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# ELECTRONIC RESETTABLE FUSE EVALUATION

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Developed under Contract NAS 5-10229 by
Electro-Mechanical Research, Inc. for
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

ABSTRACT

An electronic fuse has been developed which eliminates most objections to the use of fuses in satellites. When tripped it can be reset remotely by ground command. It can also be opened by ground command and therefore be used also as a switch. The drop in voltage across the fuse is less than 3 millivolts when the current is at the threshold level. Power to operate the fuse comes from a separate source and is only 8.4 milliwatts for a 1/8 ampere fuse. It therefore can be used in a wide variety of voltage systems. It is designed to have an inverse-current time delay characteristic with approximately one second delay at 200% rated current. The threshold level and time delay are somewhat affected by temperature and fuse electronics supply voltage. While it is usable in its present state of development, it is desirable to eliminate or reduce the dependence on temperature and supply voltage and develop further the packaging techniques.

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## ILLUSTRATIONS



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## INTRODUCTION

Experimenters have always been reluctant to allow fuses in the power line to their experiments in spacecraft for fear that a small surge in current might cause the fuse to blow and permanently kill their experiment. No one can accurately predict the precise amount of current required to blow a fuse and when it is found out experimentally it must be discarded. A need existed for a fuse which could be reset by an external pulse initiated from the ground.

A contract was made with Electro-Mechanical Research, Inc. for a feasibility study and development of an electronic fuse capable of being reset from an external pulse. It was determined that such a fuse was feasible and a breadboard was fabricated. Additional requirements were minimum voltage drop, power requirement, weight, and volume; 1/16 to 1/8 ampere rating incorporating a slow-blow characteristic with inverse time delay for transient overloads; and a voltage rating up to 70 volts. The make and break of the load current was done by a transistor controlled by a tunnel diode switch.

The fuse has several obvious limitations. First the power required was excessive; second, the physical size was too large but capable of being reduced; a third limitation was the fixed voltage at which the fuse had to be operated, taking its power for operation from the same source that it was protecting. The third limitation was made less restrictive by regulating the supply voltage to the fuse electronics so that the fuse could be used with any voltage from 30 to 70 volts with no appreciable change in efficiency which was about 96% at rated load.

An additional contract was made with Electro-Mechanical Research, Inc., for a new design utilizing a latching relay approach. It appeared that this would eliminate the first limitation of excessive power consumed since it uses no standby power. It would also eliminate the third limitation of the restricted voltage range which can be used by allowing isolation of the power to the fuse electronics from the power line being protected. For proper operation it was necessary that the fuse be capable of breaking the power line between the circuit being fused and the main power distribution bus if any of the following events occurred:

a. The current to the circuit gradually or instantaneously exceeded the current rating of the fuse for a period longer than the preset internal time delay period.

b. The power line of the circuit instantaneously shorted to power common during circuit operation.

c. The power line of the circuit was already shorted to power common when the spacecraft power was turned on.

The fuse was to meet the following specifications:

a. Rating: 1/8 ampere

b. Protection for sustained overload with inverse time delay trip characteristic. Nominal trip time shall be 1 second at 200% rated load.

c. Provision for set and reset from external pulse so that the fuse can also be used to command the experiment "on" or "off."

Design goals were as follows:

a. Low power dissipation in both "on" and "off" conditions.

b. Package in one cubic inch or less.

c. The fuse should be independent of the line voltage being protected.

d. The fusing point shall be as independent as possible of temperature variations (-20° C to +60° C).

e. It should reflect negligible noise to the power line.

f. It should provide negligible voltage drop across the device.

The fuse developed on this latest contract has been evaluated and the results constitute the subject of this report.

## DESCRIPTION

The electronic resettable fuse consists of two basic parts, the latching relay which breaks the power line circuit and the current sensing electronics. A detailed description of the circuit operation may be found in the final report prepared by Electro-Mechanical Research, Inc., which is included as Appendix A to this report. A block diagram is shown in Figure 1. Power to the fuse electronics is supplied from a 7 volt dc source. The latching relay may be closed by a pulse to the "on" coil from a command receiver. It may be opened by a pulse to the "off" coil either from a command receiver or from the relay drive within the fuse. The current sensing transformer contains three legs, with the oscillator current going through windings on the outer legs such that the fluxes

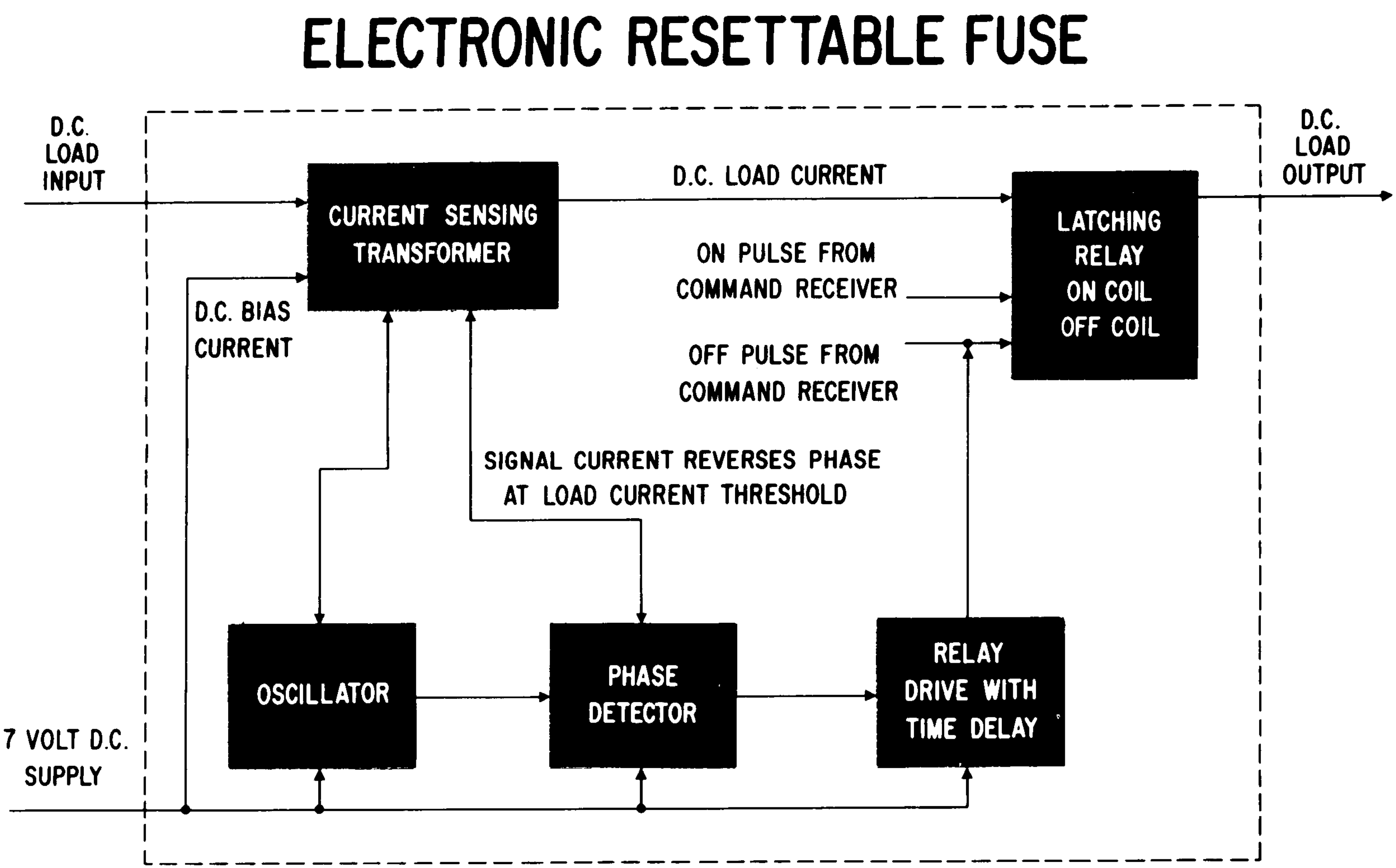


Figure 1. Block Diagram of Fuse

from this current aid each other and saturate the core in the outer legs during the peaks. The center leg contains two windings. One carrying the current being monitored is called the control winding, and the other carrying a bais current is called the sense winding. The flux in the center leg from these currents must pass through the outer legs where it is restricted by the saturated condition in these legs twice each cycle of oscillator current. The result is an ac signal generated in the sense winding. The ampere turns generated in the center leg windings oppose each other and are adjusted so that they nullify each other when the current in the control winding equals the rating of the fuse. Therefore the ac signal generated in the sense winding reverses itself when the load current reaches the fuse rating. This 180° phase shift in ac signal to the phase detector allows negative spikes, generated in an RC network fed by a square wave from the oscillator, to reach the relay drive circuitry which provides the pulse to open the latching relay. The latching relay consumes no power except during the pulse when it is opening or closing the contacts.

## TESTS

The following tests were performed on the fuse to ascertain how closely the design goals were met:

1. Determine steady state threshold current at room temperature after stabilizing temperature of fuse with 1/32 ampere load current for 30 minutes.

2. Repeat 1 except at -20° C.

3. Repeat 1 except at 60° C.

4. At room temperature determine the overcurrent time delay characteristic from 5/32 ampere to 1 ampere after stabilizing temperature of fuse with 1/32 ampere load current for 30 minutes.

5. Repeat 4 except at -20° C.

6. Repeat 4 except at 60° C.

7. Repeat 1 except after stabilizing temperature of fuse with 0.11 ampere load current for 30 minutes.

8. Repeat 1 except at -20° C after stabilizing temperature of fuse with 0.11 ampere load current for 30 minutes.

9. Repeat 1 except at 60° C after stabilizing temperature of fuse with 0.11 ampere load current for 30 minutes.

10. Repeat 4 except after stabilizing temperature of fuse with 0.11 ampere load current for 30 minutes.

11. Repeat 4 except at -20° C after stabilizing temperature of fuse with 0.11 ampere load current for 30 minutes.

12. Repeat 4 except at 60° C after stabilizing temperature of fuse with 0.11 ampere load current for 30 minutes.

13. Determine dependency of threshold current on fuse electronics supply voltage at room temperature.

14. Determine dependency of time delay on fuse electronics supply voltage at room temperature.

15. Repeat 14 except at -20° C.

16. Determine voltage drop across the fuse vs load current (below rated) at room temperature.

17. Determine power consumption of the fuse at 7 volts input to the electronics.

18. Verify operation of fuse under short circuit with power source limited to one ampere.

    a. Short circuit is applied after power source starts supplying current to the load.

    b. Short circuit is applied before power source starts supplying current to the load.

