achieved in the crystal support structure with the lower frequency (5 MHz) device.

3.5 Phase Noise.

A comparison of the phase noise characteristics of the 5 MHz and 10 MHz oscillators are as follows:

OFFSET FREQUENCY FROM CARRIER	S/N RATIO (1 Hz BW) 5 MHz	S/N RATIO (1 Hz BW) 10 MHz
10 Hz	-132 dB	-115 dB
100 Hz	-143 dB	-122 dB
1 kHz	-154 dB	-138 dB

The 5 MHz unit has a crystal filter on the output and will meet the specification goals for phase noise when the filter is optimized. The 10 MHz unit had no crystal filter. The 10 MHz unit would also meet the phase noise specification with the addition of optimized crystal filter.

4. COMPONENT DESIGN.

The following sections represent the activities since the previous reporting period. Component design representing an essential effort in accomplishing the objectives of lower power consumption, volume reduction, weight reduction, and all other parametric goals called out in the contract specification goals.

1. Four hybridized circuits were designed, fabricated and tested:
   a) RF Amplifier Hybrid (C91240T9012)
   b) Colpitts Oscillator Hybrid (C91220T9013)
   c) Pierce Oscillator Hybrid (C91380T50020)
   d) Oven control Hybrid (C91001T9011)

4.1 RF Amplifier Hybrid.

This circuit is repeated in every oscillator design. Figure 1 shows RF Amplifier Hybrid package. The dimensions of this unit are 1/2" by 1/2". The most advantageous feature of this unit is its signal isolation between the oscillator and the delivered power.

Specifications for this unit are:

a) Allowable frequencies include 5 MHz, 5.115 MHz, 10 MHz, and 10.23 MHz.

b) The power supply voltage range is 10V to 20V.

c) The current is 2 mA to 10 mA, settable by internal resistors (shorting outside pins).

d) RF Power Input is 0 dBm, $^{+3}_{-0}$ dB.

e) RF Power Output is settable 7 dBm to 13 dBm. RF power is adjustable by shorting internal resistors to ground through pins which extend outside the package. Shorting of pins enables the reduction or increase of amplifier gain.

f) Minimum harmonics is 40 dB.

g) VSWR = both input and output to be 1.2:1.

4.2 Colpitts Oscillator Hybrid.

The Colpitts Oscillator Hybrid package is shown in Outline Drawing C91225T9013 (Figure 2). This is a unique oscillator circuit which has the feature of accepting SC-cut crystals. The SC-cut crystal has 2 operating modes adjacent to each other, with 8-10% frequency differential. Only the "C" mode is desired; therefore unique circuits in the hybrid assure that the "B" mode is suppressed. The hybrid circuit also provides VCO capabilities (electronic frequency control).

4.3 Pierce Oscillator Hybrid.

The 5 MHz crystal will not work well in the Colpitts configuration as the input capacitance limits the performance of that crystal. The short and long term stabilities prove unsatisfactory and temperature coefficient is poor. The Pierce design is more suitable and has been developed to achieve these factors as desired.

The Pierce Oscillator Hybrid Package is shown in drawing C91380T50020 (Figure 3). It is a hybrid circuit design for an SC-cut crystal, 5 MHz or 5.115 MHz. It has tuning selection for the "C" mode only. The unit contains built in electronic tuning, an AGC network to control the crystal drive current and a reference zener voltage to stabilize the internal voltage.

The hybrid assembly consists of 20 resistors, 9 capacitors, 4 diodes, 4 transistors, 2 coils - all reduced to a package size of 0.80 in^3. For comparison purposes, the Pierce Oscillator breadboard is shown in Figure 4.

4.4 Oven Control Hybrid.

This design is shown in drawing C91000T9011 (Figure 5). It contains a single sensor for heat control, with a single feedback loop. The control system is capable of controlling two heater elements; one for normal heat control, the other for associated warm-up (booster heater). The unit is designed to use 50K or 100K thermistors and is capable of driver heater power from 1 watt to 20 watts. The hybrid circuit contains its own reference voltage and feedback elements can be selected externally.

Physically, it is a 12-pin flatpack design measuring 3/8" by 1/2". The oven control circuit board is shown in Figure 6 with the hybrid installed.

5. OSCILLATOR DESIGN.

5.1 Model FE-2185.

This oscillator is the first hybridized oscillator built. It consists of five major building blocks. They are three hybrid circuits, one heater ceramic substrate and one 10 MHz, SC-cut, 3rd overtone, TO-8 size crystal. The hybrid circuits are Colpitts oscillator circuit, buffer amplifier and proportional oven heater control circuit. This development resulted in a reduced volume of 3.5 cubic inches. The package shown in Figure 7 shows the vertical mounting with interface connector and mounting studs on the 1.2 inch by 1.2 inch surface. The oscillator performance test results are shown in Table II and Figures 8, 9, 10 and 11. Fast warmup with low peak input power, stability after warmup and temperature coefficient are achieved in this design relative to the previous FE-2188B and the FE-2173A. For better thermal stability and improved temperature coefficient, the Model FE-2211A was designed.

5.2 Model FE-2211A.

This new model, FE-2211A, basically has the same building blocks as Model FE-2185, except the heater ceramic substrate was redesigned for both control heater and booster heater with their drive transistors and feedback resistor integrated on one ceramic substrate. This further reduces the interwiring between heaters and driver transistors to minimize the thermal loss. In addition

TABLE II - TEST DATA SUMMARY - CURRENT REPORTING PERIOD (4/82 TO 1/85)

	SPECIFICATION REQUIREMENT	FE-2185 OSCILLATOR	FE-2211A OSCILLATOR
ITEM	10 MHz	10 MHz, 3rd OVERTONE, SC CUT TO-8, 3 POINT MOUNT	10 MHz, 3rd OVERTONE, SC CUT, TO-8, 3 POINT MOUNT
STABILIZATION TIME AT 25°C	5 x 10^{-9} OF FINAL VALUE AFTER 2 MINUTES TURN-ON	2 MINUTES: 8 x 10^{-8} 4 MINUTES: 1 x 10^{-8} 5 1/2 MINUTES: 5 x 10^{-9}	2 MINUTES: 1 x 10^{-8} 5 MINUTES: 1 x 10^{-9} DOUBLE OVEN
SHORT TERM STABILITY	9 x 10^{-13} AVERAGE FROM 1 TO 100 SECONDS	1 SECOND: 3 x 10^{-12}	10 SECONDS: 3 x 10^{-12}
AGING RATE PER DAY	1 x 10^{-10} AFTER ONE DAY OF WARM-UP	* 1 DAY: 8 x 10^{-10}/DAY 40 DAYS: 1.4 x 10^{-10}/DAY	* 1 DAY: 4 x 10^{-10}/DAY 40 DAYS: 2.5 x 10^{-10}/DAY
PEAK WARMUP POWER	10 WATTS	2 UNITS TESTED: 1ST UNIT 8 WATTS 2ND UNIT 2 WATTS	SINGLE OVEN: 17.5 WATTS DOUBLE OVEN: 22.4 WATTS
CONTINUOUS OPERATING POWER @ 25°C	0.6 WATTS	2 UNITS TESTED: 1ST UNIT: 0.98 WATTS 2ND UNIT: 0.89 WATTS	BOTH UNITS: 1.9 WATTS
TEMPERATURE STABILITY	2 x 10^{-10} (-10°C TO +50°C)	(BETWEEN -10°C TO +60°C) 2.5 x 10^{-8} FOAM INSULATION	(BETWEEN -10°C TO +60°C) SINGLE OVEN: 1 x 10^{-8} DOUBLE OVEN: 4 x 10^{-9} FOAM INSULATION
PHASE NOISE (1 Hz BW)	10 Hz: -130 dB 100 Hz: -155 dB 10 kHz: -164 dB	10 Hz: -122 dB 100 Hz: -132 dB 1 kHz: -143 dB 10 kHz: -158 dB	10 Hz: -122 dB 100 Hz: -132 dB 1 kHz: -143 dB 10 kHz: -158 dB
"g" SENSITIVITY	1 x 10^{-10}/g	< 1 x 10^{-10}/g IN BEST AXIS < 4 x 10^{-10}/g IN WORST AXIS	<1 x 10^{-10}/g IN BEST AXIS <4 x 10^{-10}/g IN WORST AXIS
WEIGHT	5 OZ.	4.5 OZ.	3.85 OZ.
VOLUME	10 IN^3	3.5 IN^3	4.20 IN^3

* NOTE: AGING CHARACTERISTICS DIFFER FOR EACH CRYSTAL.

to this improvement, an outer oven assembly has been incorporated to improve the frequency stability over wide operating temperatures. The mechanical package (Figure 12) has been designed with mounting surface on the 1 inch by 4 inch side (horizontal mounting) for better thermal balance at high ambient temperatures. Two versions of this model were tested, one with added outer oven assembly and the other without the additional outer oven assembly. This test data is shown in Table II and Figures 8, 11, 15 and 13 through 22.

Table III shows the design gains made for the current report and the previous reporting period.

5.3 Pierce Base Oscillator Development.

For 5 MHz, 5th Overtone, SC-Cut, C-Size Holder crystal, a new Pierce hybrid circuit has been designed but not yet incorporated into a completed oven oscillator assembly for testing. This newly developed hybridized 5 MHz oscillator will have fast warmup characteristics as Model FE-2211 with better short term and long term stability. The output phase noise is expected to be excellent.

6. RECOMMENDATIONS FOR FUTURE INVESTIGATION.

6.1 Improvement in "g" Sensitivity of Crystals.

The mounting structure can be improved with possible increases in diameter to achieve "g" sensitivity of 1×10^{-10}/g.

TABLE III - FE-2173A - FE-2211A COMPARISON

It should be noted that all comparisons of oscillator characteristics from this reporting period to the previous reporting period should take into account the 5 to 1 reduction in size and 3 to 1 reduction in weight.

	PREVIOUS REPORT FE-2173A OSCILLATOR	CURRENT REPORT FE-2211A OSCILLATOR	DELTA
ITEM	10.05+ MHz - 3rd OVERTONE SC TO-8, 3 POINT MOUNT	10 MHz, 3rd OVERTONE, SC CUT, TO-8, 3 POINT MOUNT	
VOLUME	20.68 IN^3	4.20 IN^3	5:1
WEIGHT	13 OZ.	3.85 OZ.	3.4:1
"g" SENSITIVITY	$<5 \times 10^{-10}$/g IN WORST AXIS	$<1 \times 10^{-10}$/g IN BEST AXIS $<4 \times 10^{-10}$/g IN WORST AXIS	1.75:1
PHASE NOISE (1Hz BW)	10 Hz: -115 dB 100 Hz: -122 dB 1 kHz: -138 dB	10 Hz: -122 dB 100 Hz: -132 dB 1 kHz: -143 dB 10 kHz: -158 dB	1.06:1
TEMPERATURE STABILITY (-10°C TO +50°C)	$<2 \times 10^{-9}$ FOAM INSULATION	(BETWEEN -10°C TO +60°C) SINGLE OVEN: 1×10^{-8} DOUBLE OVEN: 4×10^{-9} FOAM INSULATION	1:2
CONTINOUS OPERATING POWER @ 25°C	2 WATTS AFTER 5 MINUTES	BOTH UNITS: 1.9 WATTS	1.05:1
PEAK WARM-UP POWER	18 WATTS	SINGLE OVEN: 17.5 WATTS DOUBLE OVEN: 22.4 WATTS	1:1.24
AGING RATE PER DAY	* AFTER 15 DAYS WARM-UP 5×10^{-10}/DAY	* 1 DAY: 4×10^{-10}/DAY 40 DAYS: 2.5×10^{-10}/DAY	
SHORT TERM STABILITY	1 SECOND (5×10^{-11})	10 SECONDS: 3×10^{-12}	
STABILIZATION TIME AT 25°C	2 MINUTES: $<2 \times 10^{-7}$ 5 MINUTES: $<2 \times 10^{-9}$	2 MINUTES: 1×10^{-8} 5 MINUTES: 1×10^{-9} DOUBLE OVEN	2:1

6.2 Titanium Dewar.

Although the machined titanium Dewar has significant improvement in power, temperature coefficient and orientation, the manufacturing techniques presently utilized make it very expensive. Research is necessary to establish the method of making the titanium Dewar to obtain improved performance and at the same time significantly reduce the manufacturing costs.

6.3 DC Regulation.

To reduce circuit noise and save power, a hybrid power regulator needs to be developed. The present monolithic regulators are inefficient and exceptionally noisy. FEI has investigated disc component regulators but there will be a need to hybridize it in order to save volume.

6.4 Warm-Up Improvement.

Improved thermal coupling between the heater and crystal unit needs to be investigated. A possible approach is to print the heater as part of the base of the TO-8 package to both reduce size and improve thermal coupling.

