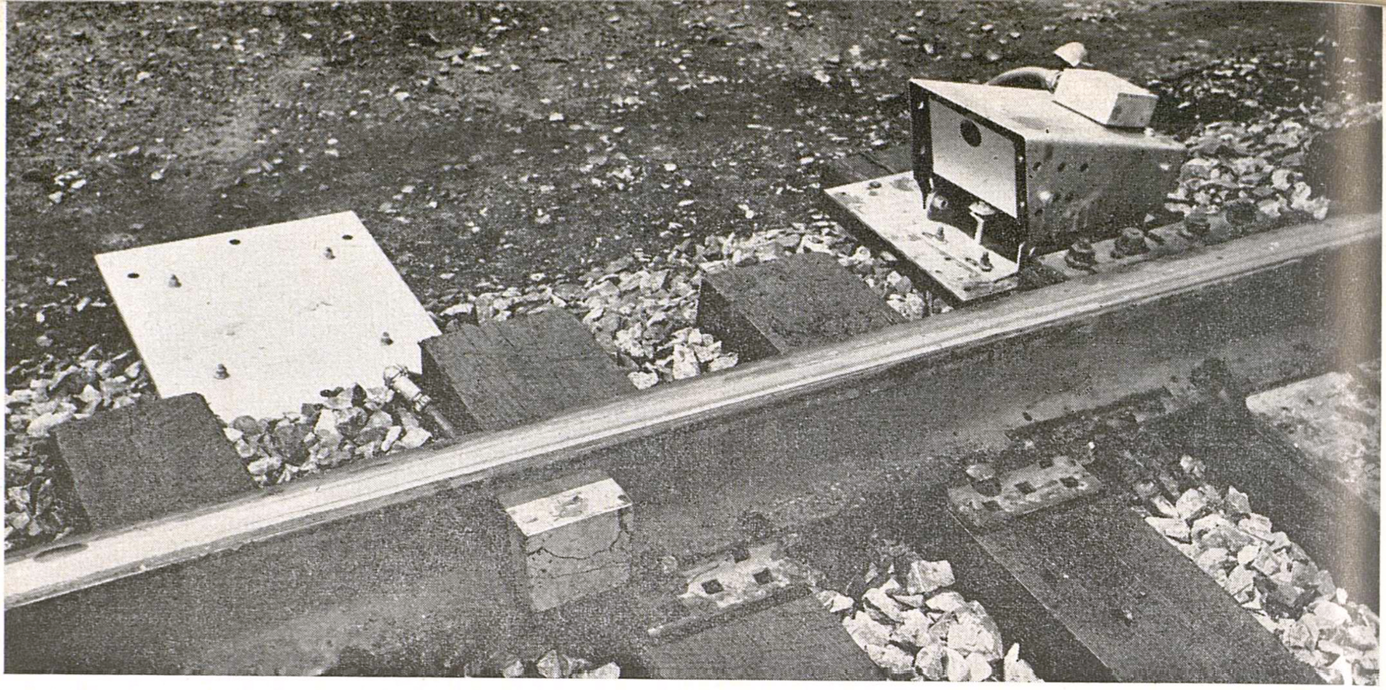


Trackside power supply (buried in ballast at left), transducer and detector head that contains bolometer and preamplifier.

New Hot Box Detector in Service

THREE RAILROADS now have General Electric Co.'s new hot box detector in service. The detector system operates on 115 volts, 60-cycle ac, and requires approximately 200 va at the trackside installation and 200 va at the receiver unit (pen graph recorder). When using FM carrier, 250 va are required at the detector location and about 300 va at the receiver location. One road is using the GE type 50 FM frequency shift carrier, operating on a frequency of 39.5 kc. The detector signals are square wave pulses with a maximum peak which may be as high as 20 volts. The carrier and detector equipment is transistorized, except for two subminiature tubes used in the detector preamplifiers.

At the detector location, one transducer is used as a wheel pickup unit. It is mounted 56 in. after the detector heads in the direction of train movement. The pickup unit consists of a permanent magnet to establish a magnetic field and a coil to detect changes in the field. When a wheel passes this unit, the wheel flange changes the reluctance of the magnetic path. The resulting change in the magnetic flux induces a voltage in the coil.