A circuit diagram showing all instrumentation is given in Figure 2. The Harrison Lab. Model 865B power supply provided the power to the fuse electronics while a Hewlett Packard Model 721A supplied the reset pulse. The stabilizing currents of 1/32 or 0.11 ampere were obtained by switching through either the 80 or 320 ohm resistors with fine adjustment of current obtained by adjusting the voltage of the Trygon power supply. The overload current was first adjusted by the three variable resistors with the double throw switch in the "adjust" position. The current was measured by reading the voltage across a 10 ampere

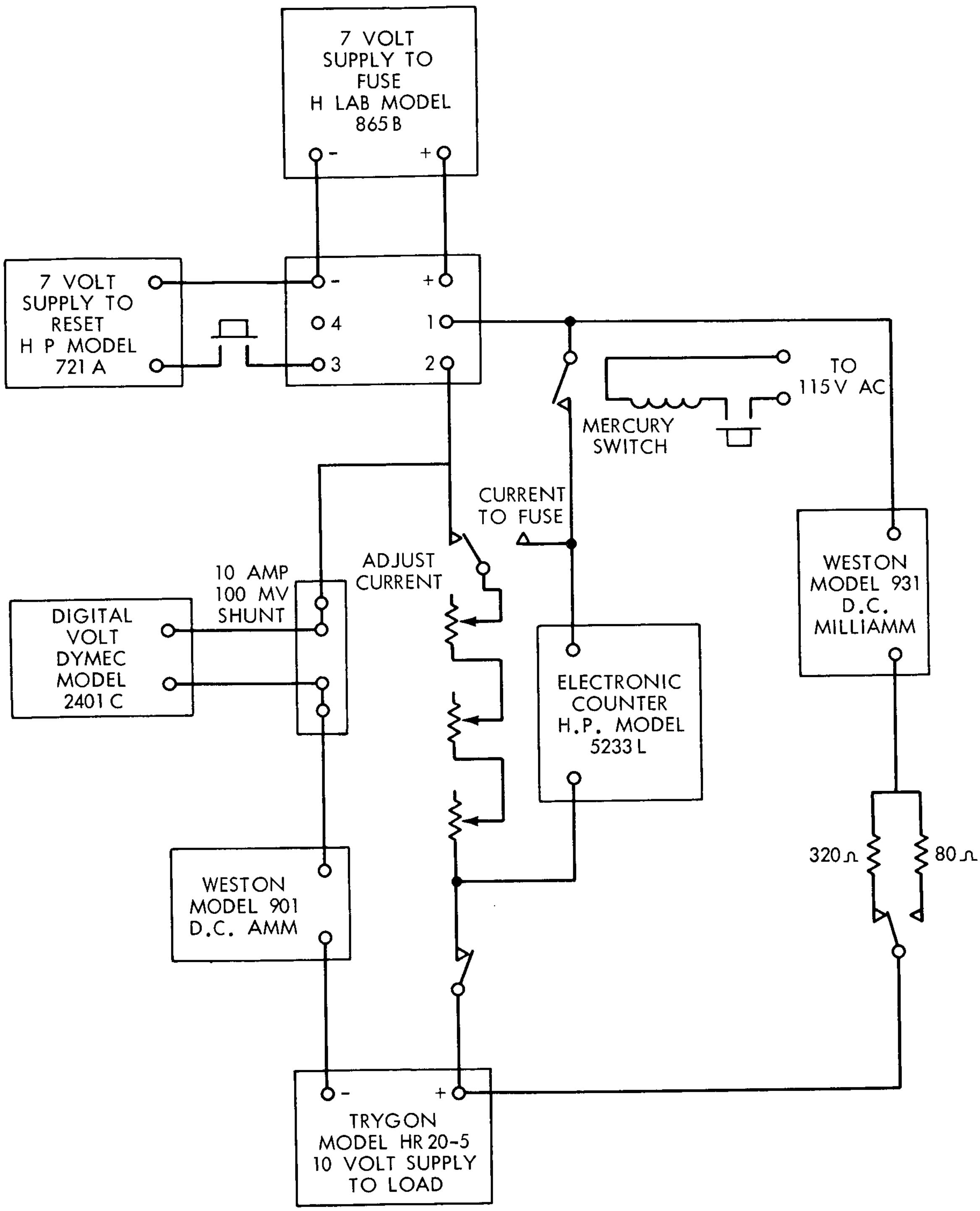


Figure 2. Circuit Diagram of Test

100 mv shunt with a Dymec Model 2401C integrating voltmeter. The double throw switch was then thrown to the "current to fuse" position. The circuit to the fuse was closed by a relay with mercury contacts to avoid contact bounce. The voltage drop appearing across the variable resistors at the instant the overload current starts through the fuse, starts the Hewlett Packard Model 5233L counter. When the fuse interrupts the current the loss in voltage drop across the variable resistors stops the counter.

## RESULTS

The results of the first six tests are shown graphically in Figure 3. The threshold currents, indicated by the horizontal portions of the curves are somewhat dependent on temperature. At 24° C they are very close to rated. At -20° and +60° C they are +25% and -5% respectively variant from its room temperature value (24° C). At room temperature, the time delay at 200% rated load is only 6% above its desired nominal value. At just above rated current, the time delays at -20° and +60° C are +35% and -29% respectively variant from its room temperature value. However, at eight times rated current, the time delays at -20° and +60° C are +1093% and -51% respectively variant from its room temperature value.

The results of tests 7 through 12 are shown graphically in Figure 4. These tests are the same as tests 1 through 6 except that the stabilizing current is increased from 1/32 ampere to the near rated value of 0.11 ampere. As might be expected these current time characteristics are not much different from those in Figure 3. The most notable difference is the reduction in threshold current variation from +25% to +9% when the temperature drops from 24° C to -20° C.

The effect of variation in fuse electronics supply voltage on the threshold current (test 13) may be seen in Figure 5. The threshold current increases 7.3% as the voltage decreases from 7 to 6.5 volts. Similarly the threshold current decreases 4.7% as the voltage increases from 7 to 7.5 volts.

The effect of variation in fuse electronics supply voltage on the time delay at room temperature for several values of overcurrent (test 14) is shown in Figure 6. It appears at the first look that the dependence of time delay on supply voltage is greater at low overcurrents than at high overcurrents but when expressed as a percentage, the time delay variations for a 10 volt variation of supply voltage are approximately twice the 1.0 ampere values for the 0.75 and 0.50 ampere curves. The time delay variation for the 0.25 ampere curve is only 11% higher than that for the 1.0 ampere curve.