6.5 Oscillator Circuitry.

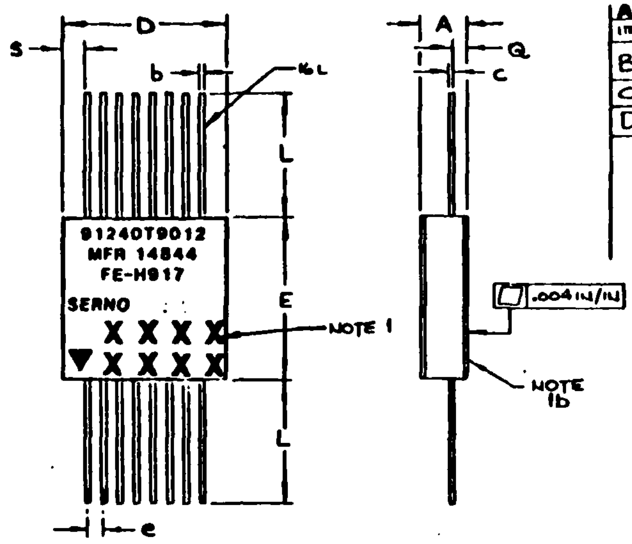
The Colpitts Oscillator has the least component recognized limitation of that oscillator due to the input capacitance to the base emitter junction. To obtain the optimum in noise and short-term stability, the Pierce will need to be adopted for the 10 MHz.

6.6 Single Hybrid Development.

Investigate the possibility of combining all three hybrids (output amplifier, oven control and oscillator) into one module in order to save space and decrease manufacturing costs.

NOTES:

1. SERIAL NUMBER KEY:
   X X X X - X X X X
   Y R W K — SERNO
   DATE CODE
2. FINISH: GOLD PLATE PER MIL-G-45204, TYPE II, CLASS I, GRADE B (50 MICRO INCHES MINIMUM) OVER ELECTROLYTIC NICKEL PER QQ-N-290 (50 MICRO INCHES MINIMUM).
3. DIMENSIONS SHALL BE MEASURED IN INCHES. METRIC EQUIVALENTS (TO THE NEAREST 0.01mm) ARE GIVEN FOR GENERAL INFORMATION AND ARE BASED UPON 1 INCH = 25.4 mm.
4. DIMENSIONING SYMBOLS ARE IN ACCORDANCE WITH MIL-M-38510.



REVISIONS					
LTR	ZONE	DESCRIPTION	BY	DATE	APPD
B		REVISED NOTE 1; ARTWORK WAS ON TOP & BOT.		3-16-83	
C		REVISED MARKING	MS	5/3/83	
D		REVISED DIMS "A" AND "Q" PER ECO 01842/9012	RH	1/1/14	

TABLE 1
DIMENSIONS

SYMBOLS	INCHES		MILLIMETERS		NOTES
	MAX	MIN	MAX	MIN	
A	.198	.182	5.03	4.62	
b	.018	.012	.46	.30	
c	.012	.008	.30	.20	
D	.505	.495	12.83	12.57	
E	.505	.495	12.83	12.57	
e	.055	.045	1.40	1.14	
L		.375		9.53	
Q	.062	.048	1.57	1.21	
S		.061 REF		.155 REF	

PIN	FUNCTION
1	CASE GND
2	N/C
3	DC RET.
4	RF INPUT RET.
5	RF INPUT
6	DC GAIN SET (33050)
7	DC GAIN SET (33050)
8	DC GAIN SET (33050)
9	AC GAIN SET (9050)
10	AC GAIN SET (5050)
11	AC GAIN SET (1050)
12	RF OUTPUT RET.
13	RF OUTPUT
14	N/C
15	N/C
16	B+

DESCRIPTION	FEI PART NO.
RF AMPLIFIER FEI MODEL FE-H917	14844-9124OT9012

FE-2210A		-----8976	1	–
FE-2211A	D	31013-9396	1	–
FE H917		FINAL	1	–
FIRST USED ON	SIZE	NEXT ASSY	QTY REQD	DASH NO

QTY REQD FINAL ASSY

ASSOCIATED DRAWINGS

TOP DRAWING USE ONLY
F102-101
SCD 9127OT9003

MATERIAL

FINISH
SEE NOTE 2

QUANTITY -3 -2 | REMARKS | FEI CODE | CODE IDENT | PART NO | FEI PART NO | DESCRIPTION | ITEM NO

MATERIALS AND TABULATED ITEMS

INTERFACE CONTROL DRAWING FIGURE 1

UNLESS OTHERWISE SPECIFIED
1. DIMENSIONS ARE IN INCHES AND INCLUDE CHEMICALLY APPLIED FINISHES

CONTRACT NO

DRWN BY RH 2-24-83
DSGN ENG'G RH 2-24-83
PROJ APPD 3/4/83
3/25/83
PROD O Valen

FREQUENCY ELECTRONICS, INC.
NEW HYDE PARK, NEW YORK 11040

HYBRID, RF AMPLIFIER
MODEL FE-H917

CODE IDENT NO 14844 | SIZE C | DRAWING NO 9124OT9012 | REV D

SCALE 4:1 | DO NOT SCALE DRAWING | SHEET 1 OF 1

LTR	ZONE	DESCRIPTION	BY	DATE	APPD
A		RELEASED			
B		REVISED NOTE 1 ; ARTWORK WA TOP & BOT.	MS	3/29/85	
C		REVISED MARKING	MS	5/9/85	
D		REVISED DIM'S "A" AND "Q" PER ECO 01843/9013	RH	1/4/84	
E		REVISED PIN FUNCTION CHART PER ECN H19-6-7	TDM	7/1/85	

NOTES:

1. SERIAL NUMBER KEY:

   X X X X - X X X X

   Y R W K — SERNO

   DATE CODE

2. FINISH: GOLD PLATE PER MIL-G-45204, TYPE II, CLASS I, GRADE B (50 MICRO INCHES MINIMUM) OVER ELECTROLITIC NICKEL PER QQ-N-290 (50 MICRO INCHES MINIMUM).

3. DIMENSIONS SHALL BE MEASURED IN INCHES. METRIC EQUIVALENTS (TO THE NEAREST 0.01mm) ARE GIVEN FOR GENERAL INFORMATION AND ARE BASED UPON 1 INCH = 25.4 mm.

4. DIMENSIONING SYMBOLS ARE IN ACCORDANCE WITH MIL-M-38510.

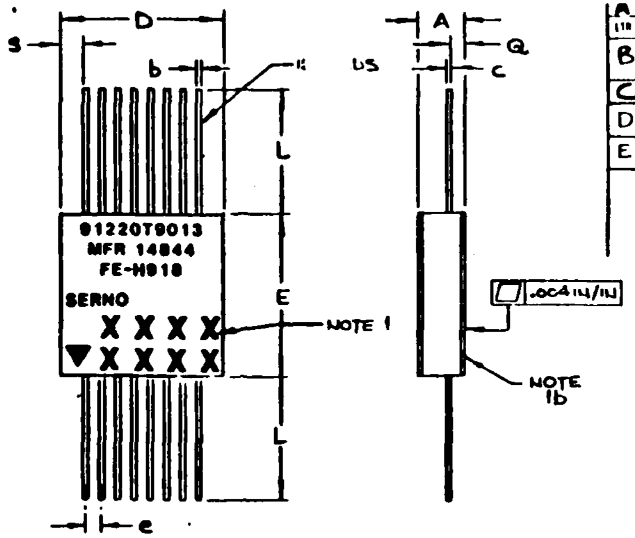


TABLE 1
DIMENSIONS

SYMBOLS	INCHES MAX	INCHES MIN	MILLIMETERS MAX	MILLIMETERS MIN	NOTES
A	.198	.182	5.03	4.62	
b	.018	.012	.46	.30	
c	.012	.008	.30	.20	
D	.505	.495	12.83	12.57	
E	.505	.495	12.83	12.57	
e	.055	.045	1.40	1.14	
L		.375		9.53	
Q	.062	.048	1.57	1.21	
S		.061 REF		.155 REF	

PIN	FUNCTION
1	CRYSTAL (Q1-b)
2	CRYSTAL (CR1)
3	VCO
4	GND
5	GND
6	GND
7	N/C
8	N/C
9	N/C
10	GND
11	C4 ADJ.
12	N/C
13	RF OUTPUT
14	GND
15	N/C
16	B+

DESCRIPTION	FEI PART NO.
COLPITTS OSCILLATOR FEI MODEL FE-H918	14844-91220T9013

QUANTITY -3	QUANTITY -2	REMARKS	FEI CODE	CODE IDENT	PART NO	SIZE	FEI PART NO	DESCRIPTION	NOTE	ITEM NO

MATERIALS AND TABULATED ITEMS

INTERFACE CONTROL DRAWING FIGURE 2

QTY REQD FINAL ASSY	FIRST USED ON	SIZE	NEXT ASSY	QTY REQD	DASH NO
	FE-2210A		-----_-8976	1	-
	FE-2211A	D	31013-9396	1	-
	FE-H918		FINAL	1	-

ASSOCIATED DRAWINGS

[redacted]

FOR PRINTING USE ONLY
F102-101
SCD=91270T9003

MATERIAL

SEE NOTE 2

UNLESS OTHERWISE SPECIFIED
1 DIMENSIONS ARE IN INCHES AND INCLUDE CHEMICALLY APPLIED FINISHES
2 TOLERANCES

FRACTIONS	DECIMALS 2 PLACE	DECIMALS 3 PLACE	ANGLES
± ~	± .~	± ~	± ~

3 HOLES
.025 TO .125 DIA + .007 - .001
.126 TO .220 DIA .003 - .001
.251 TO .500 DIA .004 .001
.515 DIA AND UP .005 - .001

4 PART TO BE FREE OF BURRS
5 BREAK ALL SHARP EDGES .003 TO .010
6 TRUE CENTER TO BE WITHIN .003 OF CENTERLINE
7 COMMERCIAL TOLERANCES APPLY TO STOCK SIZES

CONTRACT NO

DWN BY	R.A.	8-23-93
DSGN ENGR	R.A.	8-23-93
CHKD BY		
PROJ ENGR		4/4/13
PROD ENGR		4/4/13
APPD		4/4/13

FREQUENCY ELECTRONICS, INC.
NEW HYDE PARK, NEW YORK 11040

HYBRID, COLPITTS OSCILLATOR
MODEL FE-H918

CODE IDENT NO	SIZE	DRAWING NO	REV
14844	C	91220T9013	E

SCALE 4:1 DO NOT SCALE DRAWING SHEET 1 OF 1

ATTACHED ECO

LTR	ZONE	DESCRIPTION	BY	DATE	APPR
B		REVISED MARKING; REDUCED ▽		5/5/83	

NOTES:

1. SERIAL NUMBER KEY:

   XX XX - XXXX
   YRWK   SERNO
   DATE CODE

2. FINISH: GOLD PLATE PER MIL-G-45204, TYPE II, CLASS I, GRADE B (50 MICRO INCHES MINIMUM) OVER ELECTROLYTIC NICKEL PER QQ-N-290 (50 MICRO INCHES MINIMUM).

3. DIMENSIONS SHALL BE MEASURED IN INCHES. METRIC EQUIVALENTS (TO THE NEAREST 0.01mm) ARE GIVEN FOR GENERAL INFORMATION AND ARE BASED UPON 1 INCH = 25.4 mm.

