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ELECTRONIC OVERLOAD PROTECTION CIRCUIT

FOR SENSITIVE CURRENT METERS

RADIO CORPORATION OF AMERICA
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Electronic Overload Protection Circuit for Sensitive Current Meters

Approved

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Summary

Meters used to measure currents less than a few milliamperes cannot be protected against overload with conventional metallic fuses. Electronic circuits can be used to provide overload protection for these sensitive current meters. The electronic circuit monitors the voltage across the meter. When this voltage exceeds a predetermined value a thyratron-operated relay opens the load circuit. Operating characteristics and limitations of the electronic protection circuit are considered.

Electronic Overload Protection Circuit for Sensitive Current Meters

Introduction

Fuses are frequently used to protect current meters from damage when accidentally overloaded. As the sensitivity of the meter to be protected increases, fuse resistance becomes larger, and the fuse becomes more expensive. Fuses are not readily available for current meters with full scale readings of less than one milliampere. For these current meters, overload protection can be provided by electronic means. Electronic protection circuits similar to those to be described in this bulletin may also be used to replace fuses in those applications where fuse resistance is detrimental to circuit operation or where overload occurs so frequently as to make resettable operation desirable.

Description

Fig. 1 shows an electronic protection circuit[1] that has previously been used in some test equipment. This circuit consists of a triode amplifier whose input is connected across the meter to be protected and whose output is dc connected to a thyratron grid. When the voltage across the meter exceeds a predetermined value, the thyratron conducts and actuates a relay which opens the load circuit. Current meters used in test equipment are often connected in the positive side of the load circuit in which case a separate power supply is necessary to operate the protection circuit.

The circuit of Fig. 1 does not provide protection against overload currents in the reverse direction through the meter. Also, the protection provided is not fail-safe in operation. The circuit of Fig. 2 was developed to overcome these deficiencies. The mechanical size and power consumption were also reduced.

Operation of the circuit of Fig. 2 is basically the same as operation of the circuit of Fig. 1. The following comments will explain points of differences:

a. Neon glow tubes are used as dc coupling elements to reduce the overall voltage required.

b. Protection against overload in the reverse direction is provided by the following means. For reverse current, the triode grid goes more positive. The plate voltage drops to a point where the neon tube, V_4, ceases conduction. The thyratron grid voltage then drops to ground potential, and neon tube, V_5, conducts. The resulting thyratron grid voltage is sufficient to cause the tube to conduct. Proper operating voltages are required to obtain equal protection in both directions.

c. In order to reset the circuit of Fig. 1, a reset switch is used to short-circuit the thyratron causing it to cease conduction. When the reset switch is opened, the thyratron may again be triggered to conduction by an anode voltage surge generated by the stored energy in the relay coil. Reconduction is eliminated by connecting (with the aid of an auxiliary pair of relay contacts) a 20-μf condenser and series resistor in shunt with the reset switch. Resetting of the circuit of Fig. 2 or 3 is accomplished by opening the thyratron circuit. The load circuit is opened simultaneously to prevent meter overload while the protection circuit is inoperative. The two contacts on

[1] This circuit was adapted by C. W. Cain from one developed by G. D. Hanchett, Jr., "An Electronic Multi-circuit Breaker", *QST*, pp. 34-36; August 1947.