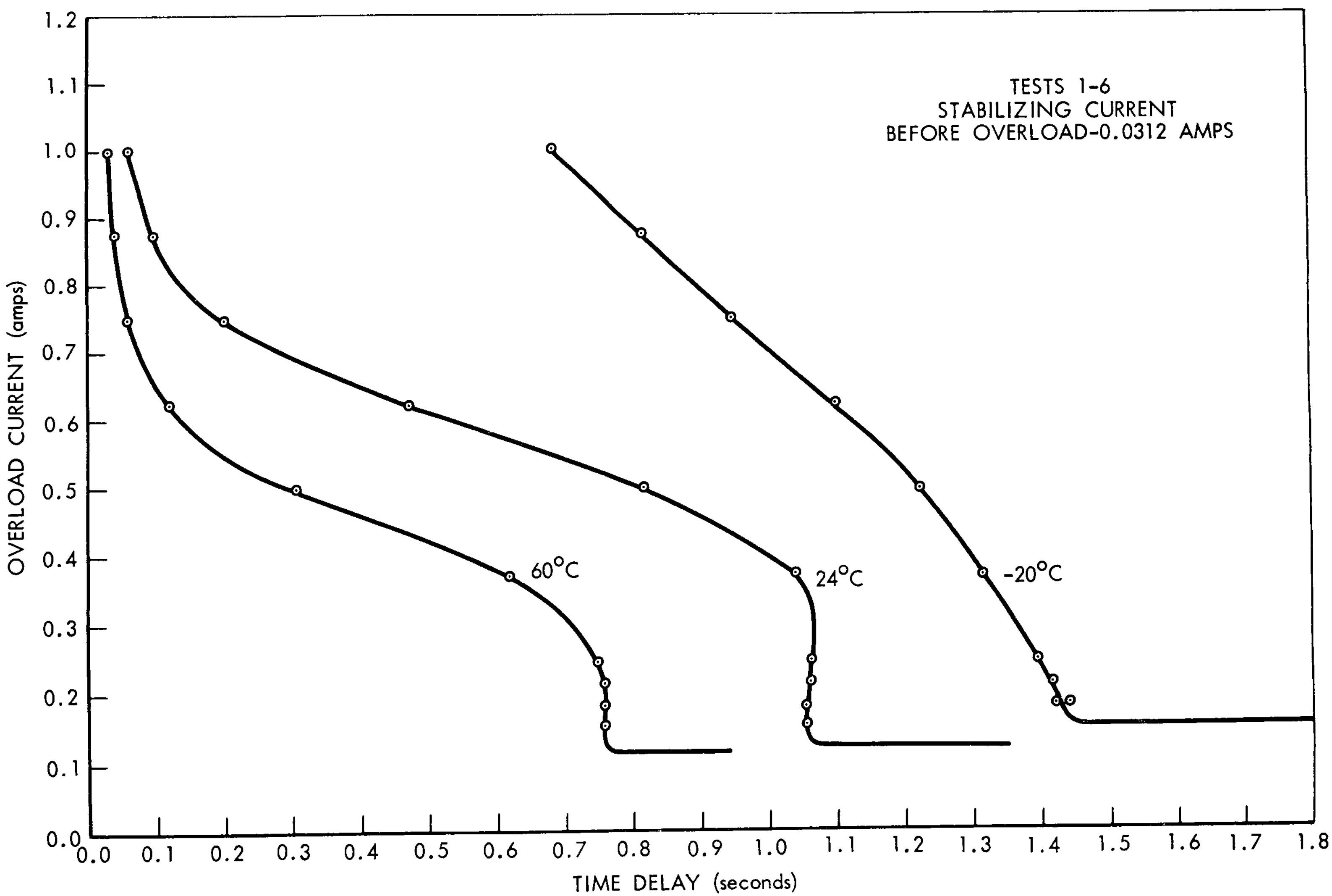


Figure 3. Current-Time Delay Characteristic for Low Stabilizing Current

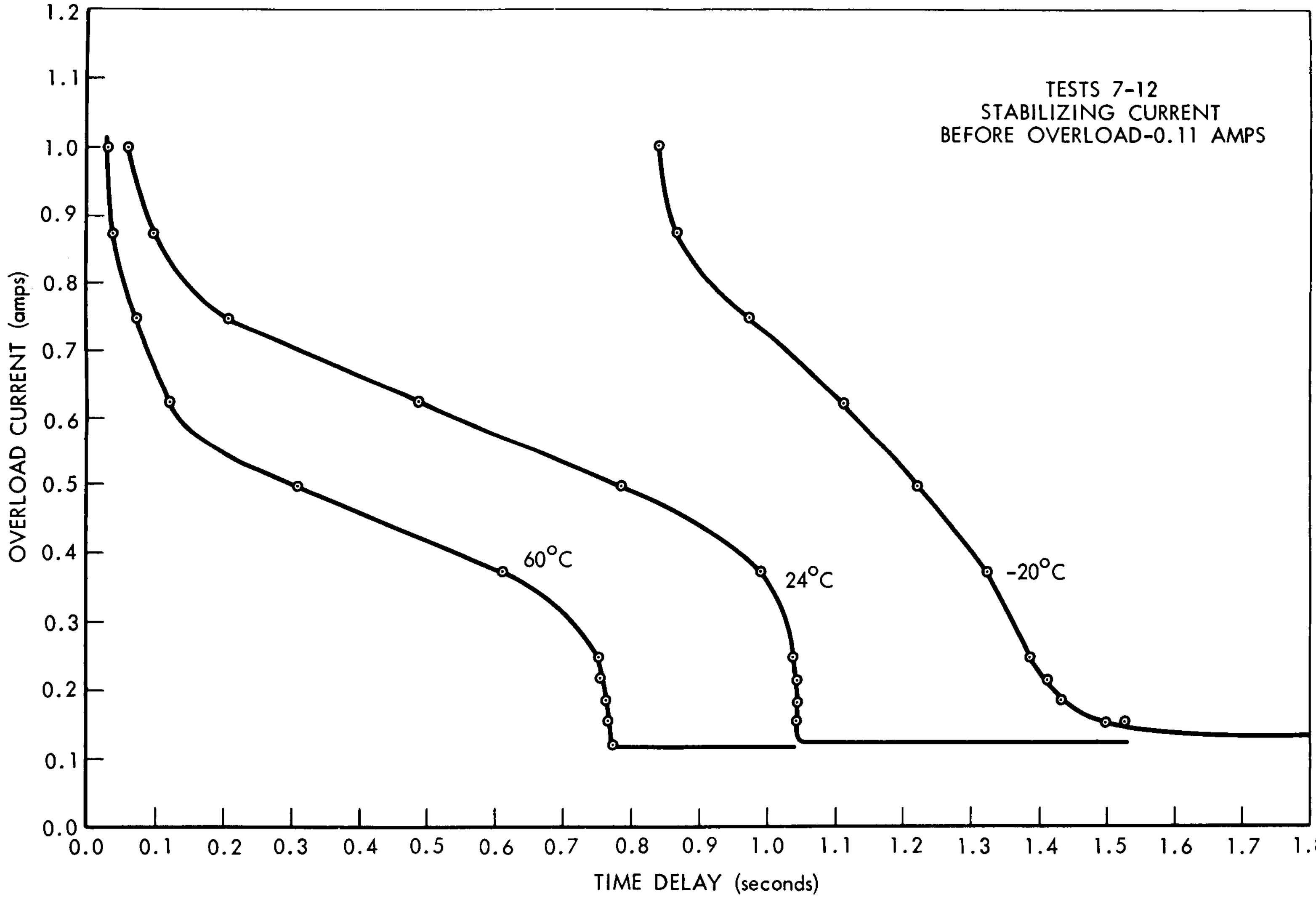


Figure 4. Current-Time Delay Characteristic for Near Threshold Stabilizing Current

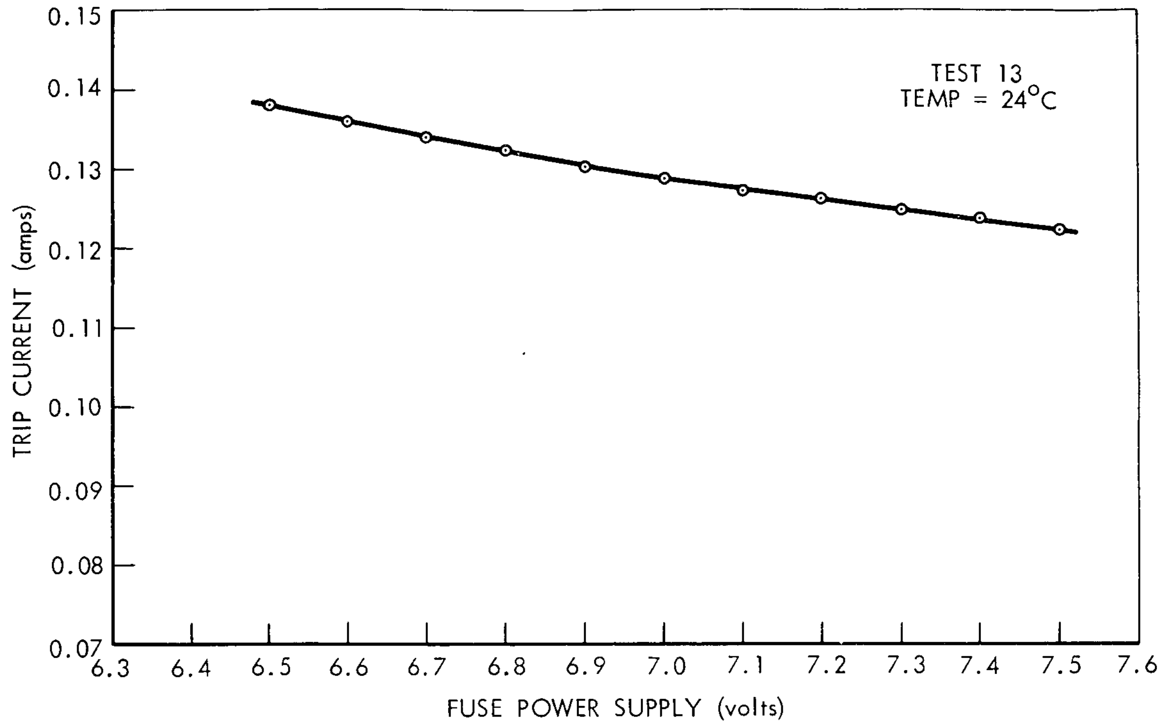


Figure 5. Trip Current as Function of Supply Voltage to Fuse Electronics

Similar data is shown in Figure 7 for a temperature of -20° C (test 15). Note here that all curves have approximately the same slope with approximately the same variation in time delay when expressed in seconds; but expressed as a percentage, the variation increases considerably from 0.25 to 1.0 ampere.

The drop in voltage across the fuse in the load circuit (test 16) is 2.78 millivolts at the threshold level. At less currents the drop is proportional. The power consumption in the fuse at 7 volts input is 8.4 milliwatts while in the load circuit it is 0.35 milliwatts at the threshold level making a maximum loss of 8.75 milliwatts.

The fuse operates satisfactorily with a short circuit applied either before or after the power source starts supplying current to the load. The maximum current to the short circuit was limited to one ampere for this test.

## CONCLUSIONS

The fuse is very consistent in time delays when all of the parameters are controlled. Where several readings were taken for a given set of conditions the values were so close that they constituted a single point on the curve in most every case. There were no occasions where the fuse failed to open the circuit so long as there was no failure of the 7 volt supply.

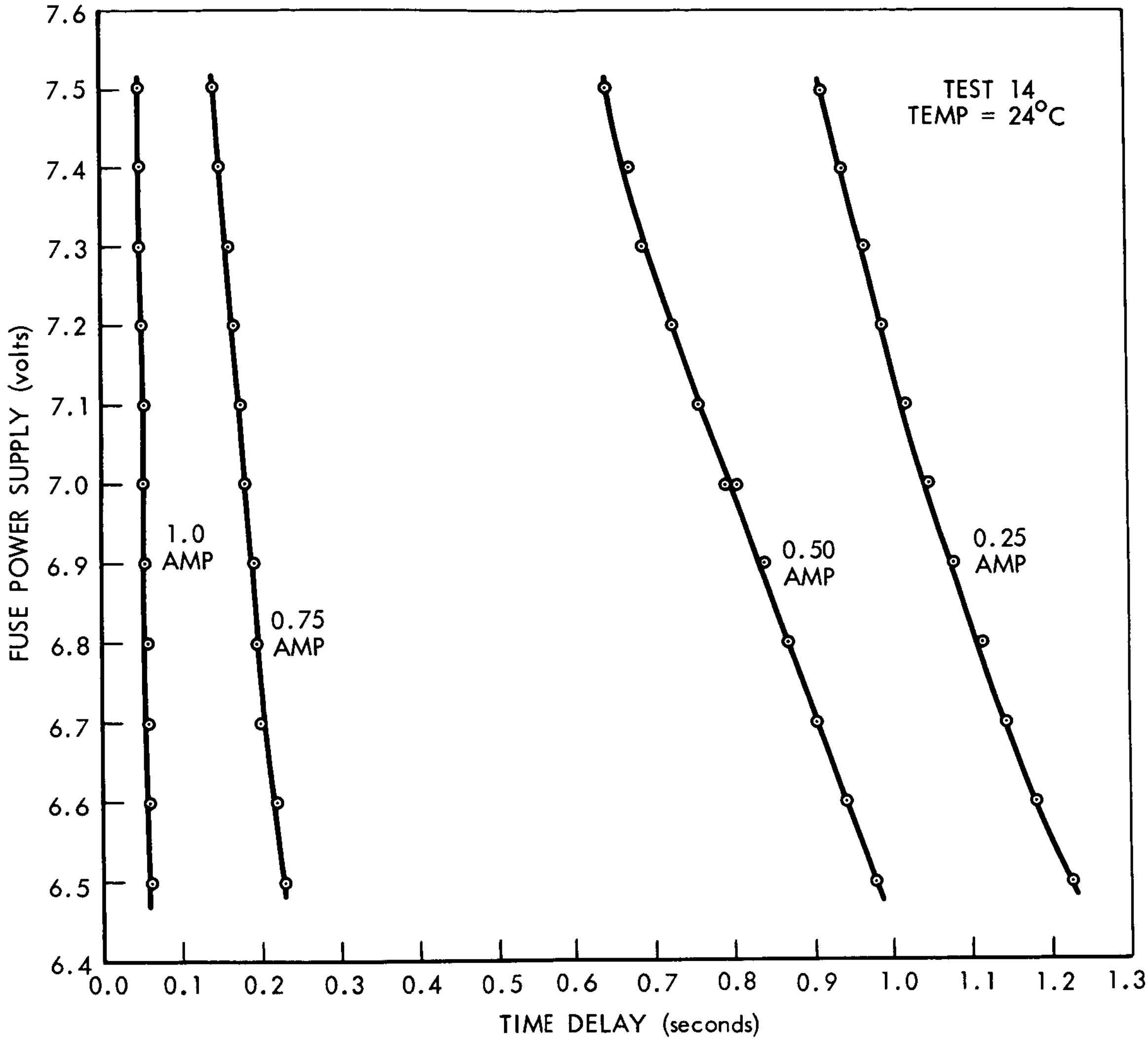


Figure 6. Time Delay as Function of Supply Voltage to Fuse Electronics at Room Temperature

It is concluded that the fuse would find many uses even with its time delay dependence on temperature. However, it would be a distinct advantage to eliminate or at least reduce this temperature dependence particularly at low temperatures. The same comments are applicable with regard to the time delay dependence on supply voltage. It would be advantageous to reduce this supply voltage dependence on time delay. The fact that, at -20° C (Figure 7), all curves exhibit the same time delay as opposed to those in Figure 6, expressed in seconds, vs fuse power supply, suggests that the greatest part of the time delay at this temperature occurs in the relay itself, since the pulse is the same in each case.