4. DIMENSIONING SYMBOLS TO BE IN ACCORDANCE WITH MIL-M-38510.

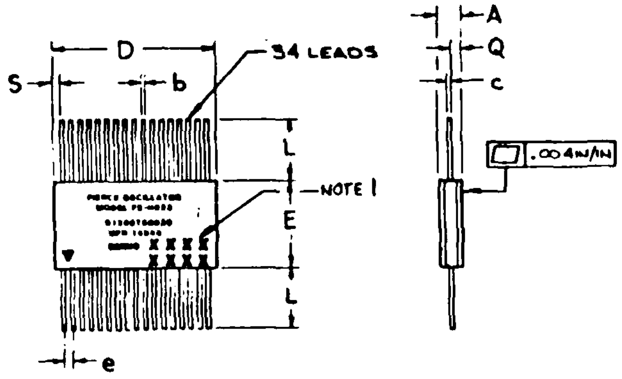


TABLE 1
DIMENSIONS

SYMBOLS	INCHES MAX	INCHES MIN	MILLIMETERS MAX	MILLIMETERS MIN	NOTES
A	.143	.127	3.63	3.23	
b	.018	.012	.46	.30	
c	.012	.008	.30	.20	
D	1.005	.995	25.53	25.27	
E	.535	.525	13.59	13.34	
e	.055	.045	1.40	1.14	
L	~	.375	~	9.53	
Q	.063	.047	1.60	1.19	
S		.086 REF		2.18 REF	

DESCRIPTION	FEI PART NO.
HYBRID, PIERCE OSCILLATOR FEI MODEL FE-H923	C91380T50020

QUANTITY -1	QUANTITY -2	REMARKS	FSI CODE	CODE IDENT	PART NO	SIZE	FEI PART NO	DESCRIPTION	NOTE	ITEM NO

MATERIALS AND TABULATED ITEMS

PIN	FUNCTION	PIN	FUNCTION
1	VCO RETURN	18	CASE GND
2	N/C	19	BIAS ADJ
3	TUNE TO C MODE	20	B+ INPUT
4	[illegible]	21	N/C
5	TUNE TO C MODE	22	TEMP OUTPUT
6	N/C	23	N/C
7	N/C	24	AMP B+
8	AGC FEEDBACK	25	[illegible]
9	N/C	26	OSC B+
10	DC RETURN	27	N/C
11	DC REF IN	28	BASE CRYSTAL
12	N/C	29	N/C
13	RF OUTPUT RETURN	30	[illegible] VCO RANGE ADJ
14	RF OUTPUT	31	[illegible]
15	[illegible]	32	VCO RANGE ADJ
16	N/C	33	VCO INPUT
17	[illegible]	34	N/C

QTY REQD FINAL ASSY	FIRST USED ON	NEXT ASSY	QTY REQD	DASH NO
	FE-	-8079		—
	FE H923	FINAL	1	—

FOR DRAFTING USE ONLY
IP 105A-06
SCD: B91380T50020

MATERIAL

FINISH SEE NOTE 2

UNLESS OTHERWISE SPECIFIED
1. DIMENSIONS ARE IN INCHES AND INCLUDE CHEMICALLY APPLIED FINISHES
2. TOLERANCES: FRACTIONS ± ~; DECIMALS 2 PLACE ± ~; 3 PLACE ± ~; ANGLES ± ~
3. HOLES
4. PART TO BE FREE OF BURRS
5. BREAK ALL SHARP EDGES .003 TO .010
6. TRUE CENTER TO BE WITHIN .001 OF CENTERLINE
7. COMMERCIAL TOLERANCES APPLY TO STOCK SIZES

CONTRACT NO

		DATE
DWN BY	M. SADAITYS	4-14-83
DSGN/ENGR	M. Sadaitys	4/14/83
CHKD BY		4/15/83
ISSUE APPD		4/19/83
		4/11/83

FIGURE 3

FREQUENCY ELECTRONICS, INC.
NEW HYDE PARK NEW YORK 11040

HYBRID, PIERCE OSCILLATOR
MODEL FE-H923

CODE IDENT NO	SIZE	DRAWING NO	REV
14844	C	91380T50020	B

SCALE 2:1
DO NOT SCALE DRAWING 91283TR
SHEET 17
ATTACHED ECO

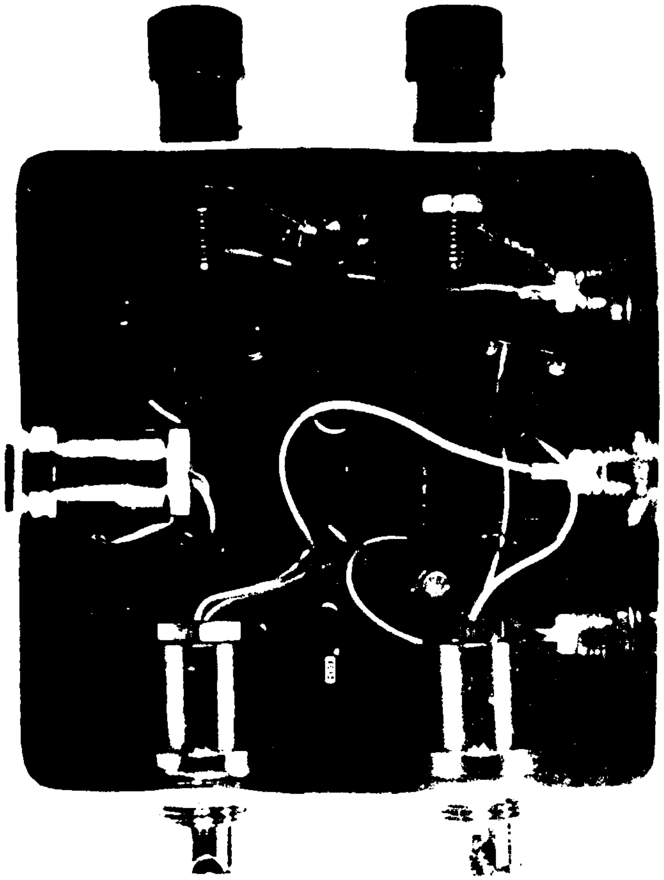


FIGURE 4

PIERCE OSCILLATOR BREADBOARD

NOTES:

1. SERIAL NUMBER KEY:

   A. TOPSIDE B. BOTTOMSIDE

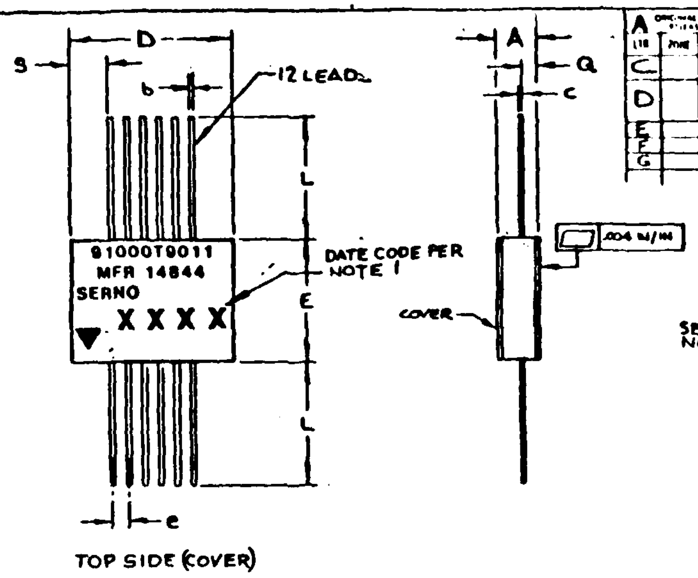
   X X X X — DATE CODE PORTION OF SERIAL NUMBER

   X X X X — SERIAL NUMBER PORTION OF SERIAL NUMBER

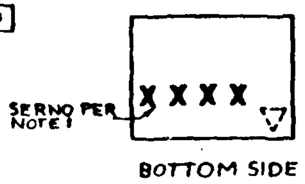
2. FINISH: GOLD PLATE PER MIL-G-45204, TYPE II, CLASS I, GRADE B (50 MICRO INCHES MINIMUM) OVER ELECTROLITIC NICKEL PER QQ-N-290 (50 MICRO INCHES MINIMUM).

3. DIMENSIONS SHALL BE MEASURED IN INCHES. METRIC EQUIVALENTS (TO THE NEAREST 0.01mm) ARE GIVEN FOR GENERAL INFORMATION AND ARE BASED UPON 1 INCH = 25.4 mm.

4. DIMENSIONING SYMBOLS ARE IN ACCORDANCE WITH MIL-M-38510.



TOP SIDE (COVER)



BOTTOM SIDE

A ORIGINAL ISSUE		REVISIONS			
LTR	ZONE	DESCRIPTION		DATE	APPD
C		REVISED & REDRAWN		4/85	
D		PN: 91001T9011 WAS 91000T9011. REVISED NOTE 1	RS	6/11/85	
E		ADDED PIN FUNCTION CHART	RN	[illegible]	
F		PN 91000T9011 WAS 91001T9011	[illegible]	[illegible]	
G		REVISED NOTE 2 AND ADDED BOTTOM VIEW	FM	[illegible]	

TABLE 1
DIMENSIONS

SYMBOLS	INCHES		MILLIMETERS		NOTES
	MAX	MIN	MAX	MIN	
A	.133	.117	3.38	2.97	
b	.018	.012	.46	.30	
c	.012	.008	.30	.20	
D	.505	.495	12.83	12.57	
E	.380	.370	9.65	9.40	
e	.055	.045	1.40	1.14	
L		.375		9.53	
Q	.058	.042	1.47	1.07	
S		.111 REF		2.82 REF	

PIN	FUNCTION
1	[illegible] DC INPUT
2	[illegible]
3	[illegible]
4	[illegible] INPUT
5	REF OUT
6	DC RTN
7	DC RTN
8	[illegible]
9	HEATER DC INPUT
10	[illegible] DC INPUT
11	[illegible]
12	[illegible] DC INPUT

DESCRIPTION	FEI PART NO.
OVEN CONTROL HYBRID FEI MODEL FE-H901	14844-91000 T9011

QUANTITY	DESIGNERS	FEI CODE	CODE IDENT	PART NO.	SIZE	FEI PART NO	DESCRIPTION	NOTE	ITEM NO

MATERIALS AND TABULATED ITEMS

	FE-10893	D	43462-9992	1	–
	FE-2201A		-8976	1	–
	FE H901		FINAL	1	–
QTY REQD FINAL ASSY	FIRST USED ON	SIZE	NEXT ASSY	QTY REQD	DASH NO