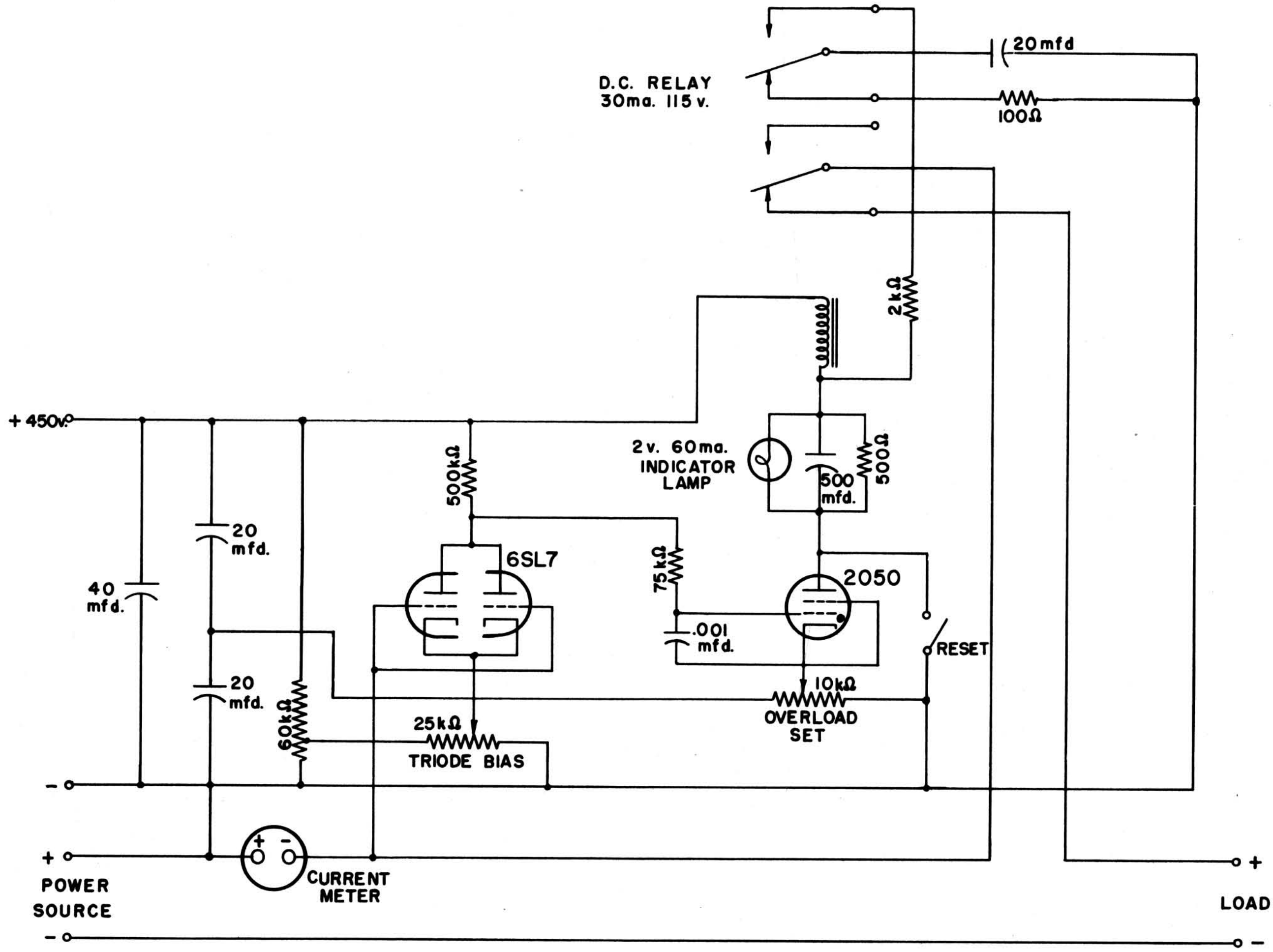

Fig. 1 – Basic electronic protection circuit.

the reset switch are mechanically interlocked so that the load circuit is opened before the thyratron circuit and closed in the reverse order. Either of the above methods of resetting appears satisfactory.

d. In order to provide fail-safe operation, the load circuit of Fig. 2 is open until current flowing through the relay coil closes the relay. This occurs at about the same time that the protection circuit becomes operative.

e. With universal shunt multirange meters the terminal voltage corresponding to full-scale deflection changes with the different ranges. In order to get the same protection, independent of range setting, the voltage across the meter coil is monitored by the protection circuit. This point is considered in greater detail under the heading, Meter Characteristics.

f. A voltage regulator tube, V_2, was introduced in order to improve reliability and stability particularly against line-voltage surges producing erroneous operation. The voltage regulator tube may not be required in all cases. The following data are typical of what may be expected without a voltage regulator tube.

Table I

Line Voltage	Operation Point*	
	Voltage For Forward Current	Voltage For Reverse Current
110	−0.02	+0.32
117	−0.1	+0.2
120	−0.11	+0.2
125	−0.15	+0.15
130	−0.18	+0.12

Meter used required −0.05 volts across terminals for full-scale deflection.

Operation

Grid current flowing in the dc amplifier tube, V_3, is a potential source of error in the meter reading. Measurements were made to ascertain the magnitude of the grid current. Using a 1-microampere full-scale d'Arsonval type instrument, no deflection was noticeable for several 6AQ6 tubes operating under the following conditions: V anode = 85, $V_g = -0.75$. It was concluded that error from this source could normally be neglected.

Circuit leakage may also produce meter errors. In particular, leakage from relay coil terminals to contact terminals can be significant (depending on reversing switch position). Adjustment of meter zero setting can be used to compensate for constant circuit leakage that cannot be eliminated.