The drop in voltage across the fuse in the load circuit is quite satisfactory. It would result in less than one millivolt drop for most normal loads with

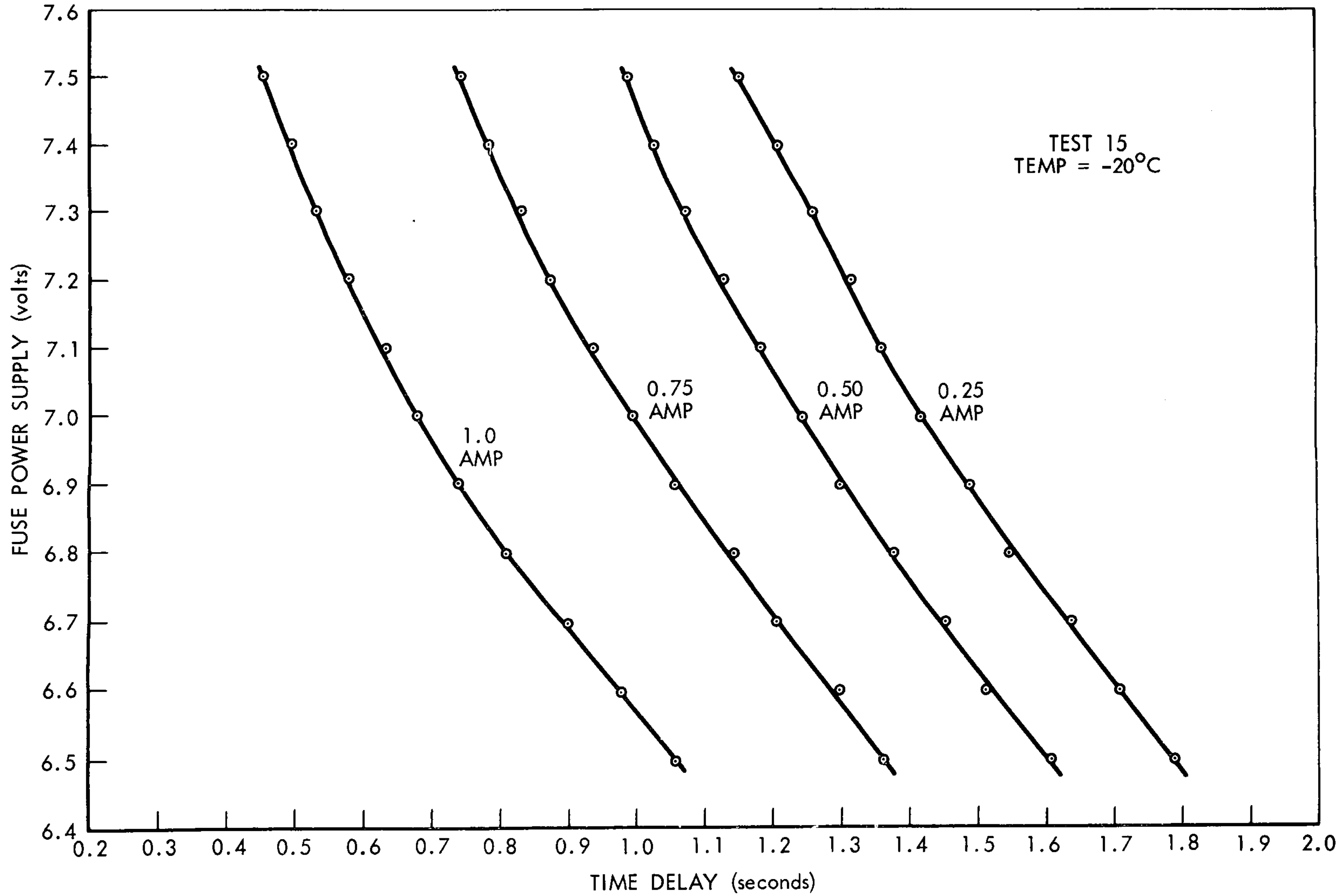


Figure 7. Time Delay as Function of Supply Voltage to Fuse Electronics at Cold Temperature

customary fuse sizing. Power consumption is also quite satisfactory for most applications.

The maximum current rating of one ampere is limited by the rating of the relay. This value is considered too low for some applications where the source can be expected to furnish greater values.

This fuse obtains its power from a 7 volt supply. From the standpoint of its use in a spacecraft it appears that a 12 volt supply would be generally more available. However, the 7 volts may be better suited to the particular components in use. The 7 volts may be easily obtained by regulating down from 12 volts but this would involve greater power consumption. Unless the input current was reduced as the voltage input was raised to 12 volts it would not be beneficial to go to 12 volts.

If a short circuit of sufficient magnitude should occur which would cause an immediate collapse of the 7 volt supply the fuse would not operate since there is no storage of energy within the fuse to supply the necessary pulse to the relay. A modification to incorporate such an energy storage would greatly increase the reliability of the fuse to handle heavy short circuits in a spacecraft with limited power.

So far the fuse has not met the design goal of packaging in one cubic inch. Present volume is 1.4 cubic inches. If several fuses were fabricated as a unit with a common oscillator or if an ac square wave were supplied from an external source, it is likely the packaging requirement of 1 cubic inch per fuse could be met.

## RECOMMENDATIONS

This fuse has shown itself to be a useful device for future use in spacecraft particularly where telemetry channels are available for remote control of switching and reset functions. It is therefore recommended that further development be done to improve its characteristics and provide suitable packaging for flight use, as follows:

1. The maximum overload current rating of the relay should be increased from one ampere to a 3 to 10 ampere range according to fuse rating.

2. Energy should be stored in the fuse electronics to insure operation of the fuse in case a short circuit causes a total failure of the spacecraft bus voltage.

3. The time delay temperature compensation of the fuse should be improved, particularly for high overloads at low temperatures.

4. Less variation in threshold current over the temperature range is desirable particularly at low temperatures.

5. The time delay supply voltage compensation of the fuse should be improved.

6. The circuitry should be checked and changed if necessary to insure that the "on" and "off" command will not be impaired in the event the oscillator or any fuse component fails.

7. The fuse should be packaged in an airborne configuration such that one or more fuses of equal or different rating may be used with a common oscillator or with an external source of ac square wave. Each fuse without the oscillator should occupy less than one cubic inch if possible.

When the fuse has been improved and packaged satisfactorily, manufacturing drawings and specifications should be procured such that the fuses may be procured in quantity and in rating as needed.

FINAL REPORT

FOR

ELECTRONIC FUSE

29 November 1966

CONTRACT NO. NAS5-10229

Prepared By

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## SUMMARY

This report describes, in detail, a fuse developed specifically for spacecraft application. The fuse has the capability of being reset and has the features of negligible voltage drop across the device, time delay trip characteristics, and low power dissipation. The fuse uses a latching relay as the current breaking element and a unique magnetic approach for detecting the fuse trip point. The fuse has a 5% trip point accuracy over normal spacecraft temperature ranges.

## 1.0 INTRODUCTION

This report summarizes the results of the devlepment program for an electronic fuse suitable for spacecraft applications. The work was performed by the Aerospace Sciences Division of Electro-Mechanical Research, Inc., under contract NAS5-10229. Results of previous efforts on this program were documented in the "First Quarterly Report for Electronic Fuse", dated September 13, 1966.

## 1.1 PROBLEM DEFINITION

In most satellites the main power distribution lines are common to all experiments, therefore, if a single experiment draws excessive current or develops a power line short it would jeopardize the complete mission of the spacecraft. A solution to this problem is to place a fusing element in series with each experiment. This final report discusses in detail the operation and test results of such a fusing element. For proper operation, it is necessary that the fuse be capable of breaking the power line between the circuit being fused and the main power distribution buss if any of the following events occur:

a. The current to the circuit gradually or instantaneously exceeds the current rating of the fuse for a period longer than the preset internal time delay period.

b. The power line of the circuit instantaneously shorts to power common during circuit operation.

c. The power line of the circuit is already shorted to power common when the spacecraft power is turned on.

## 1.2 FUSE SPECIFICATIONS

In addition to meeting the above considerations, other electrical requirements for a fuse designed for spacecraft application are:

a. Provisions for being reset by an external pulse.

b. Low power dissipation in both the "on" and "off" conditions.

c. A time delay trip characteristic to prevent the fuse from tripping on short transients which may exceed the fuse current ratings.

d. Fusing point independent of fused power line voltage.

e. Fusing point should be as independent as possible of temperature (-20° C to +60° C).

f. To provide external "set" and "reset" inputs so that the fuse can also be used to command the experiment "on" or "off".

g. To reflect negligible noise to the power line.

h. To provide negligible voltage drop across the device.

## 2.0 TECHNICAL APPROACH

Basically, the electronic fuse consists of two parts, the switch which breaks the power line and the current sensor. A latching relay was specified as the power line breaking element because of its inherent advantages of negligible power dissipation, and capability of storing its state of operation, thus eliminating a binary circuit.

The major consideration of the project was the determination of the type sensor to be used. The sensor is divided into various functional components and each is analyzed with respect to its place in the complete design.

## 2.1 TRANSFORMER CHARACTERISTICS

The method of sensing load current forms a starting point for design. Let's consider the magnetic configuration shown in Figure 2.1-1. A balanced oscillator winding is placed on the two outside legs (Windings A and B) and a sense winding (Winding C) and a control winding (Winding D) are placed on the center leg of the magnet. Because the oscillator windings are balanced and in phase, the AC flux developed by these windings cancel in the center leg. The purpose of the AC excitation is to produce an AC flux which saturates the outside path at waveform peak points.

Now consider that a DC current is passed through the control winding (Winding D). This current produces a DC flux in the center leg which completes its loop through the two outside paths. The outside path, however, is placed in and out of saturation due to the AC excitation discussed above. The DC flux path is therefore completed only during the intervals when the outside path is in the unsaturated condition because the path acts essentially as an open circuit to the DC flux when it is in the saturated condition. It is also noted that the outside loop is placed into and out of saturation twice per excitation cycle, and the DC flux path is therefore completed twice per excitation cycle, Because of this phenomena, an AC voltage appears across the sense winding (Winding C) which is twice the frequency of the excitation waveform whenever a DC current is passed through the control winding (Winding D).