ASSOCIATED DRAWINGS

FOR DRAFTING USE ONLY: IP-1025-31 K03 — 9011

MATERIAL

FINISH: SEE NOTE 2

INTERFACE CONTROL DRAWING FIGURE 5

UNLESS OTHERWISE SPECIFIED
1. DIMENSIONS ARE IN INCHES AND INCLUDE CHEMICALLY APPLIED FINISHES

CONTRACT NO

DRAWN BY SADAITYS 5/6/83

FREQUENCY ELECTRONICS, INC.
NEW HYDE PARK, NEW YORK 11040

HYBRID, OVEN CONTROL
MODEL FE-H901

CODE IDENT NO 14844 SIZE C DRAWING NO 91000 T 9011 REV G

SCALE 4/1 DO NOT SCALE DRAWING 912B4T F0R SHEET 19

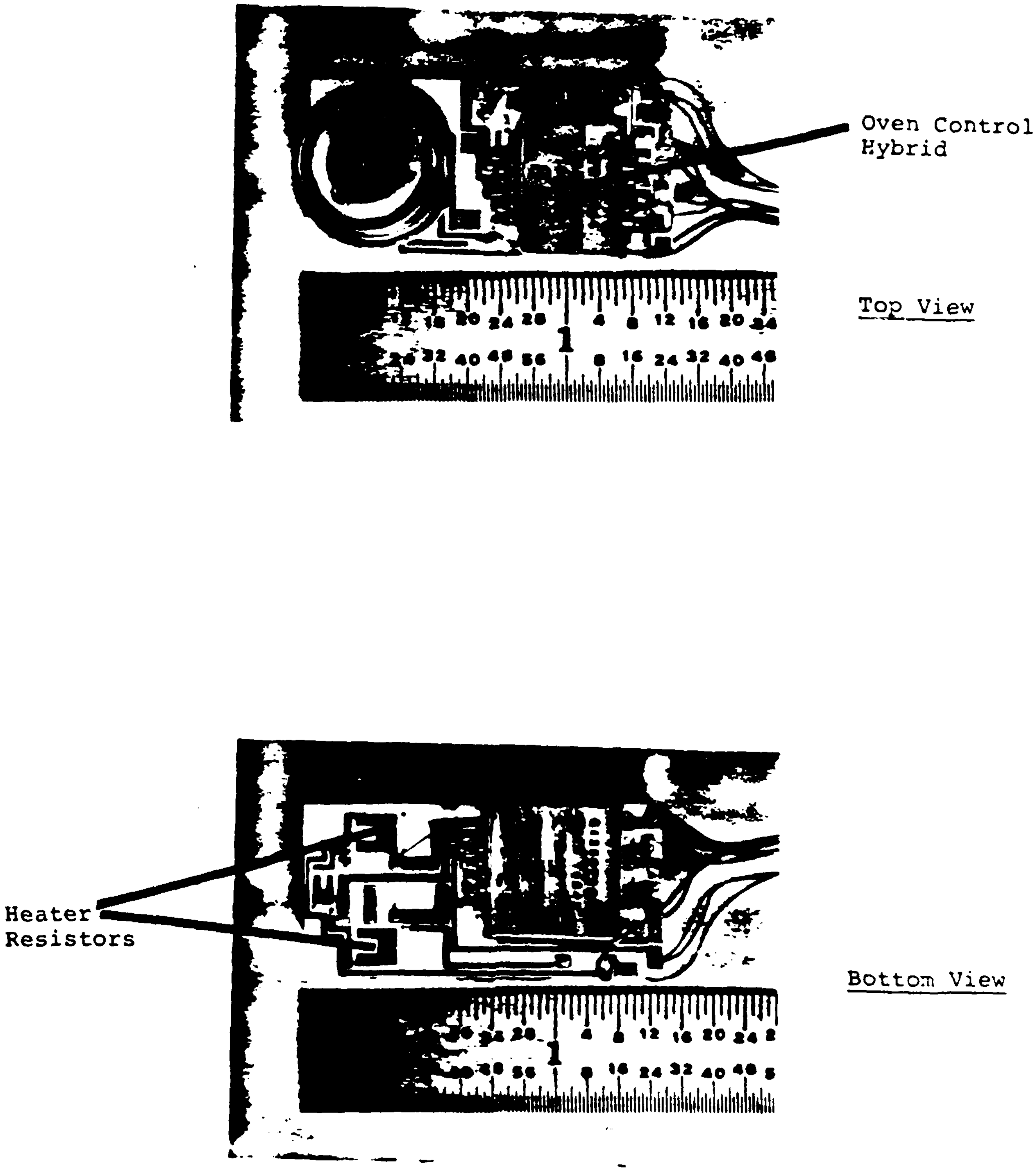
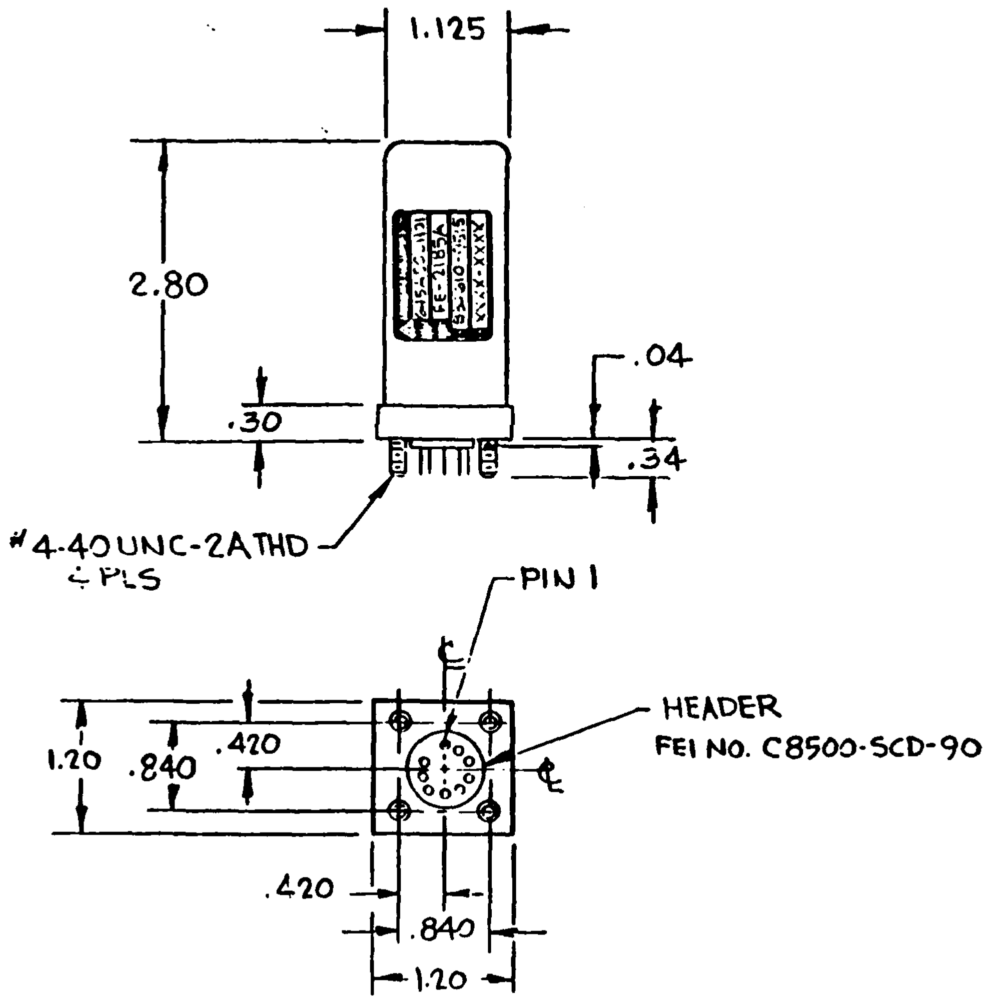


FIGURE 6

OSCILLATOR PRINTED CIRCUIT BOARD ASSEMBLY



PIN	FUNCTION
1	+8V BOOSTER HEATER
2	+8V OSC & OVEN
3	N/C
4	10MHz RF OUTPUT
5	DC & RF RETURN
6	VCO RETURN
7	VCO CONTROL
8	VCO B+
9	CASE GND

FIGURE 7

OCXO
FE-21E5A
OUTLINE

CODE IDENT NO	SIZE	DRAWING NO	REV
14844	B	34610-9515	A
FREQUENCY ELECTRONICS, INC.			SHEET 21

ATTACHED ECO

A31596-8079-1

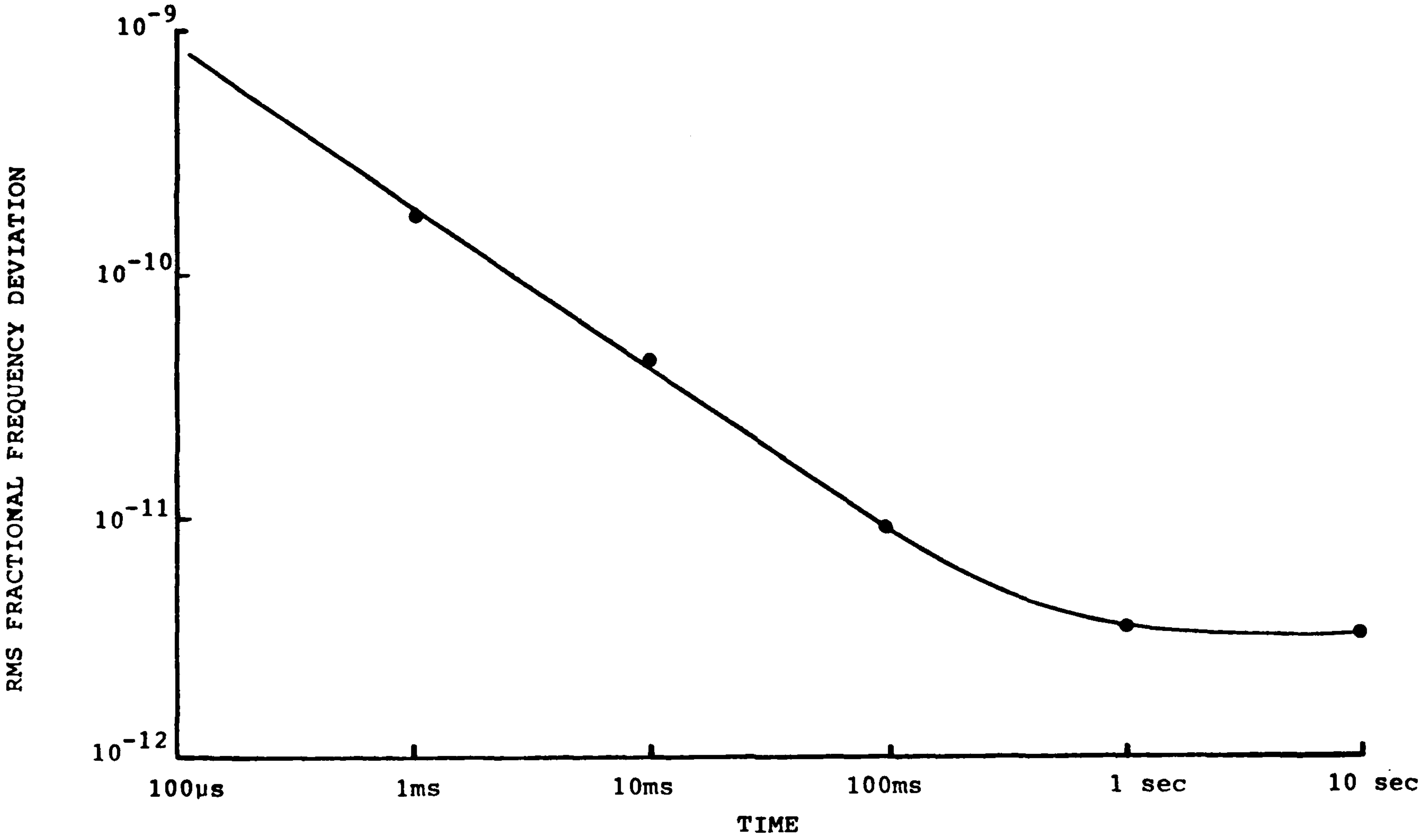
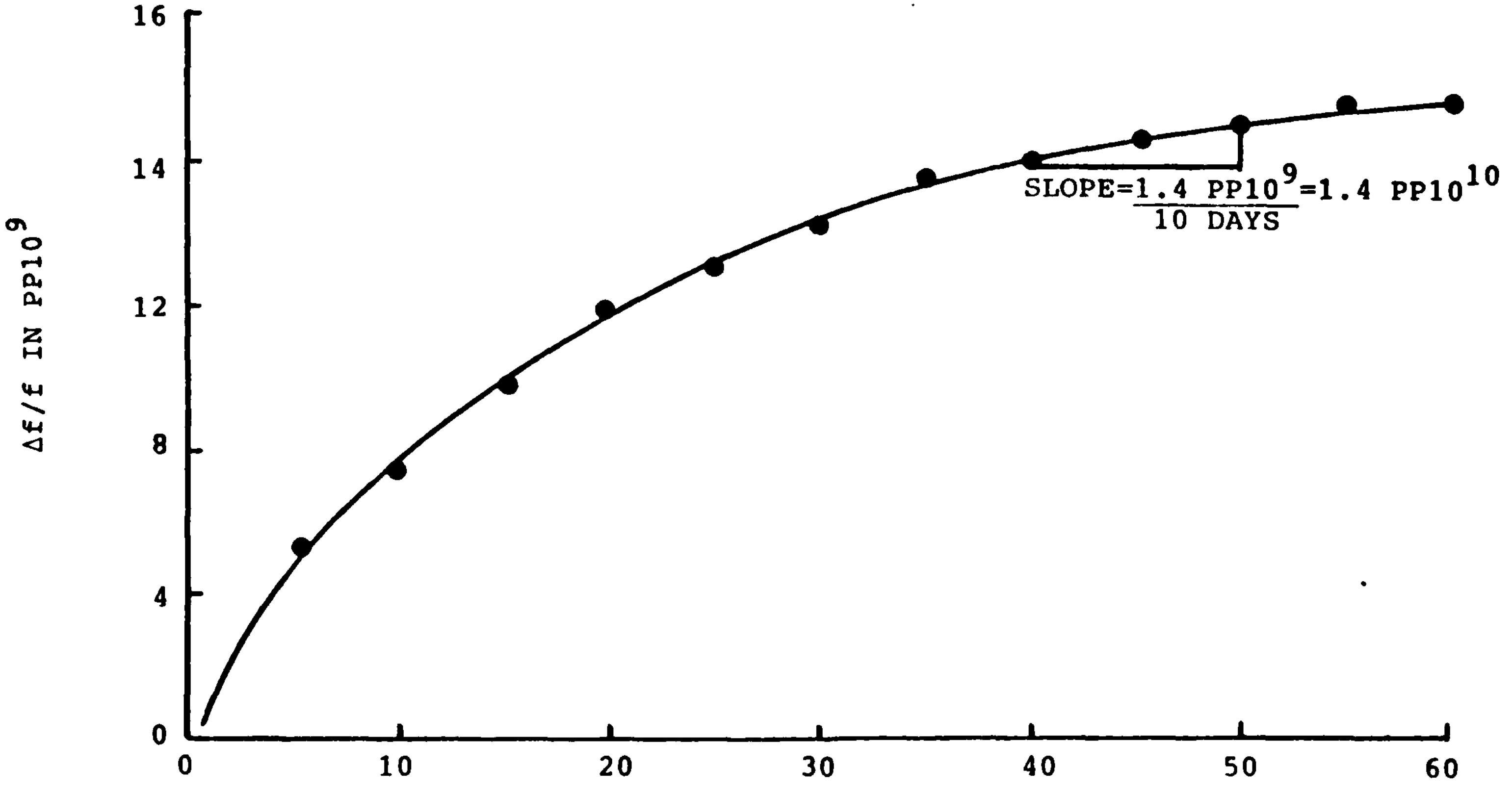


FIGURE 8 SHORT TERM STABILITY MODEL FE-2185A & MODEL FE-2211A

A31596-8079-2



LONG TERM STABILITY (DAYS)