The NE 51 neon tubes are sufficiently nonuniform[2] that the circuit will usually have to be readjusted when a tube is changed. The neon tubes should be aged several hours initially before adjusting the circuit. With these precautions, after a few minutes warm-up, the operation of the circuit is reliable and stable even with overload point set at 1.5 times full load current. A more typical adjustment is to have the relay operate for 2x forward current and 5x reverse current. Reverse current protection need not be as good as forward current protection since it is much less likely to occur and since the meter movement is immediately brought to rest in the reverse direction. By careful adjustment, the same protection in both directions can be obtained if desired. For some operating conditions the neon tube will oscillate (RC oscillations). This situation is not serious and has not caused improper operation.

The circuit was tested with meters having 30 - 50 millivolts corresponding to full-scale deflection. Trouble may be experienced in applying the protection circuit to a meter whose voltage corresponding to full-scale deflection is less than 10 millivolts.

Short-circuit protection is of considerable importance for meter safety. It is dependent in part upon the speed with which the relay coil is de-energized through the thyratron. The mechanical and electrical constants of the meter movement and the internal impedance of the power source are also important in determining short-circuit protection. The circuit of Fig. 2 provides reasonably good short-circuit protection. In order to improve short-circuit operation the time required to open the relay must be decreased. The circuit of Fig. 3 was developed to improve short-circuit operation by decreasing the relay-operate time. In this circuit the relay is normally non-

[2] Seven tubes selected at random required the following voltages for conduction: 39.2, 42.2, 43.9, 44.8, 46.1, 47.8, and 50.7.

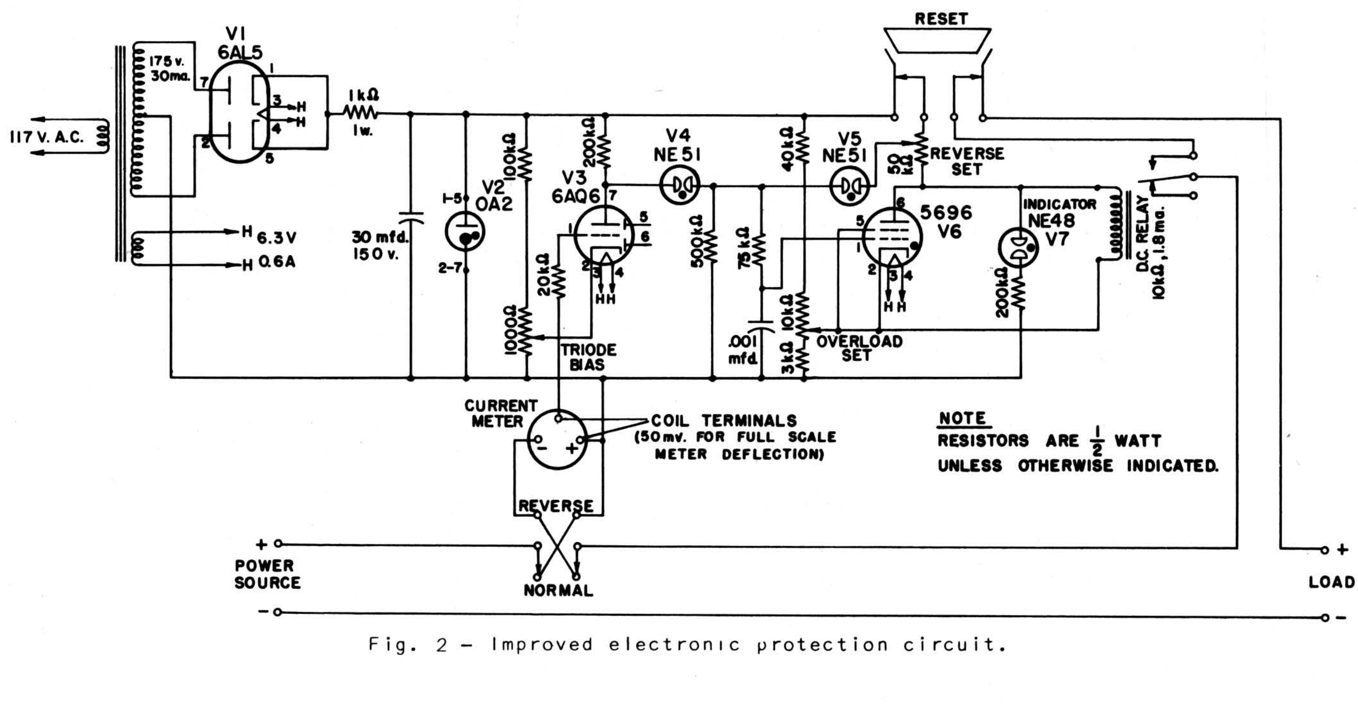

Fig. 2 – Improved electronic protection circuit.

energized until overload occurs. By overdriving the relay, fast operation can be obtained. The time required to open the relay may be further reduced by changing the adjustment of the relay for more sensitive operation (at the expense of less open contact pressure) and by increasing the relay overdrive.