At the field location, the detector preamplifier is mounted in the rear of the detector head. A power supply unit, buried in the ballast, feeds the detector preamplifiers. The other field equipment, such as amplifiers and carrier transmitter, are rack mounted in a steel relay case. Pushbuttons for testing the system are part of the equipment in the field relay case. A gate test pushbutton is used to simulate a wheel pickup signal. A hot pip pushbutton simulates a hot box, and a chart drive test button simulates a gating pulse to start the chart running. It will run for five seconds, at which time an automatic timing circuit will shut it off. An ungate switch allows all signals to pass through the system. Another pushbutton is pressed to test the operation of the pen amplifier and pen movement. A shutter switch can be used to open the shutters on the detectors. The shutters are normally closed, and open when a train passes the transducer. The chart timer circuit allows the shutters to close 5 sec. after the last wheel of the train has passed.

The problem of reading the hot box condition actually becomes three problems: (1) the ability to read the temperature with the required accuracy; (2) to know when the reading is to take place; and (3) to display the information obtained.

Reading the Temperature—Heat consists of electromagnetic waves similar to radio or light waves but having a wave length of approximately 7 to 15 or so microns. The micron is one millionth of a meter, approximately one 25-thousandth of an inch. This energy varies as approximately the fourth power of the absolute temperature (0 deg Rankine = —460 deg F).

An optical system is required to view this energy and concentrate it on the sensing element. A normal camera lens of glass would be completely useless at these wave lengths. There is no satisfactory material but perhaps the most practical is arsenic trisulfide. This is relatively hard and is not affected by sunlight or usual atmospheric conditions. It is, however, softer than glass and must be handled and cleaned with care. It does have a high index of refraction so that it is possible to make lenses with high light gathering power. For example, the lens used in the GE system has an F number of approximately 1.

The sensing element used is a flake bolometer. This consists of a very thin layer of metal alloy vaporized on a quartz block. Actually there are two flakes, each one millimeter square, one of which receives the radiated energy and the second one close by, but shielded, which operates in a bridge circuit with the first. These are actually simple resistance bolometers having a time-constant of approximately 2½ milliseconds with a bias voltage applied. When it is realized that the energy received from even a rather warm journal is able to change the resistance of the active flake by an amount to cause the bridge output to vary less than one-half millivolt, it will be seen that the total resistance change is approximately one part in a million.

The heat energy is proportional to the fourth power of the absolute temperature. The difference in energy of a certain number of degrees temperature rise of the journal will be larger at an ambient temperature of, say, 100 deg F (560 deg R) than at an ambient of 0 deg F (460 deg R). The larger heat differential will yield a larger indication to the bolometer. However, this is not great and is in the proper direction, since at the higher temperatures the requirement for detecting warm journals is more critical.

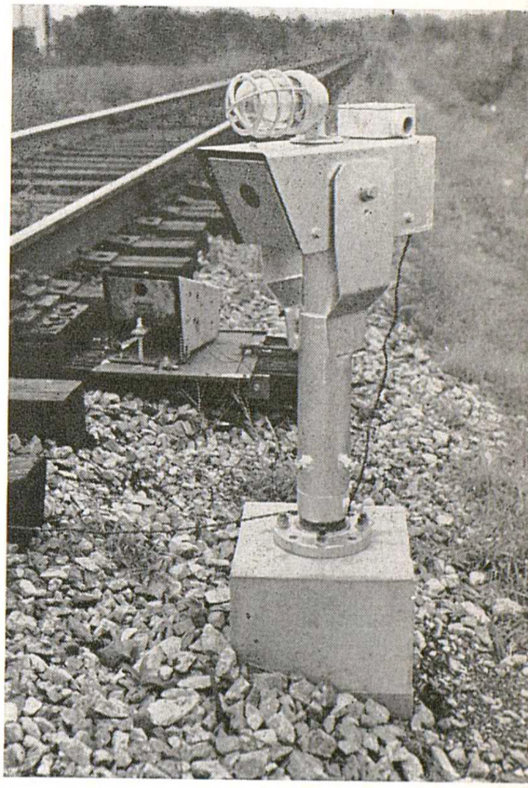
This small signal output requires a very high gain and very stable amplifier. Since the bolometer has an output resistance of about a megohm it is necessary to use electron tubes for this amplifier. The power supply for the amplifier is highly regulated and filtered, still the circuit gain is such that it is necessary to use a capacitively coupled circuit (Fig. 1). There are three stages of capacity coupled amplification and a fourth cathode-follower stage to permit low impedance output into the connecting cable. Feedback is used between the first and third cathode resistors for better circuit stabilization and to take care of variations in tubes and components. The tubes were designed for guided missile operation with quality as the primary consideration and cost secondary. This circuit is mounted compactly on a small chassis, which is then included, with the optical system, in a cast alloy case with gasketed cover and outgoing leads with screw terminal connections. It can be adjusted and aligned to standard conditions in the electronic or signal shop and then stored until needed at the track. An adjustment is included to permit setting the bolometer bias to hold the output at near ground potential in spite of normal variations in resistors, bolometers and other components.