FIGURE 9 AGING RATE MODEL FE-2185A

A31596-8079-3

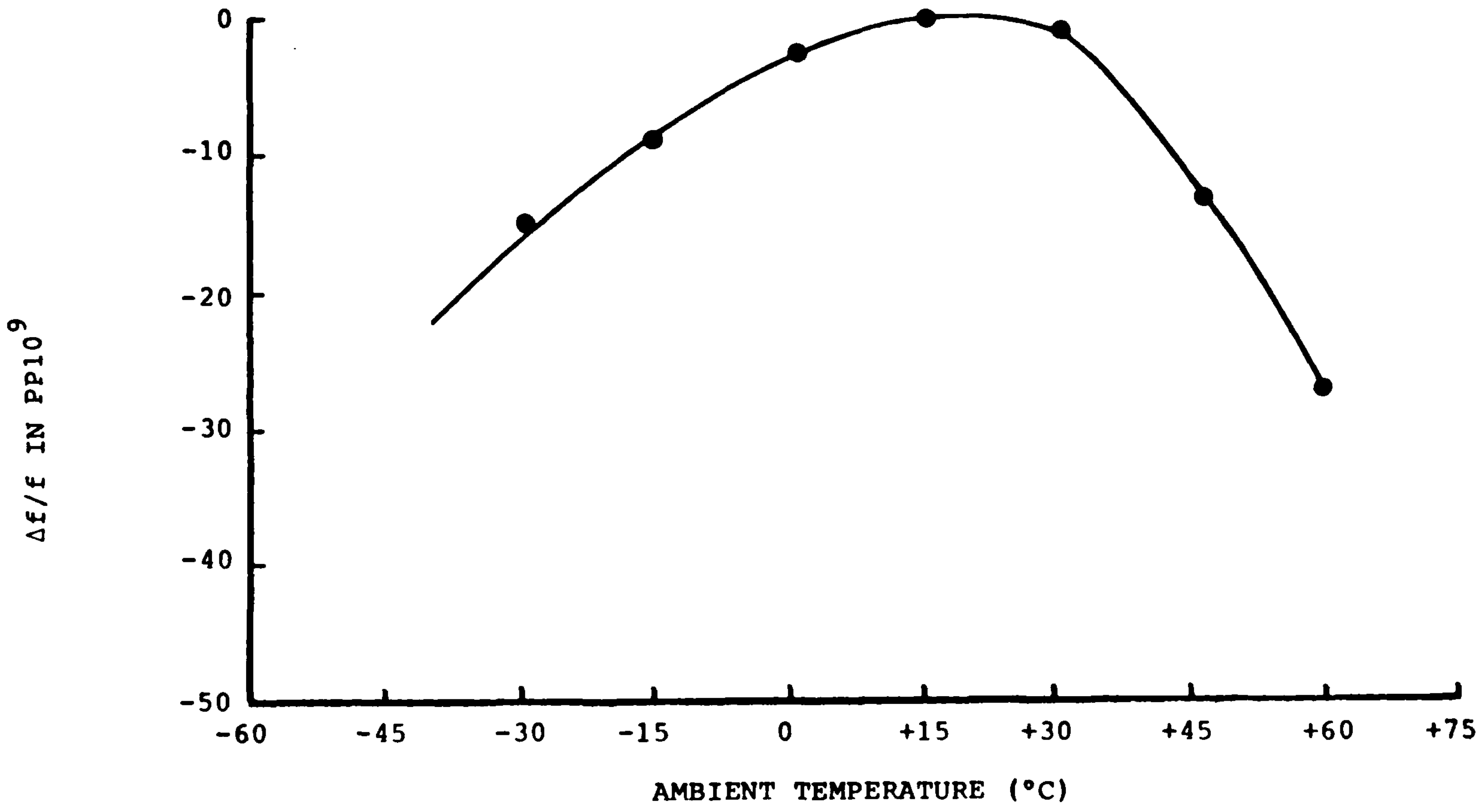


FIGURE 10 TEMPERATURE STABILITY MODEL FE-2185A

A31596-8079-4

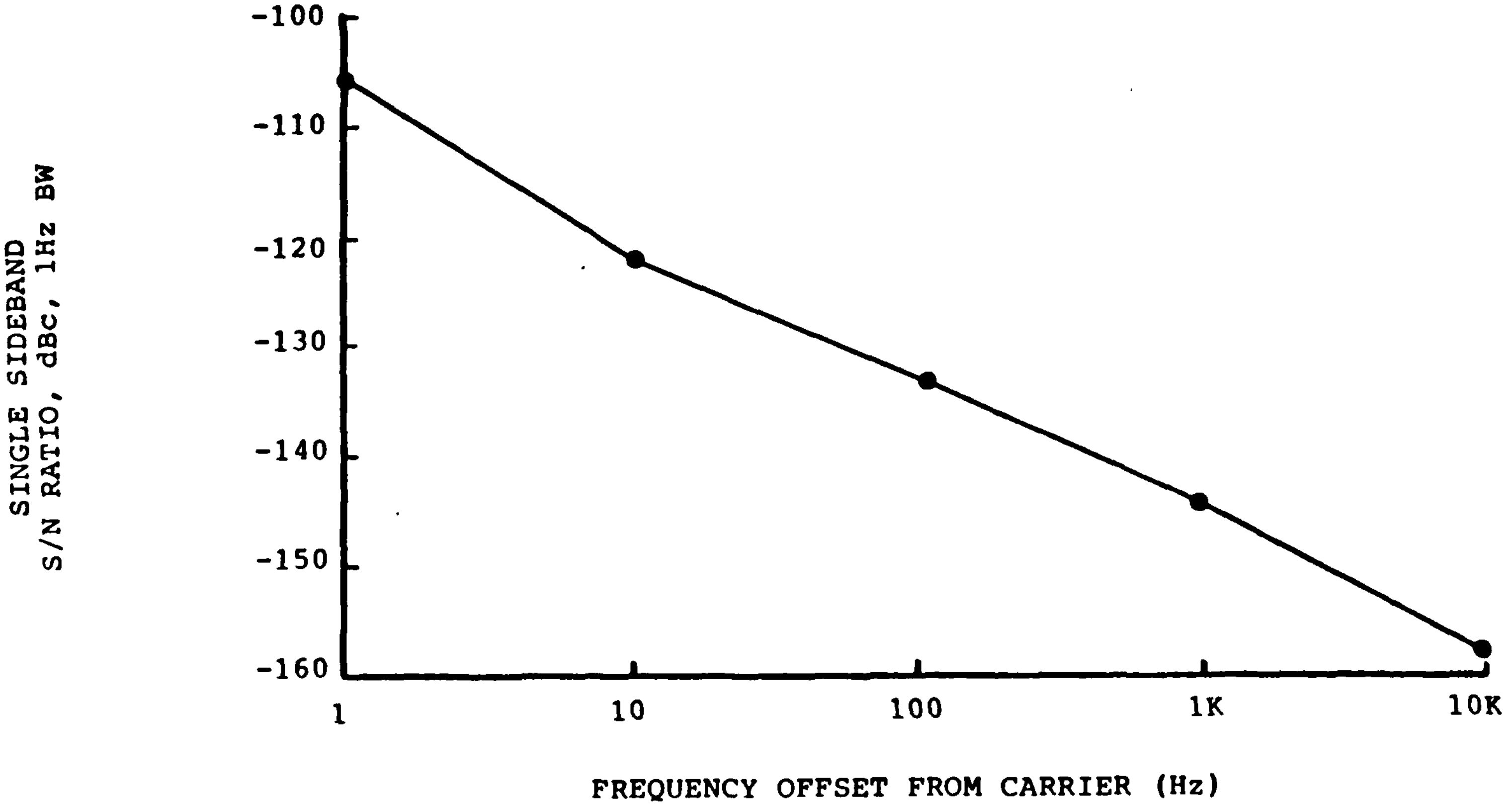
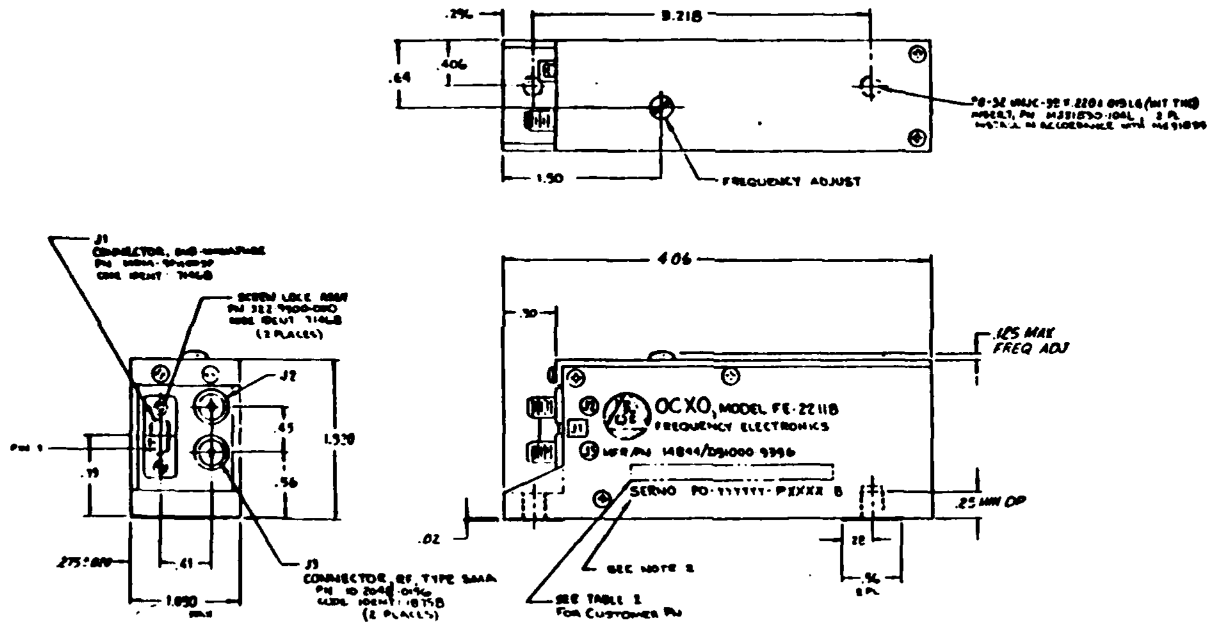


FIGURE 11 PHASE NOISE, MODEL FE-2185A & MODEL FE-2211A

NOTES:

1. ——

2. SERIAL NO KEY: (SEE TABLE 1)
PO-YYYYYY-PXXXX B
PURCHASE ORDER NUMBER
SERNO



CONNECTOR J1

PIN	FUNCTION
1	+28V OVEN
2	+15 V OSC
3	OVEN MONITOR
4	RF OUTPUT MONITOR
5	+15V OSC BATTERY BACK-UP
6	DC RETURN, OSC
7	DC RETURN OVEN
8	CASE GROUND
9	N/C

RF CONNECTORS

CONN	FUNCTION
J2	10MHz OUTPUT 1
J3	10MHz OUTPUT 2

TABLE 1

FEI PN DASH NO	SERIAL NO
-1	PO [illegible] B
-2	PO [illegible] B
-3	PO [illegible] B

REVISIONS

LTR		DESCRIPTION			
B		REVISED PER COMMENT [illegible]	JG	[illegible]	[illegible]
C		REVISED PER [illegible]	JG	[illegible]	[illegible]
D	B1 C4 B1	[illegible] LOCATED FREQUENCY ADJ [illegible] [illegible]	JG	[illegible]	[illegible]
E		REVISED [illegible]	[illegible]	[illegible]	[illegible]
F		ADDED FREQ ADJ LOCATION	JG	[illegible]	[illegible]
G		[illegible] 1.520 WAS 1.500 ADDED [illegible]	[illegible]	[illegible]	[illegible]
H		DELETED NOTE 1	[illegible]	[illegible]	[illegible]
J		REVISED HARDWARE	[illegible]	[illegible]	[illegible]
K		REVISED NOTE 2	[illegible]	[illegible]	[illegible]
L		ADDED TABLE 1	BA	[illegible]	[illegible]

FIGURE 12

FREQUENCY ELECTRONICS, INC.