The circuit of Fig. 3 is no longer fail-safe in operation. If desired, this feature can be obtained by adding a relay activated through the supply voltage with relay contacts placed either in series with the line or in short circuit across the meter.

Since the overload protection circuit is practically instantaneous in operation, some load current surges, as for instance, condenser charging current, may operate the relay although the meter would not be in danger of damage. Relay operations caused by very rapid surges are eliminated by the RC elements in the thyratron grid circuit. The RC time constant must not be made too large, however, since meter protection against short-circuit overload conditions becomes worse.

Adjustment

The *Triode Bias*, *Overload Set*, and *Reverse Set* controls permit the initial adjustment of the protection circuit as follows: With V_5 and V_6 nonconducting and no load current, the *Triode Bias* control is adjusted so that V_4 just conducts (V_4 glows faintly). The load current is then increased to correspond with the maximum overload current, and the *Overload Set* control adjusted to cause V_6 to conduct. If desired, the maximum overload current can be simulated by connecting a suitable dc potential at the coil terminal leads.

In order to adjust the *Reverse Set* control reverse current is passed through the current meter of sufficient magnitude to cause V_4 to cease conduction. The *Reverse Set* control is then adjusted so that V_5 conducts sufficiently to cause V_6 to conduct. Normally with this procedure of adjustment the reverse current required to produce relay operation will be comparable to the forward current required to produce relay operation. If this is not the case, the controls can be adjusted slightly to achieve the desired operation.

The point of relay operation can be checked by passing forward or reverse current through the current meter and measuring the voltage across the meter with an auxiliary voltmeter. If a multirange current meter is being protected, the overload current can be measured by using the next higher meter scale.

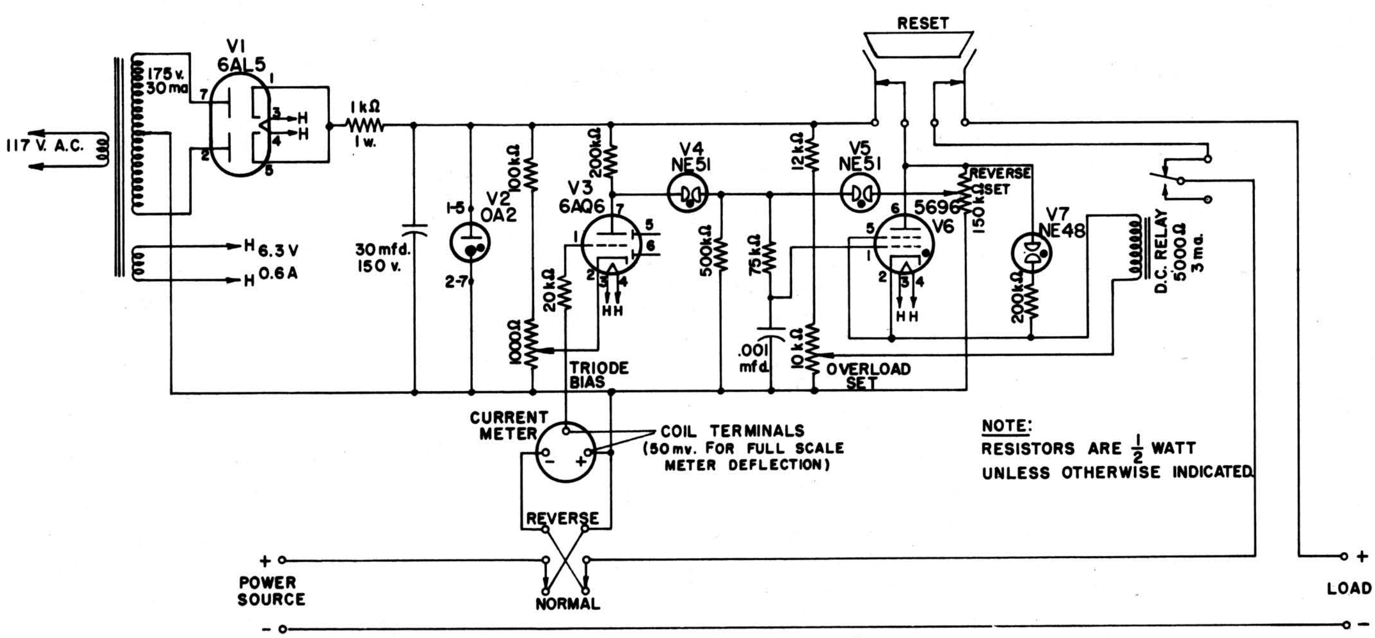

Fig. 3 – Fast operation electronic protection circuit.