A track-side power supply is included in a cast alloy case to permit the various power requirements of the preamplifiers to be supplied as close as possible to the amplifier themselves, and thus avoid the drop in long leads and the possible pickup of stray signals on the somewhat sensitive bolometer bias leads and similar circuits.

This panel supplies positive 300 volts for the tube plate supply, positive 180 volts and negative 200 volts to the bolometer and 12 volts dc to the tube filaments. There is a common transformer and rectifier, but separate filters for the supplies for each of the two amplifier heads. Adjustments for each voltage are supplied convenient to the outgoing terminals. In general, these adjustments are made once for each installation and need be checked only at normal inspection intervals.

When Is the Temperature to be Read?—The amplifier described above senses the energy received from a given direction and gives an output signal proportional to this energy. It is necessary now to select the signal which is received from the journal only so it may be analyzed. To do this a "gate" or switch is added, which permits the signal to pass only when desired. It is obvious that it must be known when the journal is being seen by the sensing element. Various methods could be used for this, but a magnetic device has been chosen because it is the simplest and requires no mechanical moving parts. It consists of a permanent magnet which establishes a magnetic field and a coil of wire to detect changes in this field. If the field is set up so that the wheel flange changes the reluctance of the magnetic path, a voltage will be induced in the coil which can be used to indicate the presence of the wheel flange. Since there is adequate power available as the wheel passes by, the problem is to design the pickup so that is has not too much sensitivity and does not respond to slight track vibration or other unwanted signals. It must be rugged enough to withstand the somewhat severe environment conditions which it must face. The voltage induced depends on the speed of the train, the depth of the flange, and other factors. However, the instant of the voltage reversal as the wheel passes the top of the magnet is quite constant, so it is this reversing voltage which is used as an indication of the presence of the wheel and journal. This moment of reversal is amplified in the gating panel for circuit use.

A timed gate formed by a multi-



One road has detector on pedestal (keep it above snow). Test lamp on top is lighted when detector is operating.

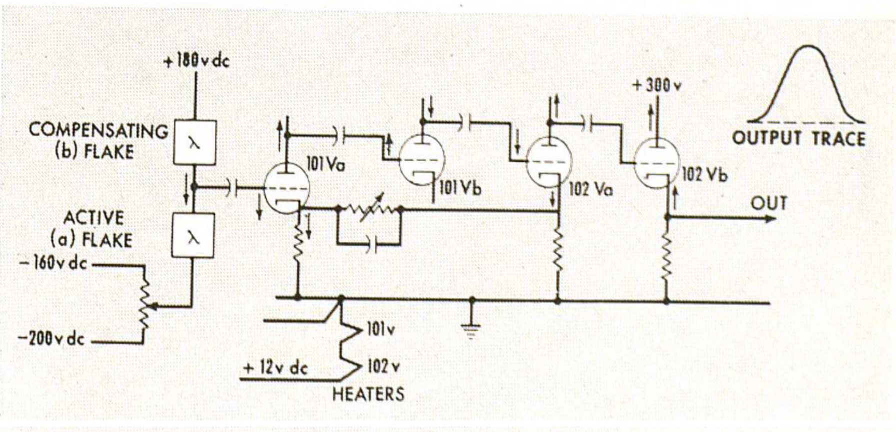


Fig. 1—Simplified diagram of GE preamplifier.