OVEN CONTROLLED CRYSTAL OSC.
OCXO, FE-2211A
OUTLINE

14844 D 31000 - 9396 L

AL ALY [illegible]

26

A31596-8079-5 (A19098-FOR)

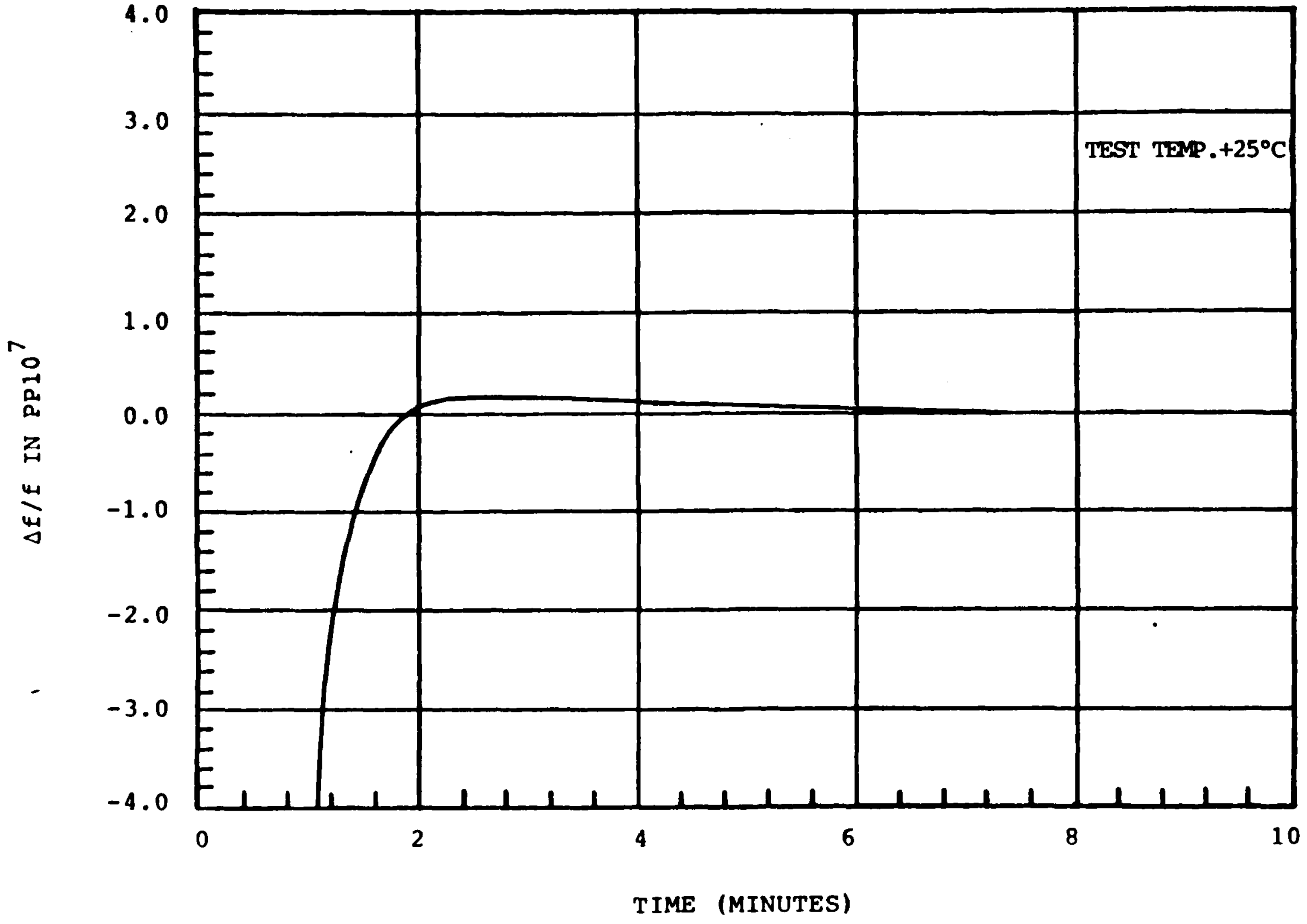


FIGURE 13 WARM-UP TIME - MODEL FE-2211A

A31596-8079-6 (A19098-FOR)

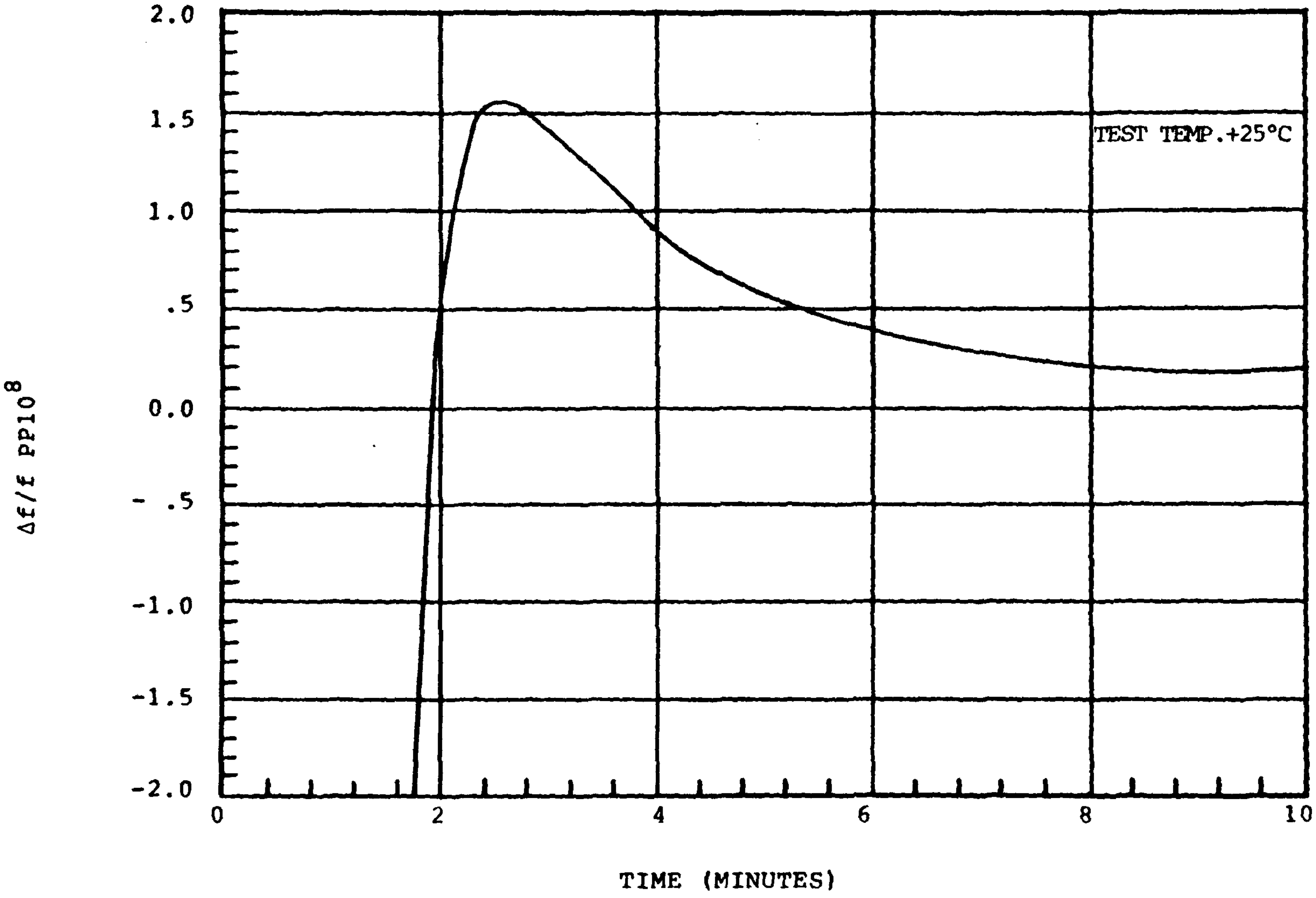


FIGURE 14 WARM-UP TIME - MODULE FE-2211A

A31596-8079-7 (A19098-FOR)

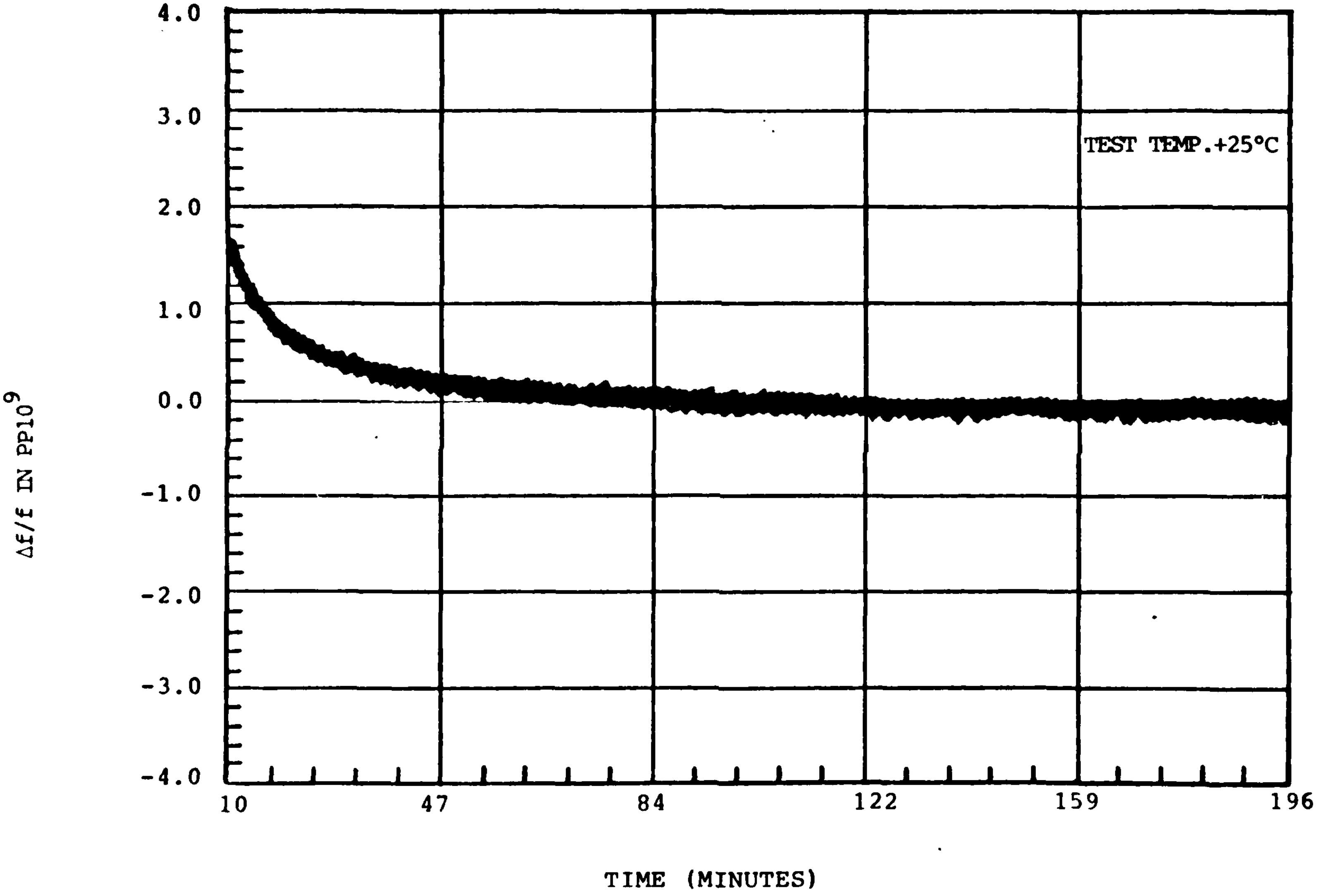


FIGURE 15 WARM-UP TIME MODEL FE-2211A

A31596-8079-8

(A19098-FOR)