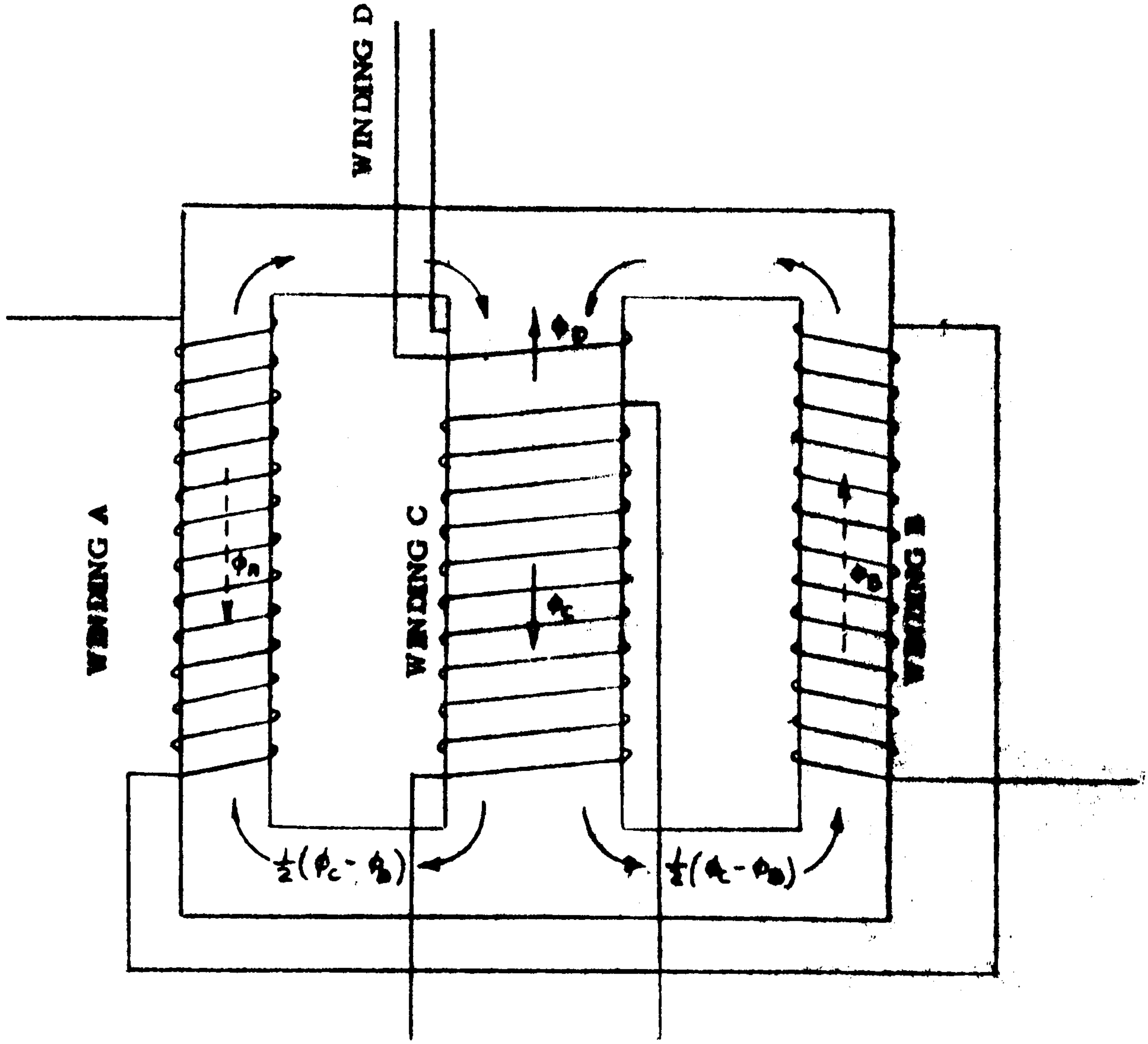



FIG. 2.1.1 - TRANSFORMER

Shown in Figure 2.1-2 are the waveforms across the various windings with positive current, no current, and negative current through the control winding. Because the induced DC flux direction reverses when the current through the control winding reverses, a phase shift of 180° of the induced AC voltage across the sense winding occurs.

The control winding has only one turn and the sense winding has approximately 1000 turns around the center leg of the transformer. In the actual case, a DC bias current is passed through the sense winding in such a direction as to cause the induced flux to be opposite to the induced flux produced by positive current through the control winding. Under this condition as the current through the control winding gradually increases, there will be a point where the flux induced by the control winding exceeds the DC flux induced by the sense winding. At this point, the phase of the AC voltage induced in the sense winding changes 180°. The phase reversal characteristic is the phenomena utilized in the fuse detection circuitry. The fusing point is determined by the following relationship:

$$I_f = N_s I_s$$

where:

$I_f$ = Fusing Current

$N_s$ = Number of sense winding turns

$I_s$ = Sense winding DC bias current

It is noted that the fusing point can easily be made any value by controlling $N_s$ for course adjustment and $I_s$ for precise adjustment.

Permalloy 80 was selected as the transform core material due to its low magnetizing force. The core consists of 30 layers of .004 gage EE laminations. The laminations are Magnetics Inc., part number EE-28-29-4D.

## 2.2 CIRCUIT DESCRIPTION

The circuit shown in Drawing 03-19-103 is composed of five parts: The transformer, oscillator, phase detector, relay drive, and latching relay. The AC excitation current for the transformer discussed in Section 2.1 is produced by the oscillator. The oscillator is a complementary circuit which was selected because of its low power dissipation and low

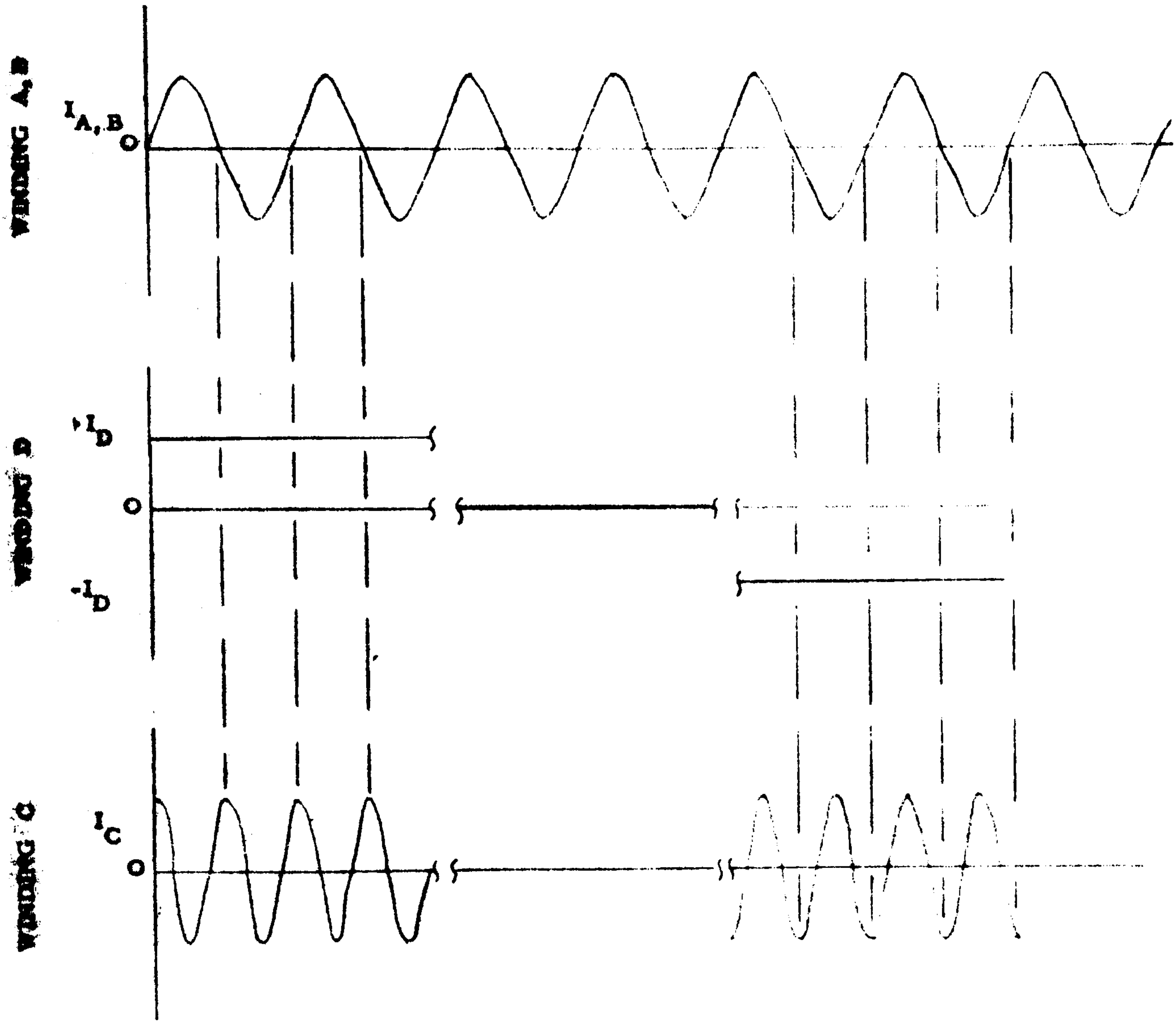



FIG. 2.1.2 TRANSFORMER WAVEFORMS

output impedance. The output is capacitively coupled to both the oscillator windings of the transformer and to the phase detector.

The phase detector (transistor stages Q5, Q6, Q7, Q10 and Q11) detects the phase reversal point of the transformer sense winding induced signal. This sense winding signal is amplified by differential amplifier Q10 and Q11. This amplified signal which is essentially a square wave is applied to transistor stage Q6 which either inhibits or allows the negative spike through C7 from turning on Transistor Q7. As shown in Figure 2.2-1, the phase relationship which is controlled by the transformer is such that under normal operating conditions Q6 is turned "on" when the negative pulse through C7 occurs. If the current set point is exceeded, the phase of the sense winding changes 180°, therefore, Q6 is "off" when the pulse through C7 occurs, allowing Q7 to apply positive pulses to the relay driver circuit.

The relay drive circuit has a delay characteristic which is controlled by components R12, R13 and C9. If pulses from the phase detector are present for a sufficient period of time, the voltage on capacitor C9 will reach the turn on threshold of transistor Q8. Q8 turns "on" transistor Q9 which is the current drive stage for the "set" coil of the relay. R26 and CR2 are placed in the circuit to assure that the circuit would react to a very high current overload which would be sufficient to saturate the magnetic core of the transformer. The relay, in addition to opening the power line circuit when a "set" pulse is received from the relay driven circuits, has the capability of being externally controlled by a "set" or "reset" pulse.