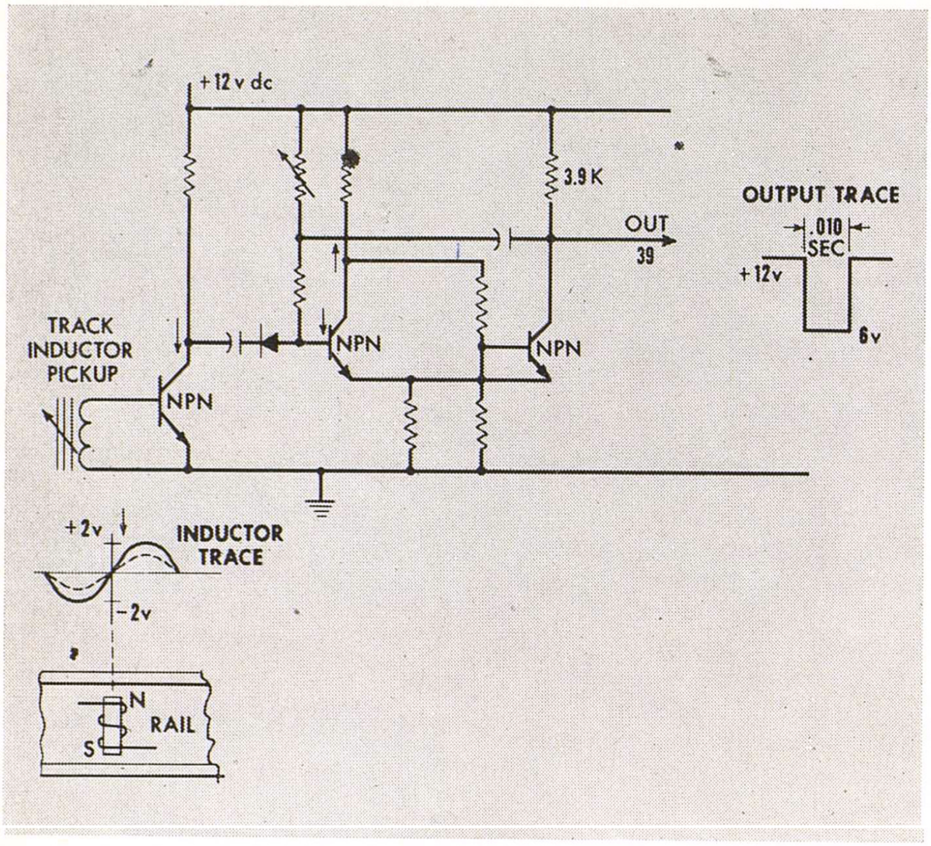


Fig. 2—Simplified diagram of GE gate timer circuit.

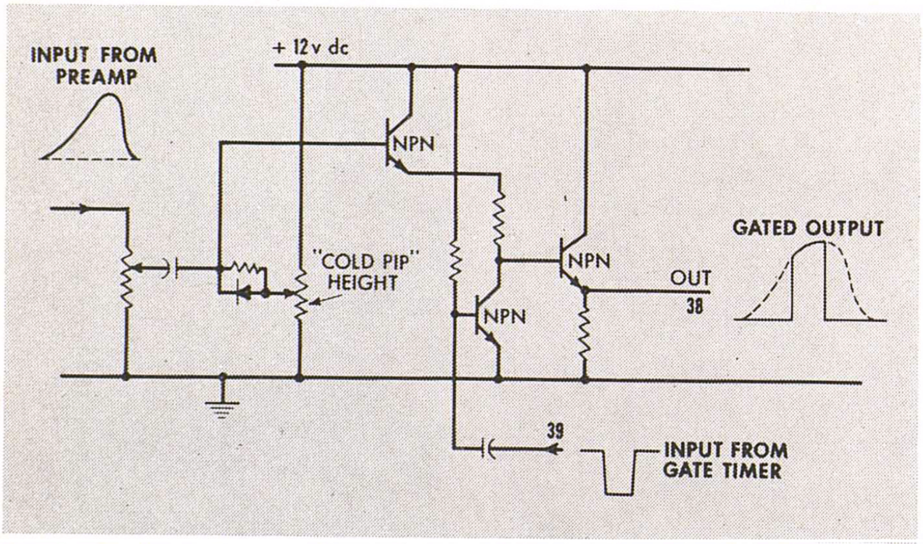


Fig. 3—Simplified diagram of GE gate clamp circuit.