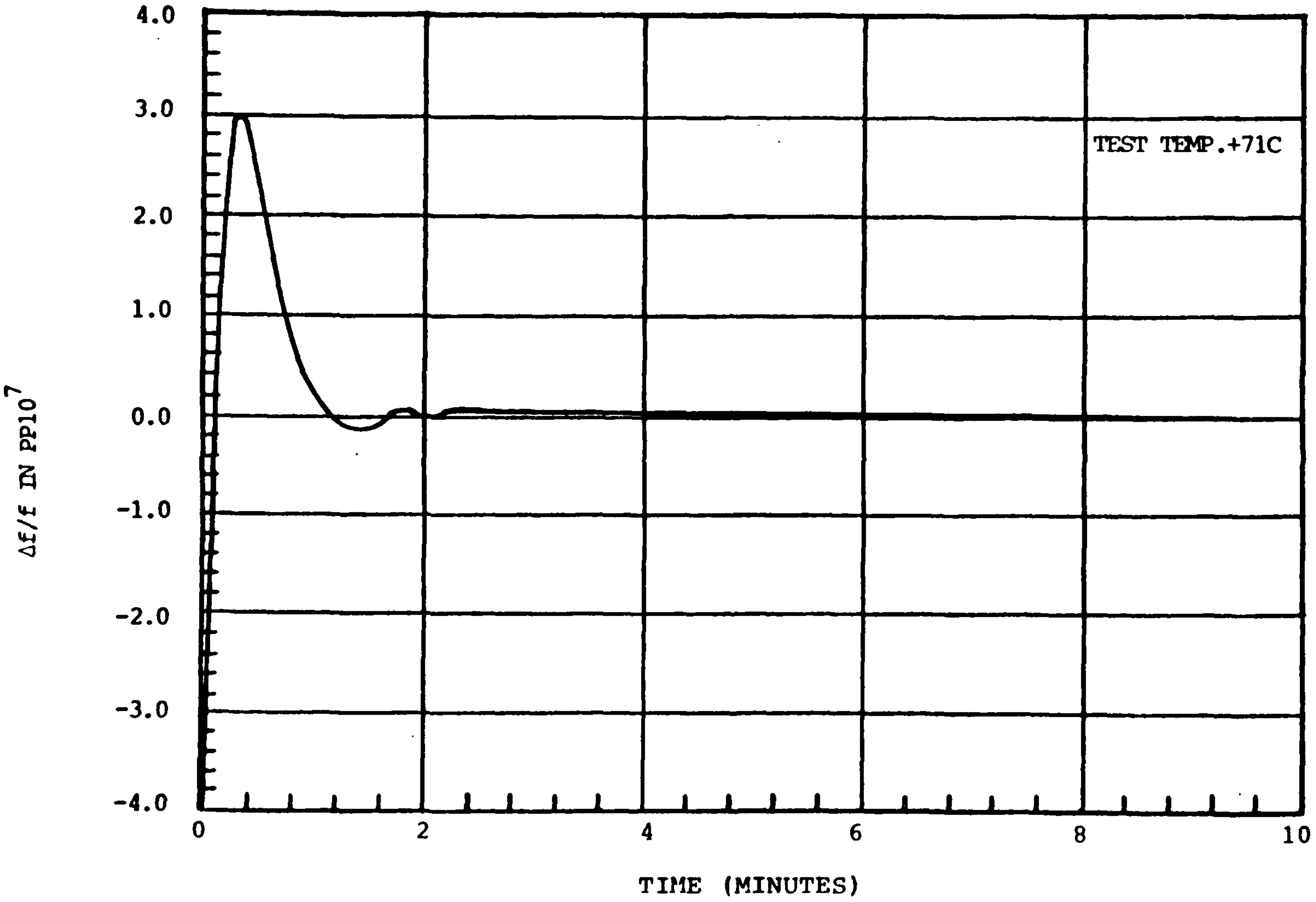


FIGURE 16 WARM-UP TIME MODEL FE-2211A

A31596-8079-9 (A19098-FOR)

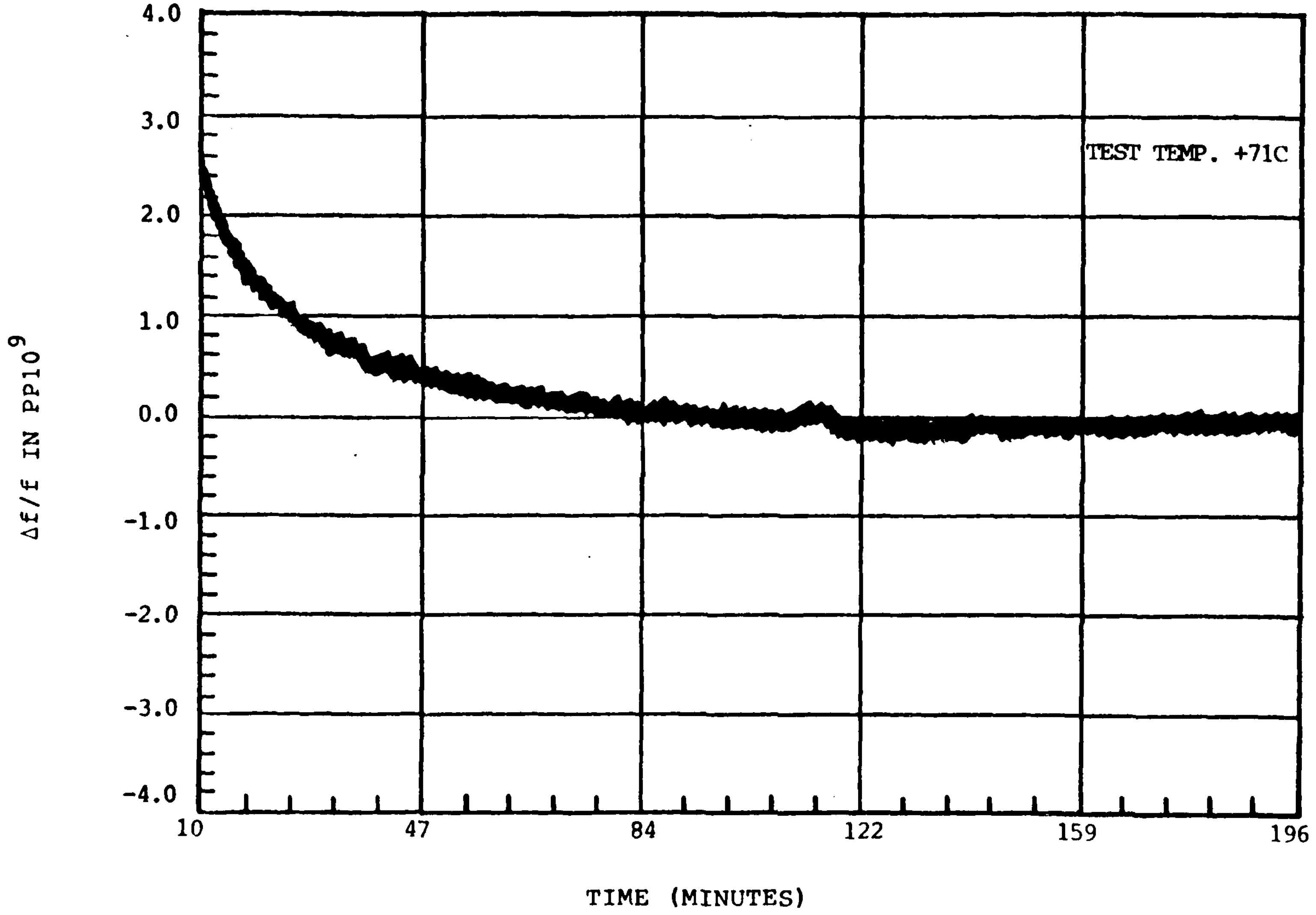


FIGURE 17 WARM-UP TIME MODEL FE-2211A

A31596-8079-10 (A19098-FOR)

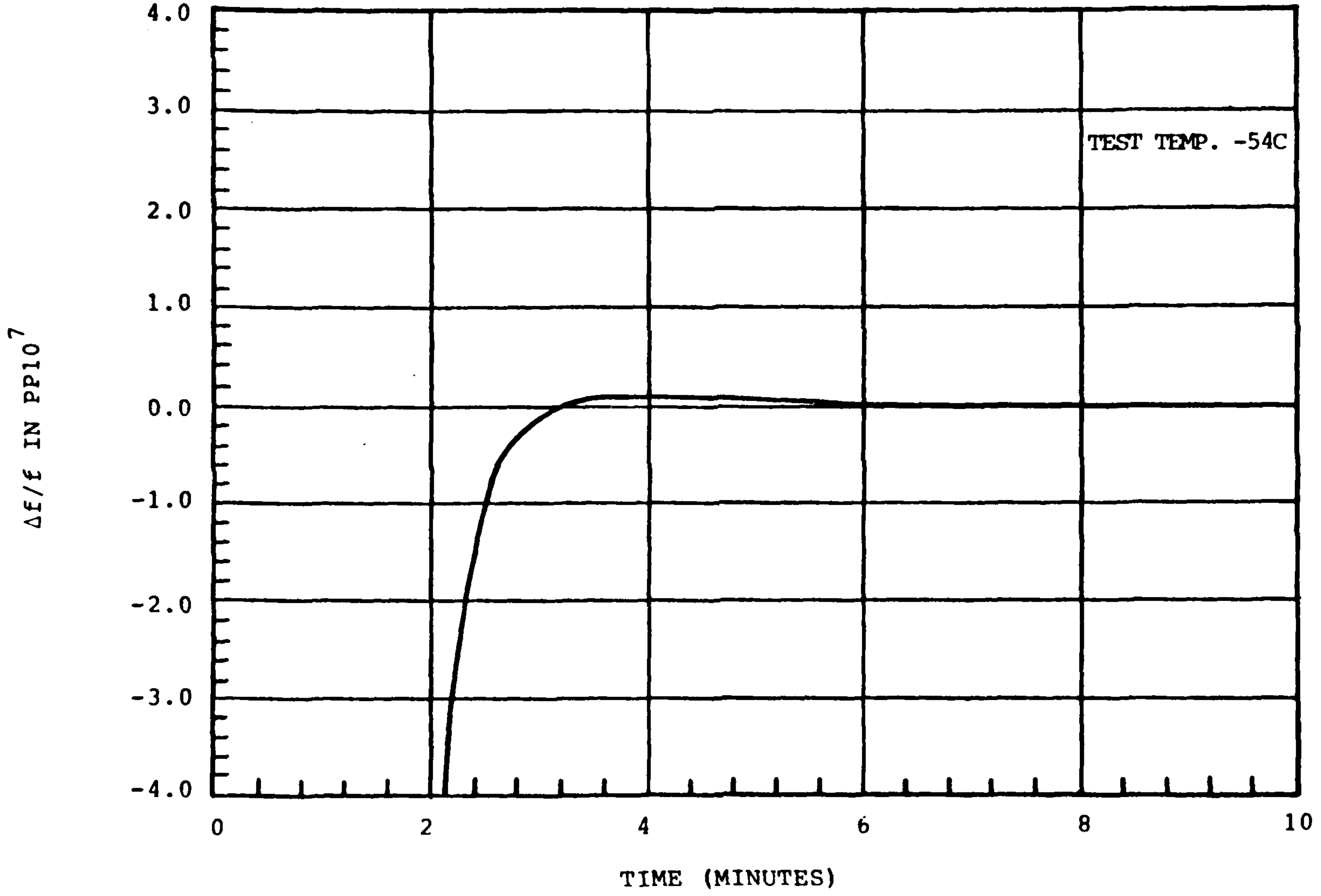


FIGURE 18 WARM-UP TIME MODEL FE-2211A

A31596-8079-11 (A19098-FOR)

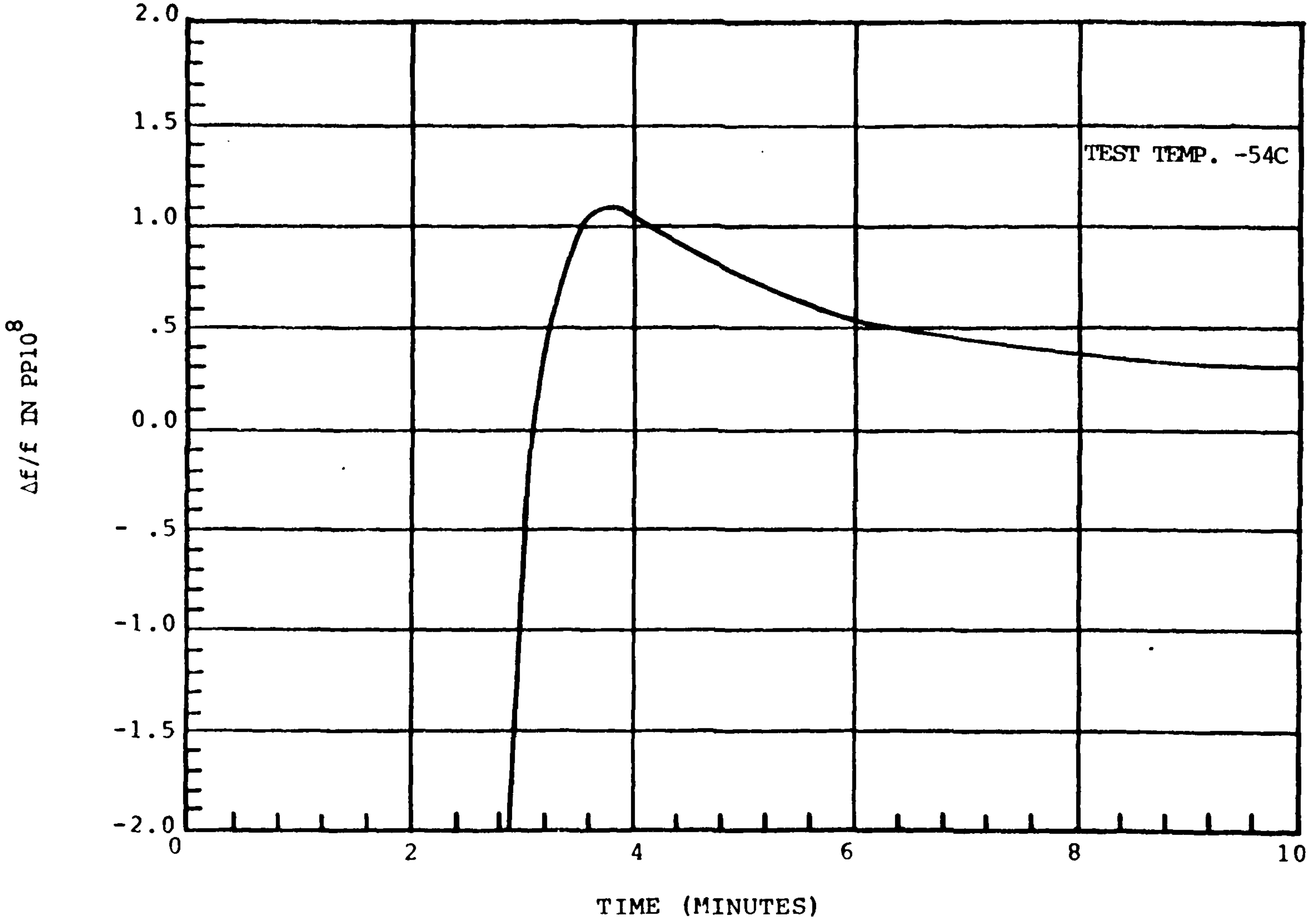


FIGURE 19 WARM-UP TIME MODEL FE-2211A

A31596-8079-12 (A19098-FOR)