## 2.3 FUSE TEST RESULTS

The electrical specifications and interface requirements are as follows:

a. Fuse Rating - 1/8 ampere

b. Fusing point dependence on temperature - The fusing point will vary less ±5% from its room temperature value over the temperature range of -20°C to +60°C (As shown in Figure 2.3-1, the fusing point of the prototype unit varies less than ± 3% from its room temperature value over the temperature range).

c. Fusing point dependence on fused buss voltage - no dependence observed.

d. Fusing point dependence on 7v power line voltage - approximately ± 5% variation for a ± 10% variation in the 7v power line voltage (See Figure 2.3-2).

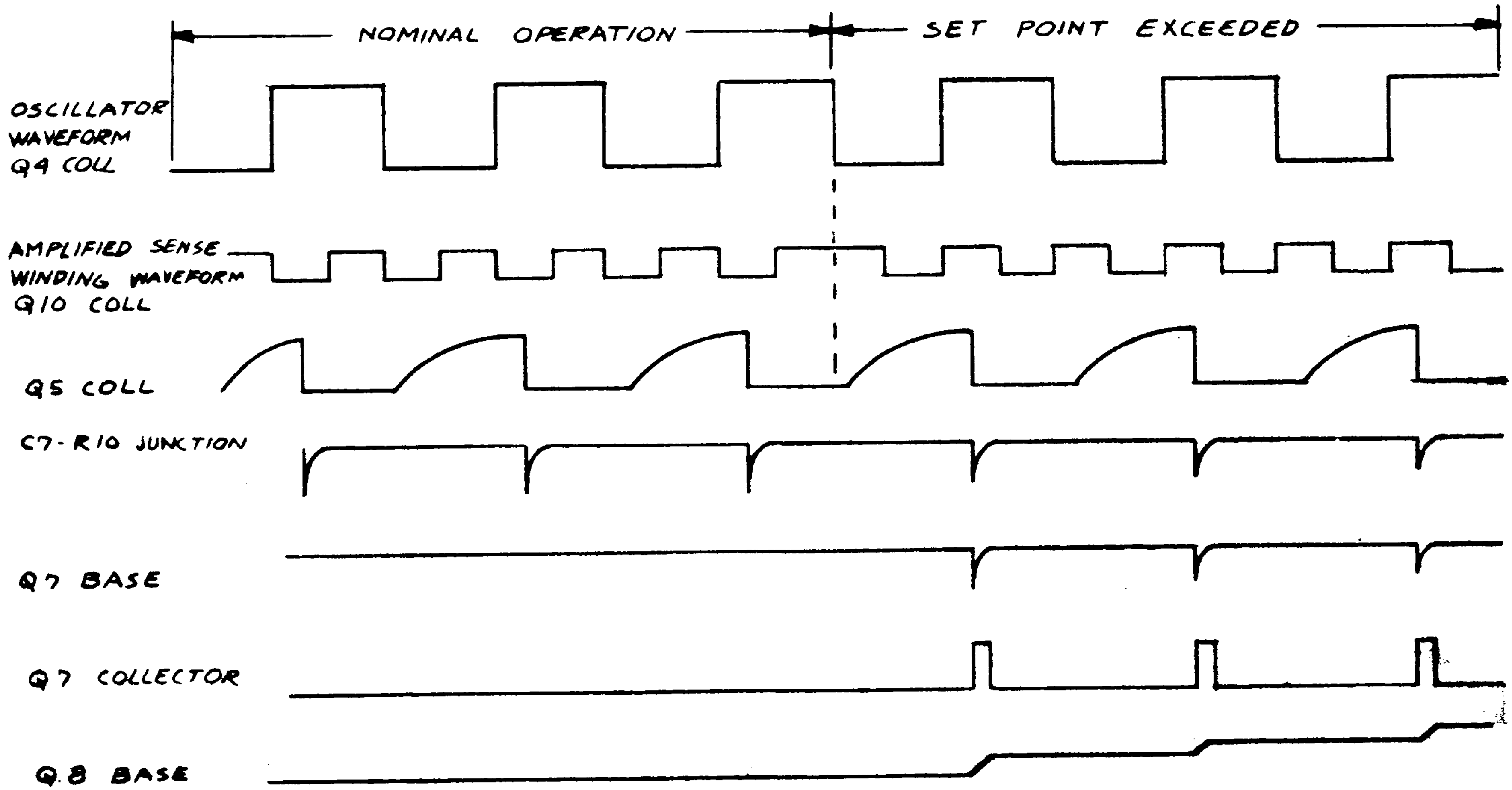



FIGURE 2.2-1 CIRCUIT WAVEFORMS

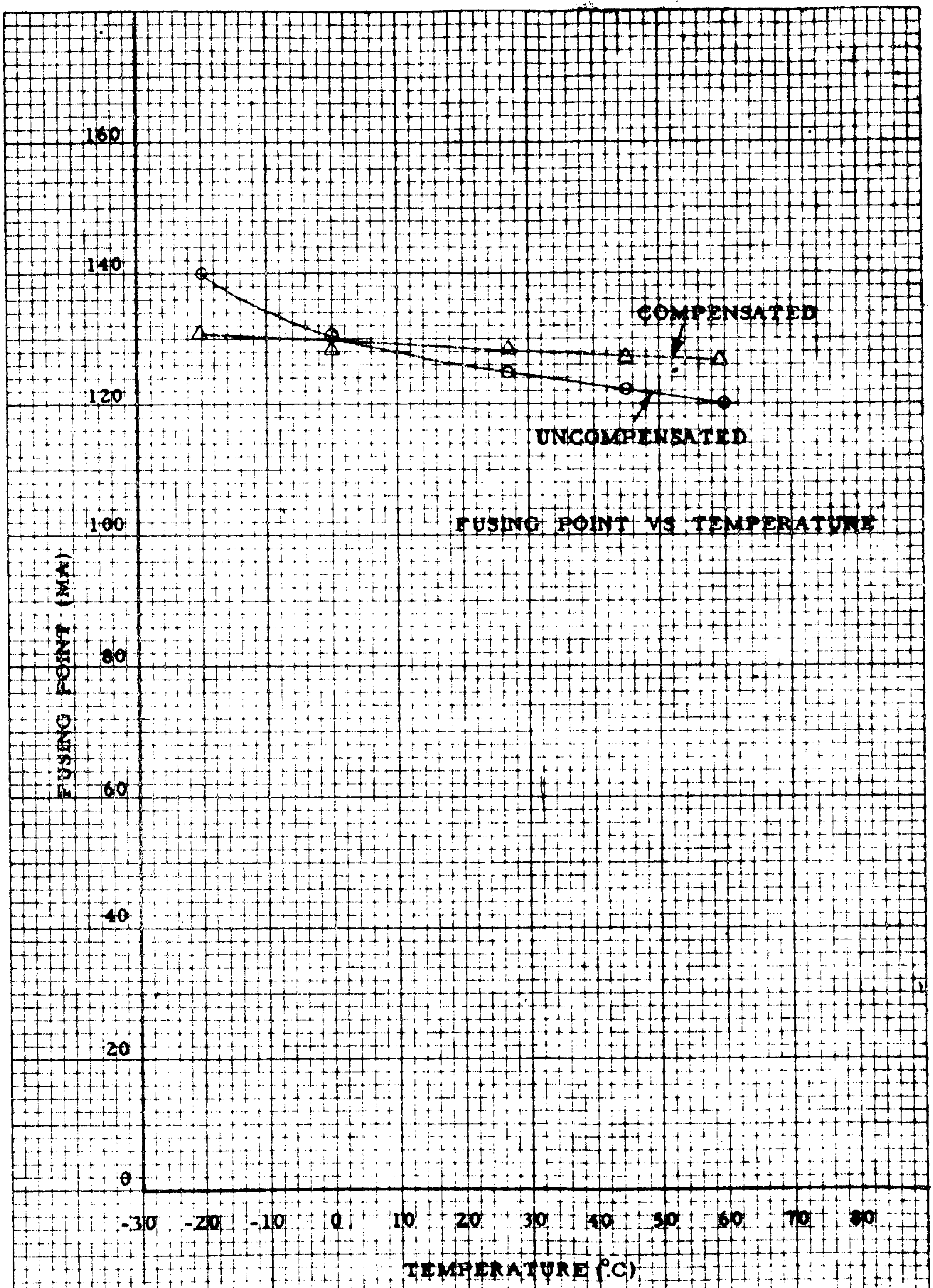

COMPENSATED
UNCOMPENSATED
FUSING POINT VS TEMPERATURE
FUSING POINT (MA)
160
140
120
100
80
60
40
20
0
-30
-20
-10
0
10
20
30
40
50
60
70
80
TEMPERATURE (°C)