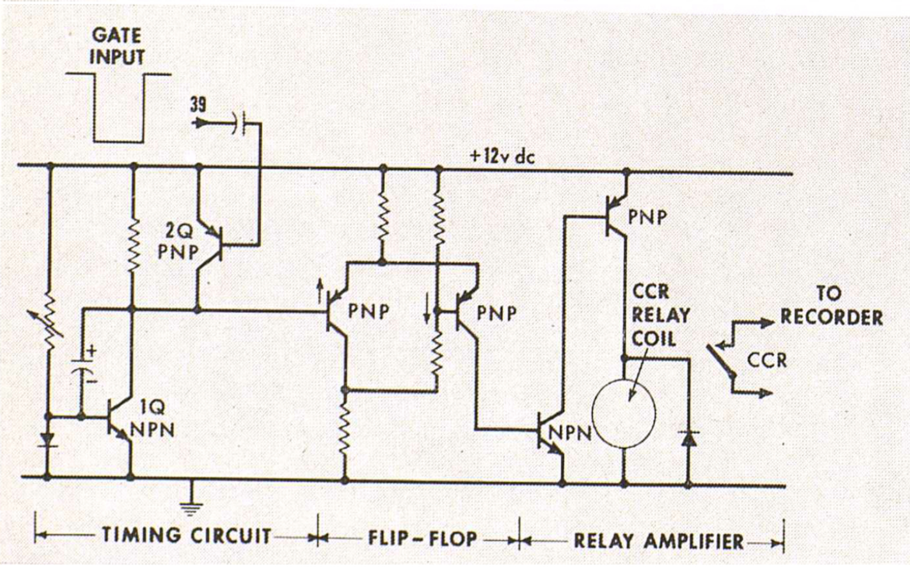


Fig. 4—Simplified diagram of GE chart run timer (3 to 6 seconds).

vibrator is used. This circuit is also called a flip-flop, Ecles-Jordan circuit, etc. A timed gate was chosen because it gives a uniform output no matter what the train speed, which varies over a wide range. When carrier radio or similar transmission means are used, this permits a constant width signal to be transmitted. Since a standard recorder pen cannot respond precisely at the highest train speeds, this permits a ballistic kick to be applied to the pen and thus obtain consistent readings of pen traverse in spite of widely different train speeds. The multivibrator is triggered by the inductive pickup signal. This is an emitter coupled circuit (Fig. 2). Under normal conditions the left-hand transistor is conducting, but when triggered, the right-hand transistor conducts until the capacitive timing circuit has timed out, permitting the reset to occur. The diode in the input circuit prevents the incoming signal from the inductor from turning the circuit off as well as on. The output signal appears on the 3.9 K collector resistor of the output transistor. It will be noted that this voltage moves first in the negative direction and, after the timed interval, it has a positive return.

It now remains to apply the gate to the incoming signal from the amplifier. This is done in the clamping and emitter-follower circuit (Fig. 3). The clamp consists of a conducting transistor which is applied at the output of the first transistor stage to lock its output to ground under normal conditions. However, when the gate signal appears, the base of this clamping transistor is driven negative, so that the transistor becomes an open circuit and the signal from the amplifier is passed to the emitter follower, and out of this portion of the circuit. It will be remembered that the multivibrator output consisted of a negative going square wave. This, applied through a capacitor to the clamp transistor base, will thus open this transistor for the time of the gate.

Under certain conditions, such as snow or sleet storms or heavy rain storms, it may be possible that a properly lubricated bearing will run so cool that the housing will not have a temperature appreciably above ambient. Nevertheless, under these conditions an indication that the axle has passed is desired, so that an accurate axle count may be obtained for determining the location of a hot box. To provide a signal in this case, a "cold pip" is provided, consisting of a fixed dc potential as determined by the potentiometer "cold pip" (Fig. 3). Thus, even though no signal is obtained from the amplifier, each time the gate operates a signal of adjustable height is obtained to indicate that an axle has passed. It will be noted that the amplifier signal is capacity coupled in series with this cold pip, so that any signal received from the amplifier will be seen above the cold pip reference.

Presentation — Electrical signals which are proportional to the temperature of the journals are now available. It now remains to present these signals to an operator so that he may interpret them quickly and easily. It will be remembered that a long freight train may present the problem of perhaps 800 journals passing by a point in two or three minutes. The temperature of each must be seen and evaluated. Also, the nature of roller bearing design is such that the housing exterior is warmer than that of sleeve journals and will, of course, read higher.

The journal temperatures are presented on a two-pen recorder chart. A chart speed of approximately five millimeters per second has been generally used although this, of course, can be varied to suit a particular location and train speed.

Since the train is before the detectors only a small portion of the day, it is necessary that chart be run only when the train is there. It is simple to start the chart motor when the first axle reaches the inductive pickup. However, it is not desirable to stop the chart between trucks, so a short time delay is included in the chart motor control circuit (Fig. 4). This delay is usually set between three and five seconds to allow the time for the longest freight car to pass at the slowest speed which may be expected at a given location. The circuit used for this is a transistorized form of a Miller integrating timer circuit. This circuit permits reasonably accurate time calibration without the requirement of massive capacitors (which are not especially practical under these environment conditions). When it is realized that this time delay must be reset during a single gate period, the advantage of a small timing capacitor is realized. In the detailed timing circuit, the timing capacitor is charged by a cascade pair of PNP transistors (represented by 2Q on Fig. 4) which are triggered from the gate signal through a capacitor. The timing capacitor is discharged through the cascade NPN transistors (represented by 1Q on Fig. 4) with integrator circuit type feedback to limit the discharge rate. The time potential change next actuates a bi-stable multivibrator which gives a positive action to the timing relay. The timing relay is then actuated by the chain of complementary transistors shown at the right of the circuit.

The final problem that remains is that of supplying sufficient power to operate the chart pens. The GE system uses the Sanborn Company series 1300 "Twinviso" recorder, which has a standard factory modification of remote chart-motor relay. Because the pen coil has been designed for vacuum tube operation the typical low voltage transistor output had to be stepped up by a transformer to supply 80 volts maximum for full scale deflection. This is done by the galvanometer drive, or pen amplifier (Fig. 5). The gated signal, a positive pulse of perhaps 6 to 10 volts maximum and 10 to 15 milliseconds wide, is applied to the input of the three-stage amplifier. The output transistor is a type 2N375, capable of supplying an ampere or so, if necessary, at 24 volts. This more than adequate power is then stepped up by the transformer to supply the 25 milliamperes, 80 volts maximum required by the pen coil.

In order to have a linear amplifier in spite of the various variations of transistors and components, current feedback is used. In tracing the circuit it will be noted the current that flows in the galvanometer coils also flows through the feedback resistor and adjustment potentiometer. The circuit is grounded between the coil and the resistor so that the galvanometer voltage is negative and the feedback voltage on the resistor is positive. This voltage is applied to the emitter of the input transistor and thus supplies the feedback, which is utilized when maximum linearity and reliability are desired.

An advantage of current feedback is that no matter how long a transmission line is used, within reason, the impedance of the line does not affect the accuracy of the pen movement. Also, a short circuit of the transmission line can do no harm to the amplifier or pen circuit. (Open circuit of the transmission line is taken care of by protective resistors within the circuit.) Diodes and bypass capacitors in the circuit permit refinements and more reliable operation under extreme environment conditions.

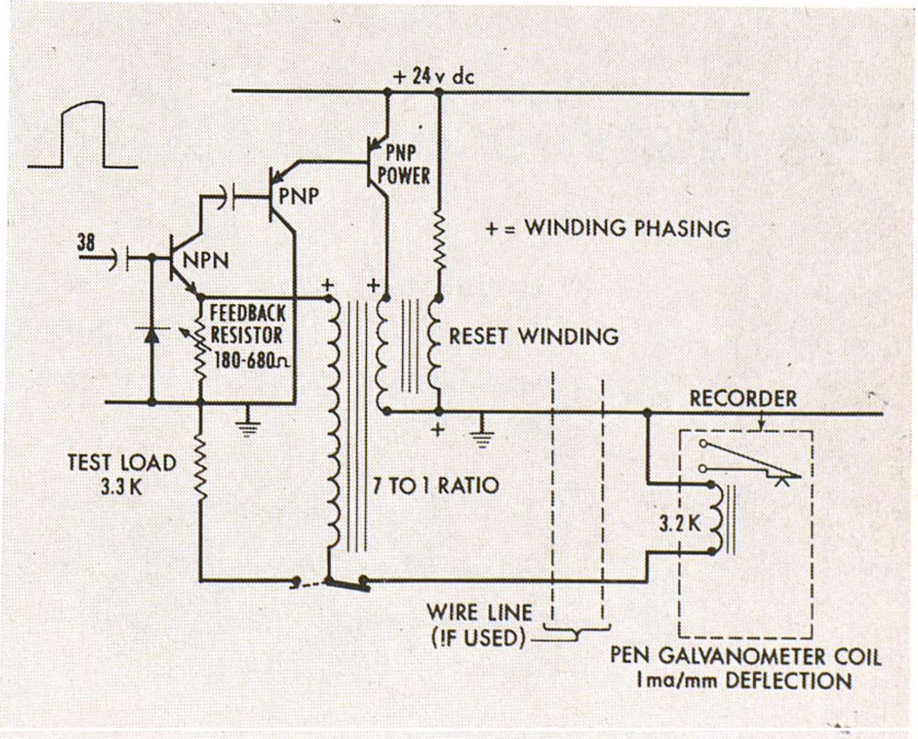


Fig. 5—Simplified diagram of GE pen galvanometer drive amplifier.