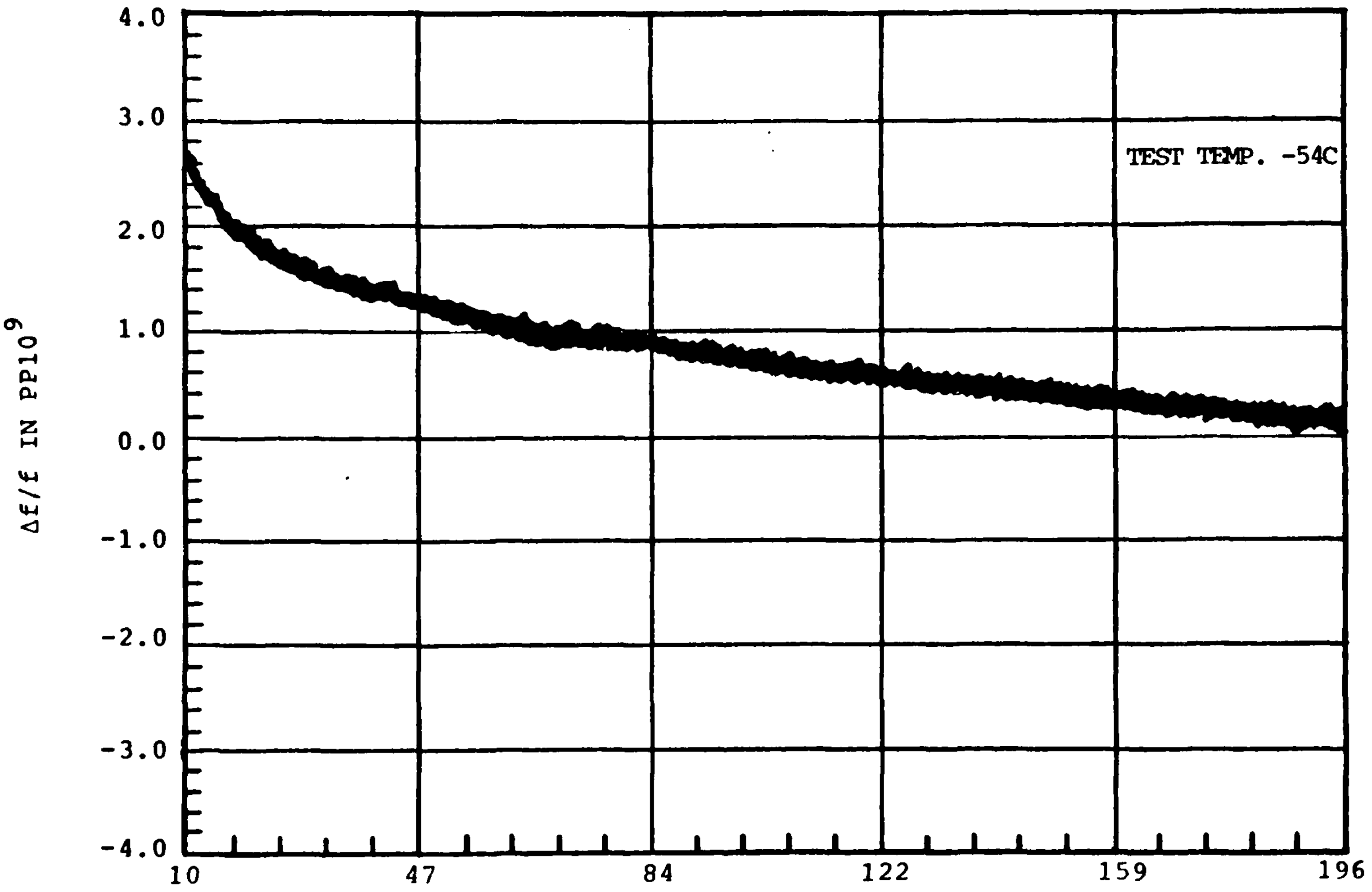


FIGURE 20 WARM-UP TIME MODEL FE-2211A

A31396-8079-13

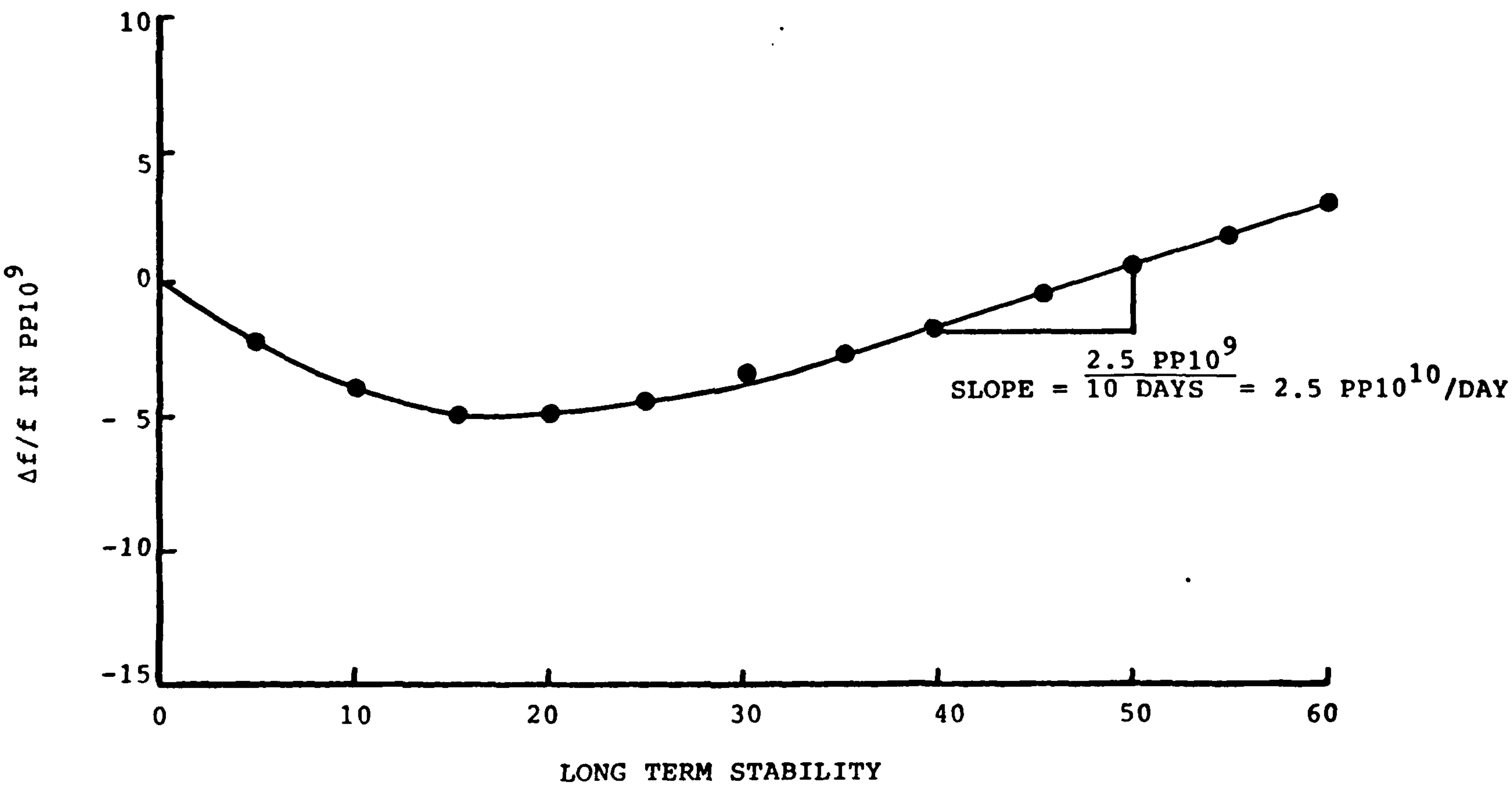


FIGURE 21 AGING RATE MODEL FE-2211A

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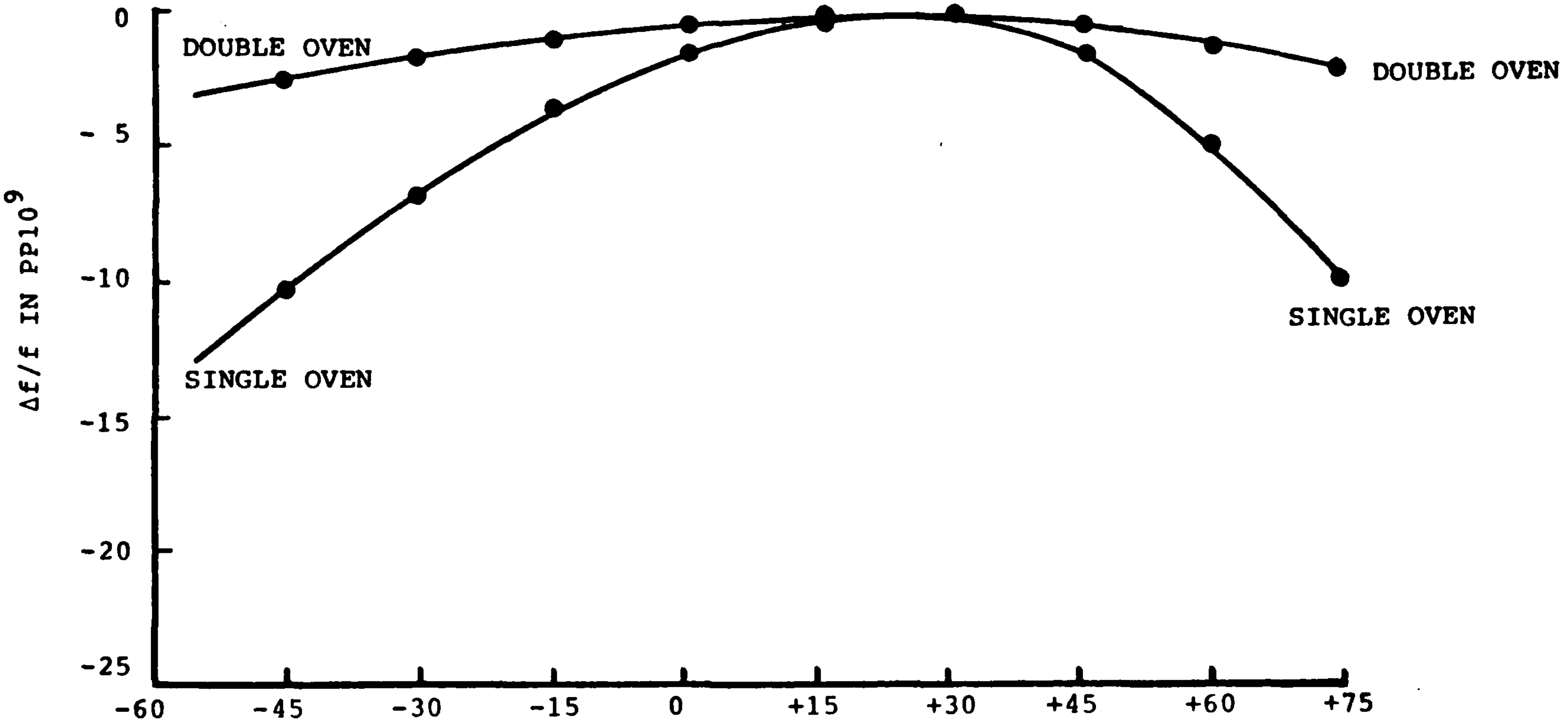

AMBIENT TEMPERATURE (°C)

FIGURE 22 TEMPERATURE STABILITY MODEL FE-2211A

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