Fig. 2.3-1

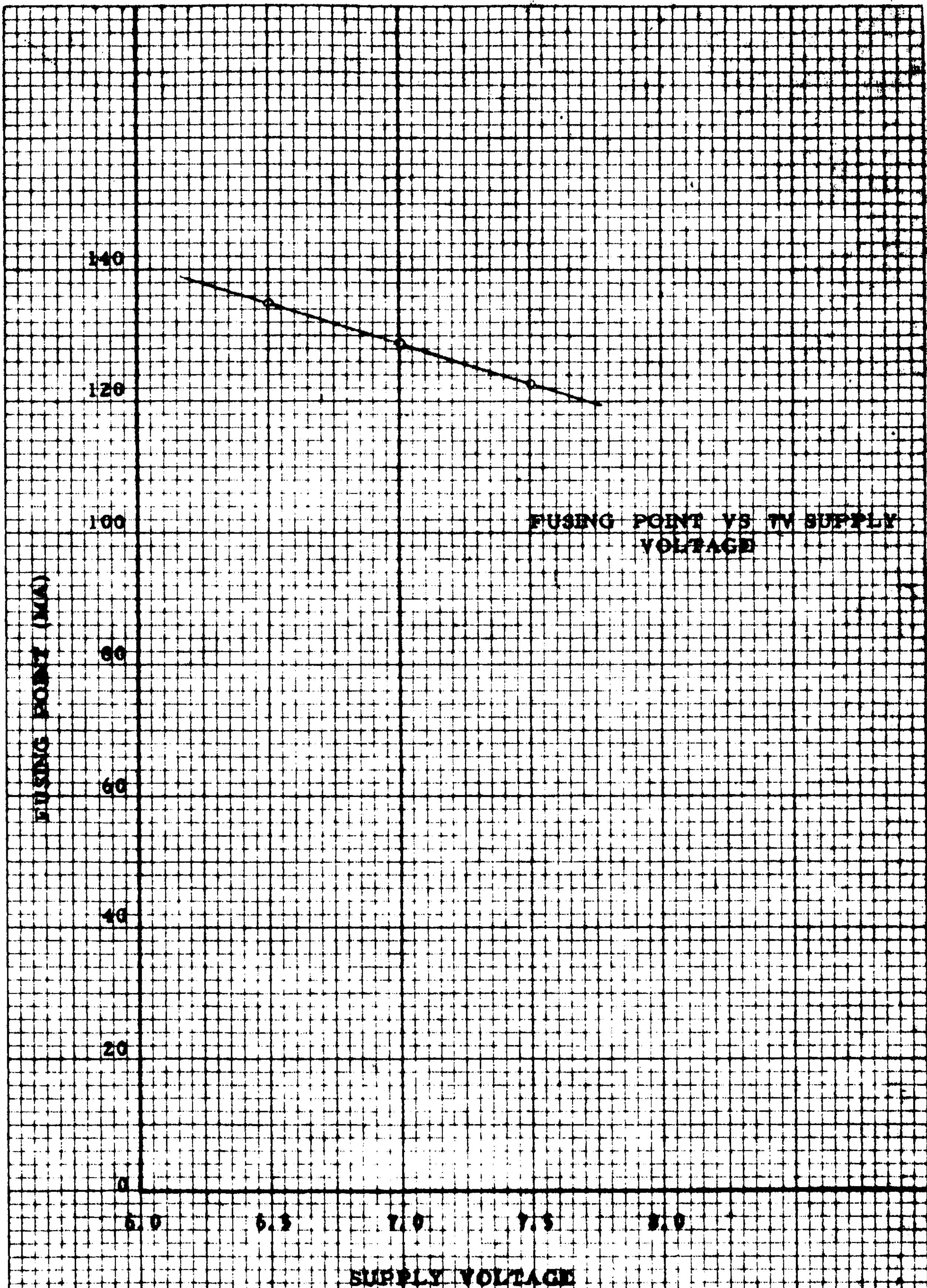

FUSING POINT VS TV SUPPLY
VOLTAGE
FUSING POINT (MA)
140
120
100
80
60
40
20
0
6.0
6.5
7.0
7.5
8.0
SUPPLY VOLTAGE

Fig. 2.1-2

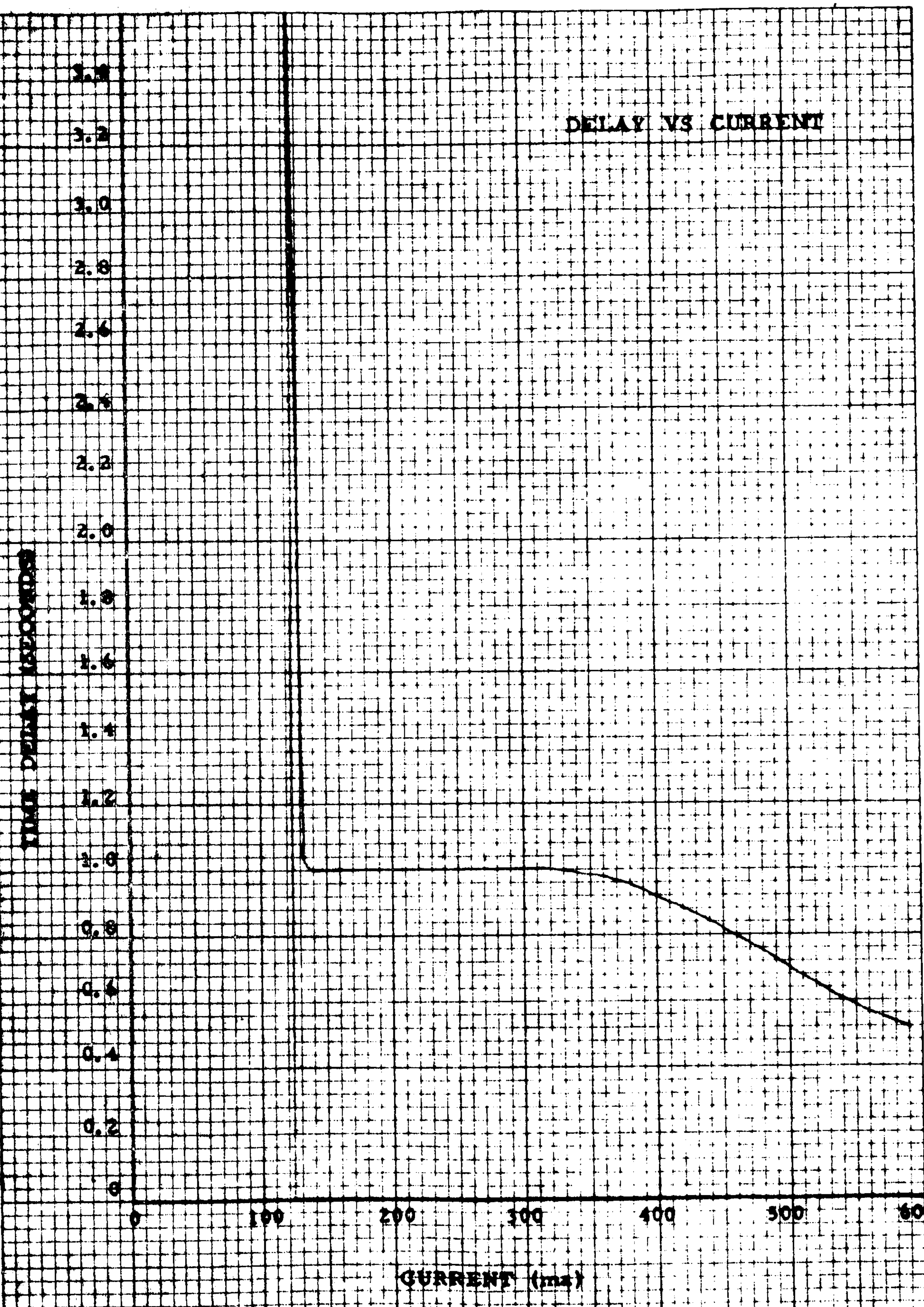

DELAY VS CURRENT
TIME DELAY (SECONDS)
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
CURRENT (ma)

Fig. 2.3-3

e. Ripple - less than 1 mv induced on fused buss line.

f. Delay - One second to 100% overload. Inverse time delay characteristic after 200% overload point. (See Figure 2.3-3).

g. Max Overload Current - 1 amp at 28v - (This is determined by the relay contact maximum rating.)

h. Fuse Power Dissipating - The fuse requires 900 micro amps from the 7v supply. (Of the 6.3 mw dissipated by the fuse, 4.2 mw is required by the oscillator).

i. External set and reset requirement - A 10 millisecond 6 volt pulse capable of driving a 50 ohm load is required for the external "set" and "reset" input.

j. Size - 1-1/2 x 1.1/2 x 5/8 or 1.4 cubic inches. (The unit without the oscillator as discussed under paragraph 2.4 could be packaged with discret components in 1 cubic inches. Thin film or microelectronic techniques could be utilized to package the unit in a small minature package if the requirement exists.

## 2.4 MODIFICATION FOR SPACECRAFT OPERATION

When many fuses are used within a spacecraft, it is proposed that a modified unit which does not include the oscillator be used. This modification would have the prime advantage of reduced power dissipation. Presently the oscillator requires 4.2 of the 6.3 mw dissipated by the fuse, therefore if a single oscillator could be used, only 2.1 mw of additional power would be required to fuse each experiment. A circuit simillar to the one illustrated in Figure 2.4-1 is proposed. This converter circuit would provide both the 7v dc voltage and oscillator square wave. The only disadvantage to this approach is the additional square wave wire which must be run to each fuse circuit. It is required that this converter not obtain its power from the power buss being protected by the fuses because if a short should develop on the line, the fuse would not have power to open the relay connected to the shorted load.