Meter Characteristics

The electronic protection circuit has been employed satisfactorily with several current meters having full-scale deflection with a few hundred microamperes. When the protection circuit was used with more sensitive current meters (10 microamperes), it became impossible to reset the circuit when there was current flowing. Thus, with the circuit adjusted to operate with a coil voltage corresponding to 2x full-scale current, resetting could not be accomplished even though the current through the meter was only a small fraction of its full-scale value. In addition, even after the circuit was reset, a small change in meter current would cause the operation of the protection circuit.

It became apparent that the trouble was caused by the current meter coil voltage momentarily exceeding its normal value. This matter was studied further by using a triggered sweep oscilloscope to examine the coil voltage when a step rise in current was applied to it. Fig. 4a indicates the coil voltage for a 100-microampere meter. Fig. 4b indicates the coil voltage for a 10-microampere meter. For the

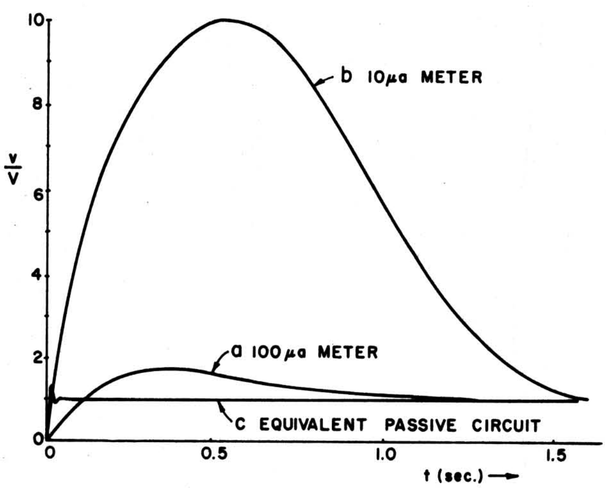

Fig. 4 - Circuit and meter responses to step current.

100-microampere meter the voltage overshoot is only moderate whereas for the 10-microampere meter considerable voltage overshoot is encountered. The equivalent passive circuit (i.e., the equivalent meter circuit when movement is clamped) for the 10-microampere meter is indicated in Fig. 5. The response of such a circuit to a step current should indicate only a small overshoot in the voltage "across the meter" and this is a short-time phenomenon. This was checked by constructing the passive network of Fig. 5 and closing a circuit through a battery and a high impedance. The resulting voltage is shown in Fig. 4c.

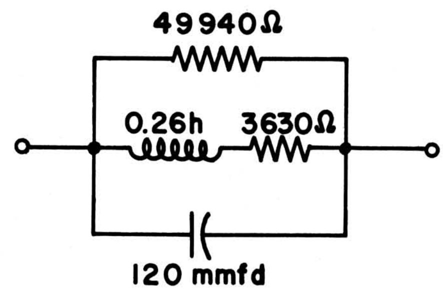

Fig. 5 - Equivalent passive circuit for 10-microampere meter.

It is apparant that the voltage overshoot phenomenon is related to the dynamic response of the meter. Resetting difficulty was not observed when a very low-impedance battery was used as the power source. Also more overshoot is observed for highly damped meters.

Resetting difficulty can be eliminated by placing a resistor of suitable value in series with the current meter to be protected and using the voltage drop across this resistor to operate the protection circuit.[3] This method of protection increases the load circuit resistance, but for small currents this is not a serious problem.

Conclusions

The circuits of Figs. 2 and 3 are reliable and feasible for current meter protection. The circuit of Fig. 3 gives faster relay operation than the circuit of Fig. 2, but does not include fail-safe feature although this could be added if desired. These circuits can be used to protect current meters provided:

(1) That the meter coil voltage corres-

[3] This mode of operation has been employed with the circuit of Fig. 1 to protect a 15 μa meter.

ponding to full-scale deflection is not less than approximately 10 millivolts.

(2) That the meter response to a current step exhibits small voltage overshoot.

If the meter exhibits large voltage overshoot, protection can be obtained by using a monitoring resistor to indicate overload as explained above.

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