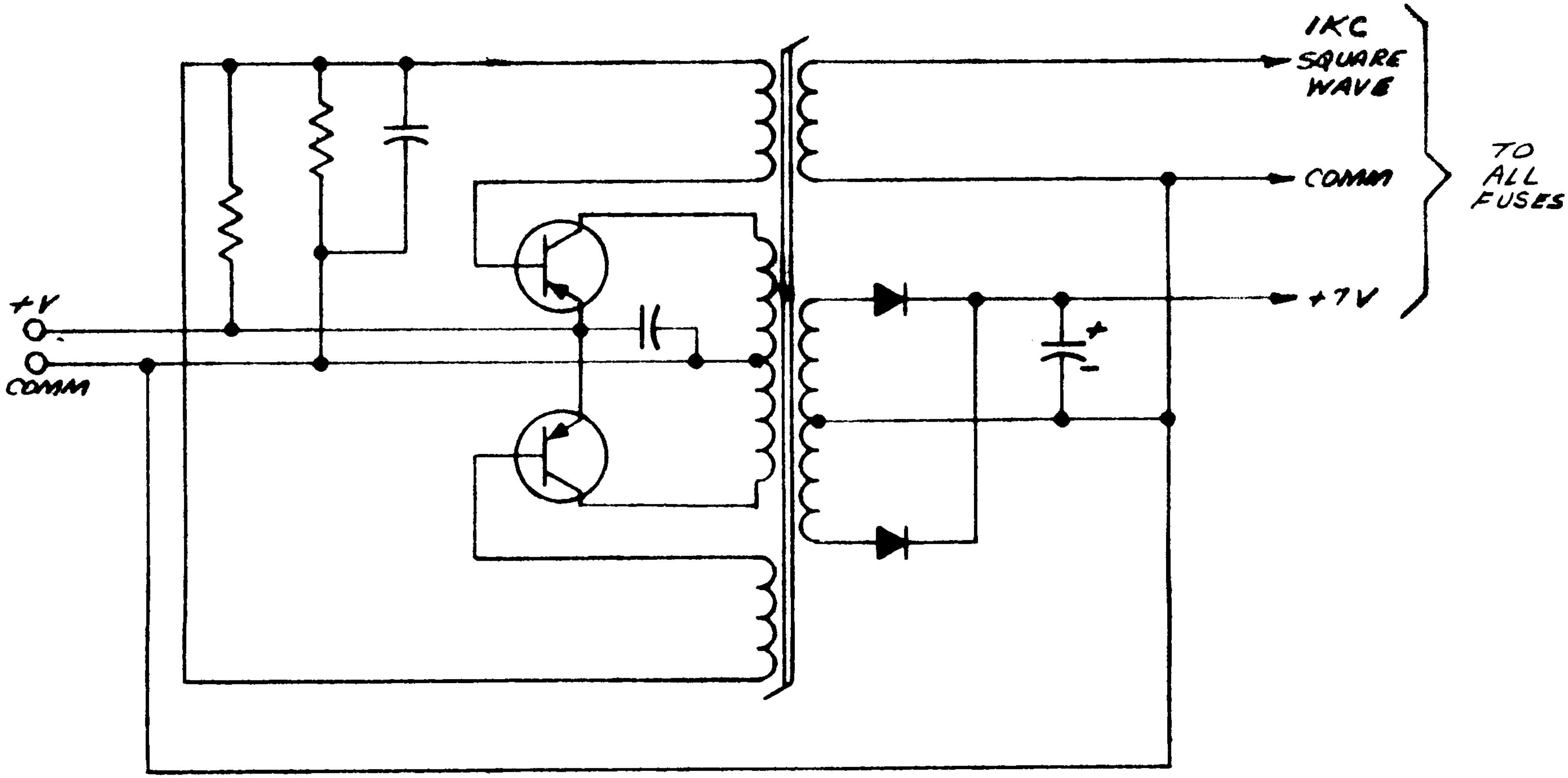
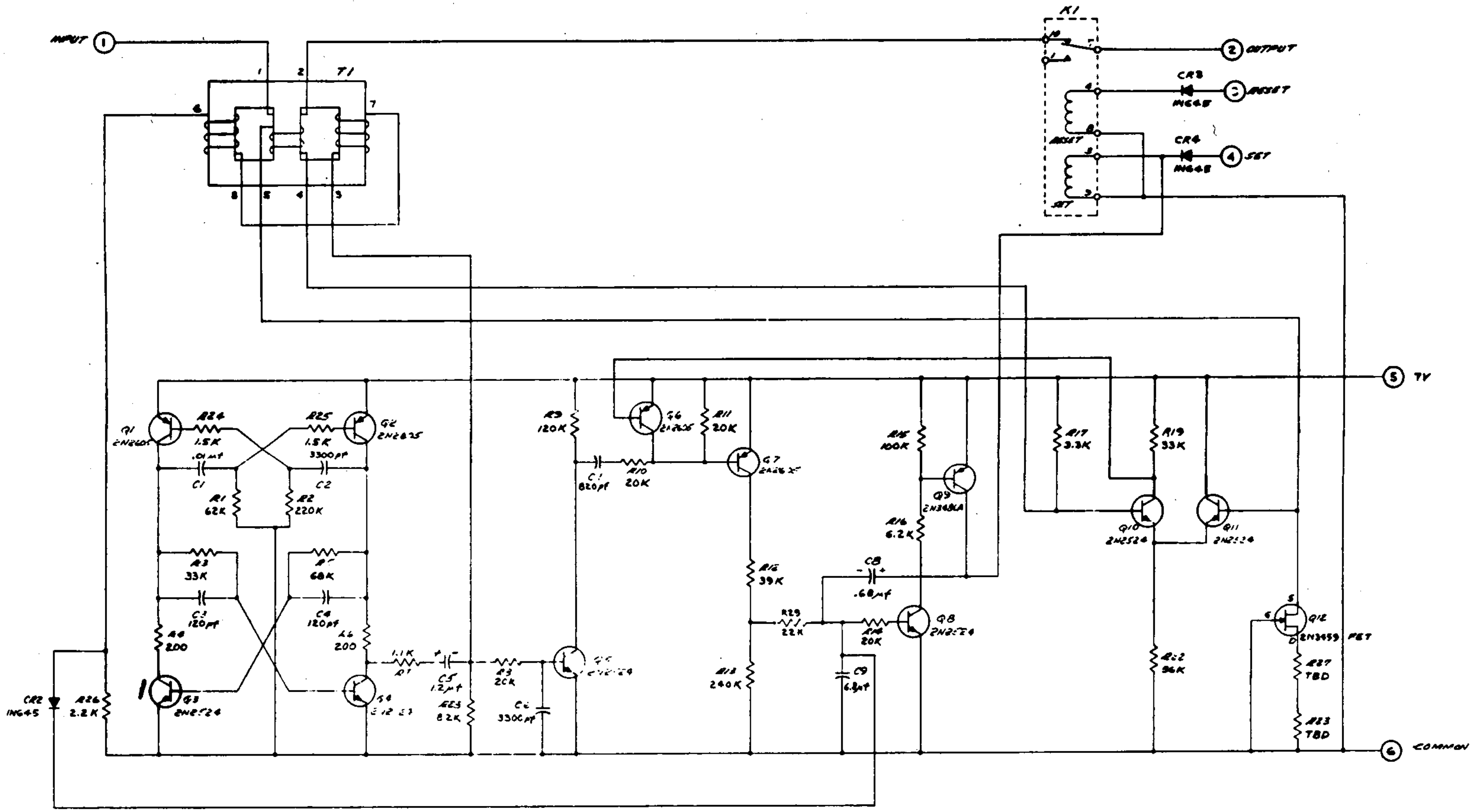



FIGURE 2.4-1 FUSE CONVERTER

RELEASED BY EMR-DATE OCT 21 1966




LAST CIRCUIT SYM. USED:

R29
Q12
C9
CR4
T1
K1

CIRCUIT SYM. NOT USED:

CR1
R18
R20
R21

GD

LIST OF MATERIAL

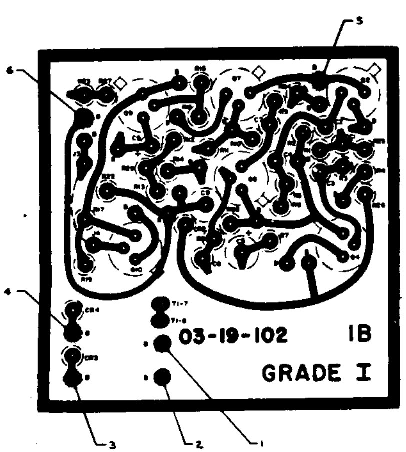
EMR 03-19-103

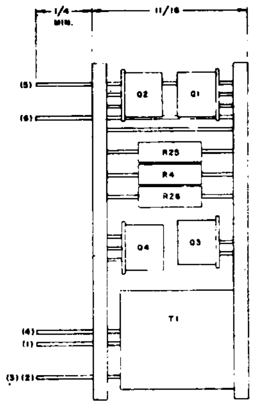
# ELECTRONIC FUSE SCHEMATIC

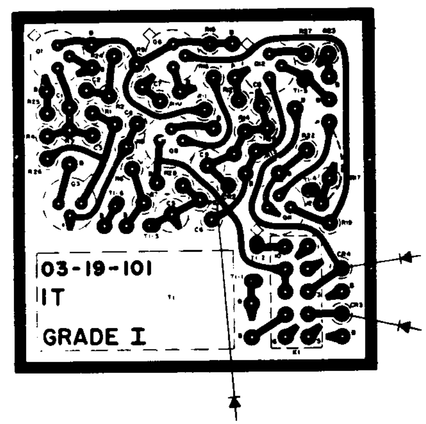
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

03-19-100

GD




NOTES:

1. ENCAPSULATION RECORD:
   ECCOFOAM F.F. RESIN
   11 PARTS CATALYST 12-6 TO
   100 PARTS BASE RESIN
2. LEGEND:
   BUS WIRE ——— → B
   OUTPUT SYMBOL ———→
   OUTPUT PIN NO. ——→ (1)
3. USE ITEM 37, BUS WIRE, AS A JUMPER BETWEEN J1 AND J2 AND BETWEEN J3 AND J4.

| REQD | PART NO. | ITEM | DESCRIPTION | MATL | MATL SPEC | UNIT WT |
|---|---|---|---|---|---|---|
| 1 | RC07GF223J | 39 | RESISTOR, FIXED COMP., 22K, 1/4W, 5% MIL-R-11E | | R29 | |
| 1 | RC07GF822J | 38 | RESISTOR, FIXED COMP., 8.2K, 1/4W, 5% MIL-R-11E | | R28 | |
| AR | 44/7004-22-9 | 37 | BUS WIRE #22 RAYCHEM | | | |
| AR | | 36 | SOLDER, SN60/SN63 | | | |
| AR | | 35 | BUS WIRE, BELDEN #22 TINNED COPPER 8022 | | | |
| 1 | | 34 | TRANSFORMER, EMR | | T1 | |
| 1 | | 33 | RELAY, BRANSON, TYPE LJ, DPDT, LATCHING | | K1 | |
| 3 | | 32 | DIODE, IN645 | | CR2, CR3, CR4 | |
| 1 | | 31 | CAPACITOR, TANTALUM, 1.2µf, 10%, T.I. | | C5 | |
| 1 | | 30 | TANTALUM, 6.8µf, 10%, T.I. | | C9 | |
| 1 | | 29 | TANTALUM, .68µf, 10%, T.I. | | C8 | |
| 1 | | 28 | CERAMIC, 820pf, 10%, WEST CAP | | C7 | |
| 2 | | 27 | CERAMIC, 120pf, 10%, WEST CAP | | C3, C4 | |
| 2 | | 26 | CERAMIC, 3300pf, 5% VITRAMON | | C2, C6 | |
| 1 | | 25 | CAPACITOR, CERAMIC, .01µf, 5% VITRAMON | | C1 | |
| 2 | | 24 | RESISTOR FIXED COMP. TBD | | R23, R27 | |
| 1 | RC07GF222J | 23 | RESISTOR FIXED COMP. 2.2K, 1/4W, 5% MIL-R-11E | | R26 | |
| 2 | RC07GF152J | 22 | 1.5K | | R24, R25 | |
| 1 | RC07GF563J | 21 | 56K | | R22 | |
| 1 | RC07GF332J | 20 | 3.3K | | R17 | |
| 1 | RC07GF622J | 19 | 6.2K | | R16 | |
| 1 | RC07GF104J | 18 | 100K | | R15 | |
| 1 | RC07GF244J | 17 | 240K | | R13 | |
| 1 | RC07GF393J | 16 | 39K | | R12 | |
| 1 | RC07GF124J | 15 | 120K | | R9 | |
| 4 | RC07GF203J | 14 | 20K | | R8, R10, R11, R14 | |
| 1 | RC07GF112J | 13 | 1.1K | | R7 | |
| 1 | RC07GF683J | 12 | 68K | | R5 | |
| 2 | RC07GF201J | 11 | 200 | | R4, R6 | |
| 2 | RC07GF333J | 10 | 33K | | R3, R19 | |
| 1 | RC07GF224J | 9 | 220K | | R2 | |
| 1 | RC07GF623J | 8 | RESISTOR, FIXED COMP. 62K, 1/4W, 5% MIL-R-11E | | R1 | |
| 1 | | 7 | TRANSISTOR, 2N3459 FET | | Q12 | |
| 1 | | 6 | TRANSISTOR, 2N3486 | | Q9 | |
| 6 | | 5 | TRANSISTOR, 2N2524 | | Q3, Q4, Q5, Q8, Q10, Q11 | |
| 4 | | 4 | TRANSISTOR, 2N2605 | | Q1, Q2, Q6, Q7 | |
| 1 | 03-19-102 | 3 | PC BOARD | | | |
| 1 | 03-19-101 | 2 | PC BOARD | | | |
| — | 03-19-103 | 1 | SCHEMATIC | | | |

LIST OF MATERIAL

EMR 03-19-100

GD

| | NAME | INIT | DATE |
|---|---|---|---|
| DESIGNER | W.T. MALTBY | | 10-14-66 |
| DRAWN | W.T. MALTBY | | 10-14-66 |
| CHECKED | | | 10-17-66 |
| APPROVED | | | 10-18-66 |

# ELECTRONIC FUSE ASSEMBLY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

GD

SCALE 4:1

SHEET 1 OF 1

1911

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES