Relays in action

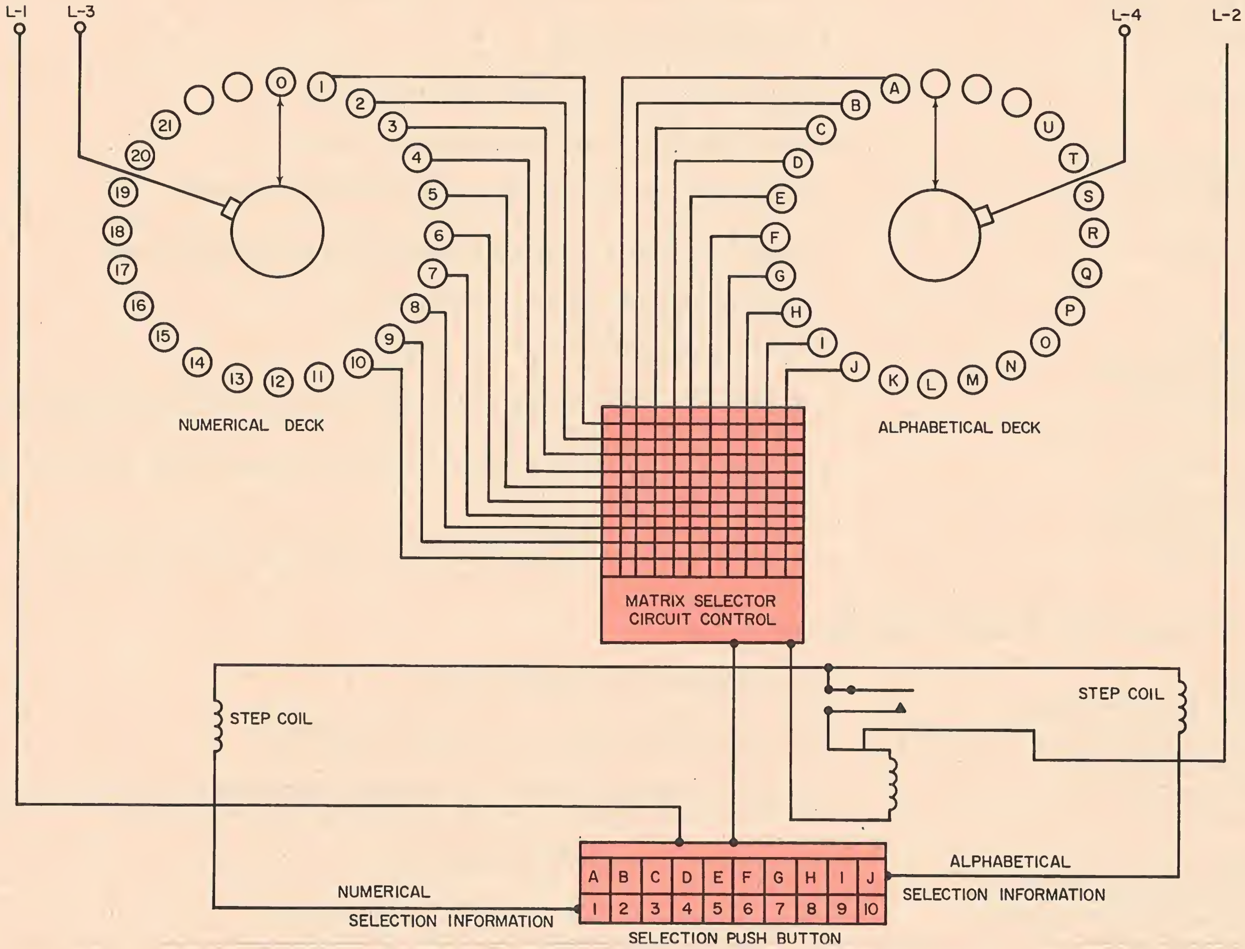
This collection of useful relay circuits shows the versatility of this "old standby."

Stepping relay establishes matrix selector control

A 24-point stepping-relay can easily permit the selection of any one of a hundred circuits through a 10 × 10 matrix arrangement. The relay is directly connected to a push-button selector for system simplicity.

The control circuit in the illustration uses a dual-deck, 24-point stepper. Direct drive on each of the step magnets and indirect operation on the reset magnet is provided. The normally open switch (contacts) on the reset magnet completes the selection circuit.

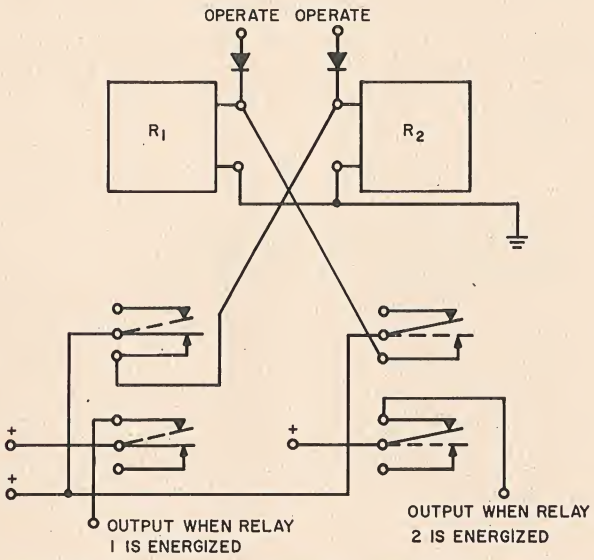
Action is initiated by depressing a push-button selector. This puts the scanning device into operation. The pulse output of the scanner moves the wipers to the desired position, as determined by the push buttons. **SOURCE:** *Guardian Electric Mfg. Co.*



Stepping-relay matrix selector control locates any one of a hundred circuits through a 10 × 10 matrix arrangement.

Two relays form bistable trigger circuit

Two single-coil relays can be used to make a bistable trigger circuit (see illustration). The trigger is always in one of two states: either Relay *1* or Relay *2* is energized, with its corresponding contacts transferred. The trigger remains in one state until a pulse is received to switch it to the other state.



Bistable trigger circuit switches states each time a pulse is applied to the coil of the de-energized relay.

As shown, Relay *2* is held operated by the normally-closed contacts of relay *1*. The circuit remains in this state until an operate pulse is applied to the coil of Relay *1*. When this happens, Relay 1 becomes energized, and its normally closed contacts open. As a result, the holding circuit for the coil of Relay *2* is opened, and Relay *2* drops out. The contacts of Relay *2* then provide a holding circuit for the coil of Relay *1*.

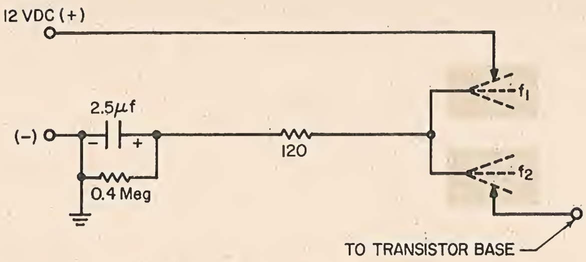
The trigger remains in this state, with Relay *1* energized and Relay *2* de-energized, until an operate pulse is applied to the coil of Relay *2*.

SOURCE: *IBM*

Multiple-reed relay acts as 2-frequency decoder

A simple 2-frequency decoder circuit uses a resonant-reed relay that has two resonant reeds and a single coil. Each reed is resonant at a different audio frequency. The circuit will switch a desired control function only when the two reeds are activated, in sequence, by their respective frequencies.

When the first frequency, f_1, is received, its corresponding reed vibrates. This charges the 25 μf capacitor. When the second frequen-



Multiple-reed relay performs a control function by decoding two audio frequencies.

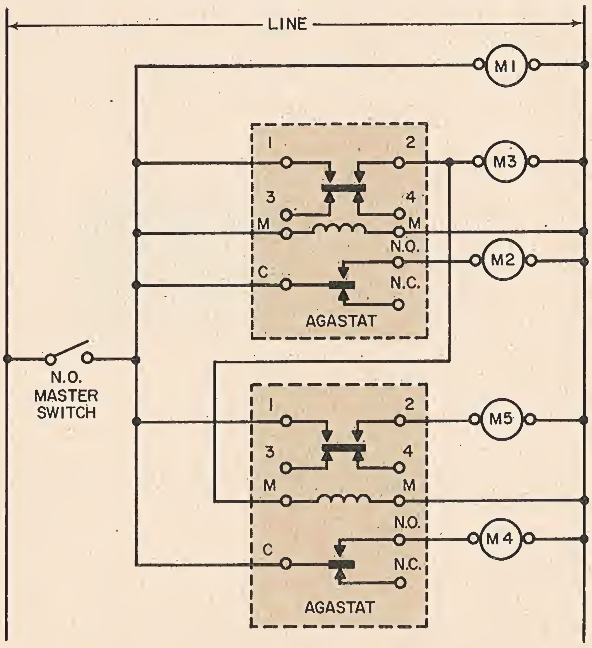
cy, f_2, is received, its reed vibrates, transferring the charge on the capacitor to a tube grid or transistor base. The 0.4 Meg resistor serves as a bleeder across the capacitor to prevent the switching action from being activated by undesirable codes.

SOURCE: *Bramco Controls Div., Ledex, Inc.*

Time-delay relays sequentially switch motor starting system

Many industrial installations employ a series of electric motors that must be started at the same time, and preferably with one switch. A two-step type of time-delay relay can perform this function, while still preventing overcurrent damage.

Drive motors of progressive stands in mill



Two double-step, time-delay relays sequentially switch five motors and prevent them from being damaged by high starting currents.

operations that use multi-stand reduction are examples of such usage, as are the multiple motors used in long conveyor systems. Placing the combined load of all the motors across the line at once would create an excessive current demand and risk the possibility of motor burnout. The relays in the illustration each provide a series of sequential time delays. The starting sequence of the five motors is programed as follows:

1. Closing of the master switch energizes starter circuit of Motor *1* and the coil of the first relay. This starts the first motor and initiates time delays in the starter circuits of Motors *2* and *3*.
2. After the preset delay has expired, the auxiliary contacts of Relay *1* close, thereby energizing the starting circuit of Motor *2*.
3. At the end of second preset delay, the main contacts of the first relay close and energize the starting circuit of Motor *3* and the solenoid coil of the second relay.
4. Motors *4* and *5* are started sequentially in similar fashion, as the two time-delay periods of the second relay first close the auxiliary contacts and then the main contacts of that unit.

SOURCE: *Agastat Timing Instruments*

Double-coil relay simplifies AND circuit

The number of contacts in a relay-logic AND circuit can be reduced by using a double-coil relay. With conventional single-coil relays, two separate relays are used to make up an AND circuit (Fig. 1). The contacts of the relays are wired in series, so that both must be energized to produce an output.

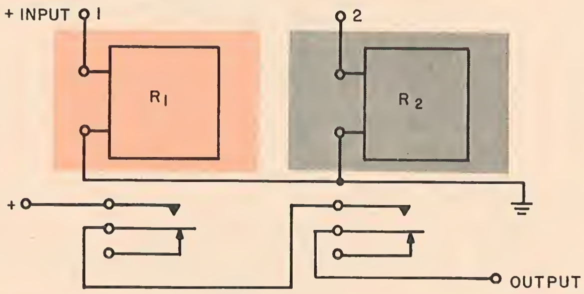


Fig. 1. **Two single-coil relays** are required to produce an AND circuit.

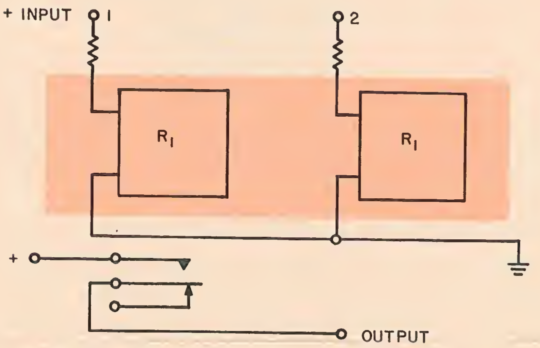


Fig. 2. **Double-coil relay** reduces the number of contacts in an AND circuit.

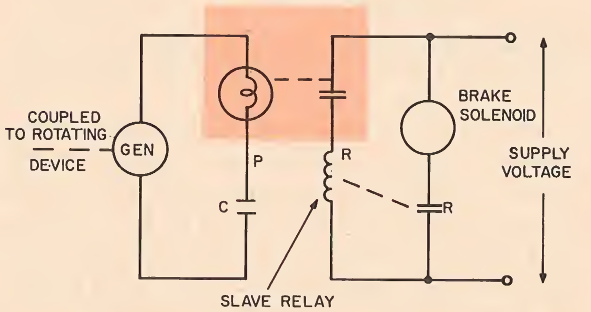
A double-coil relay requires only one set of contacts to provide the AND function. The circuit of Fig. 2 has two coils wound on the same core. An input to either of the coils will not cause the relay to operate, because of the resistor in series with each coil. But when both coils receive an input simultaneously, the combined flux is sufficient to operate the relay.

Once the double-coil relay operates, only one input is required to keep it energized. This is because one coil can provide the flux necessary to hold the armature sealed.

SOURCE: *IBM*

Polarized relay controls acceleration, deceleration

An ultrasensitive micropositioner-type of polarized relay forms a simple means of controlling the acceleration (or deceleration) of a rotating device. The pre-calibrated coil trip adjustment on the relay permits the braking action to be set anywhere below the skid level.



Micropositioner-type polarized relay forms acceleration/deceleration control.

In this system (see illustration), a Barber-Colman micropositioner, capable of operation with inputs as low as 40 μw, is connected in series with a capacitor across the output of a permanent-magnet dc generator. The generator is coupled to the rotating device (in this case, a wheel). When the wheel acceleration is zero, the generator velocity is constant and no voltage appears across the micropositioner coil.

A change in velocity produces a coil input proportional to the acceleration. When the acceleration reaches the predetermined trip limit, the coil is momentarily energized. This closes the micropositioner contacts, *P*, which in turn energize the slave relay, *R*. The contacts of *R* close and permit the brake solenoid to be supplied with power.

SOURCE: *Electro-mechanical Products Div., Barber-Colman Co.*

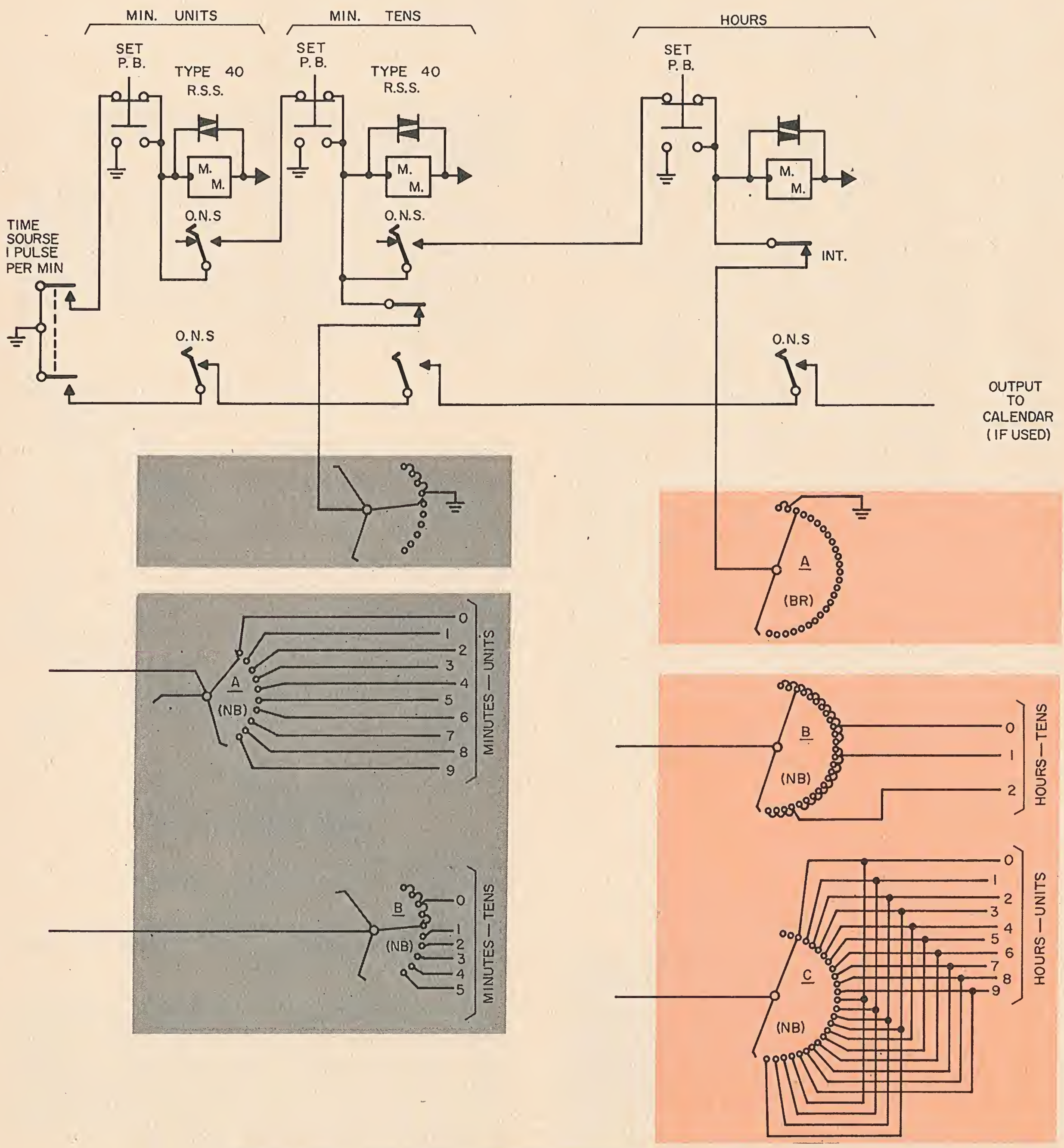
Digital clock uses 3 rotary stepping switches

A 24-hour clock that gives a decimal readout in minutes, tens of minutes, hours and tens of hours uses three rotary stepping switches. The clock is driven by a time source, which delivers one output pulse a minute.

Associated with each stepping switch is a pushbutton used for setting the clock. As shown, the clock is set at 0000, which normally corresponds to midnight.

When the pulse contacts of the time source close, the motor magnet of the minutes-units switch is energized. When the pulse contacts open, the minutes-units switch advances one step to its second, or one-minute, contact. This sequence occurs for each time pulse, until nine minutes have been registered, at which time the off-normal contacts of the minutes-units switch close. The next time pulse therefore steps the minutes-tens switch, as well as the minutes-units switch.

The interrupter (INT) contacts of the minutes-tens switch, together with their associated contact bank, cause the minutes-tens switch always to skip the first four bank contacts. So after the tenth time pulse, the minutes-units switch is at zero, and the



Digital clock uses rotary stepping switches to count time pulses and give 24-hour readout.

minutes-tens switch at one.

The minutes-hours switch operates in a similar manner when both the minutes-units and minutes-tens switches are on their tenth bank contact. If a digital calendar is used, a pulse will be sent along the off-normal switch chain to the calendar once each day.

SOURCE: *Automatic Electric*

Polarized latching relay forms free-running flip-flop

A free-running multivibrator with a cycling capability of up to 20 minutes can be designed using a bistable magnetic-latching relay and a neon lamp. A dual, variable-potentiometer arrangement within the multivibrator circuit permits the delay to be independently adjusted.

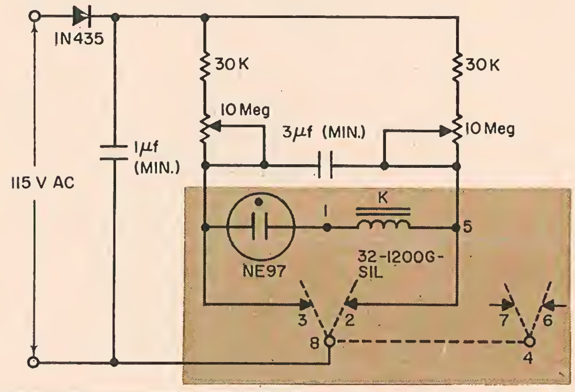
The free-running oscillator (see illustration) operates as follows: The 115-volt, 60 cps power is rectified by the diode. The 1.0 μf capacitor filters the rectified voltage such that the output is reasonably smooth and of the order of 150-175 volts dc for normal line voltage variations (105-130 vo Hs).

The relay is connected so that one of its contact sets always grounds one side or the other of the timing circuit. One side of the timing capacitor is also grounded, while the other is charging up through one of the two variable resistances. When the capacitor charges to the breakover voltage of the neon tube (110-140 volts), a pulse discharge through the relay coil occurs until the capacitor discharges to the maintaining voltage of the lamp (60-80 volts). This discharge pulse transfers the relay to its other stable position so that the positive-voltage side of the capacitor now becomes ground and the other side of the capacitor reaches 60 to 80 volts. From this value, it starts to charge in the positive direction. The next transfer will occur when the capacitor reaches the positive polarity value of 110-140 volts. Then, the second portion of the cycle commences.

Three times the product of the potentiometer resistance and the capacitor gives the time in seconds (approximately) from one transfer to the next. With 10 Meg and 10 μf, the delay is 3 x 10 x 10 = 300 seconds per half cycle. The limit is determined by the leakage currents of the insulation or the capacitor.

The accuracy of the cycling primarily depends on the tolerances of the resistor and the leakage associated with the capacitance and secondarily on the characteristics of the relay and the neon tube.

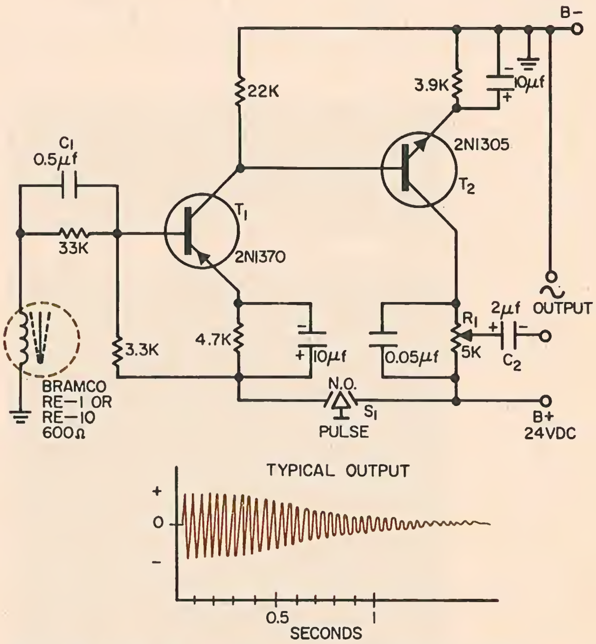
SOURCE: *Sigma Instruments Inc.*



Bistable, magnetic-latching polarized relay and neon lamp form long time-delay (up to 20 min), free-running multivibrator.

Resonant reed-relay produces pulsed tone

A resonant-reed relay can be used to produce a pulsed tone with an extremely narrow bandwidth. Each time the reed relay is pulsed, it produces a damped audio tone. The tone is amplified by T_1 and then clipped to the desired level by T_2.



Damped tone is produced each time the reed relay is activated by a dc pulse.

When S_1 is closed, a dc pulse is applied to the reed relay by means of C_1. This causes the reed to vibrate and generate an audio signal in the relay coil. After amplification by T_1, the generated tone is clipped at the level determined by the setting of R_1.

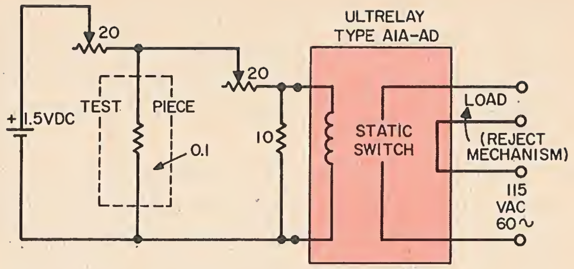
SOURCE: *Bramco Controls Div., Ledex, Inc.*

Sensitive static relay detects resistance limits

An ultrasensitive static relay that responds to fractional microwatt excitation can be used to detect resistance changes as small as 0.1 ohm. The relay also conveniently plugs directly into a 115-volt, 60-cps line.

The relay's sensitivity is derived from solid-state components built into its case. A magnetic-amplifier-driven SCR performs the actual switching. The trip point, which is adjustable through an external control, varies between 0.1 and 0.5 mv.

In the sensing system (see illustration), the 20-ohm potentiometers are adjusted such that if the resistance of the test piece has increased less than 0.1 ohm, the Airborne Accessories "ultRelay" coil is maintained below its energization level. A resistance increase of 0.1 ohm (or more) will cause a greater flow of current into the relay coil. The relay contacts then activate a solenoid reject mechanism, which can either label or remove the faulty test piece.



Ultrasensitive static relay placed in a bridge configuration detects resistance changes as small as 0.1 ohm.

SOURCE: *Airborne Accessories Corp.*

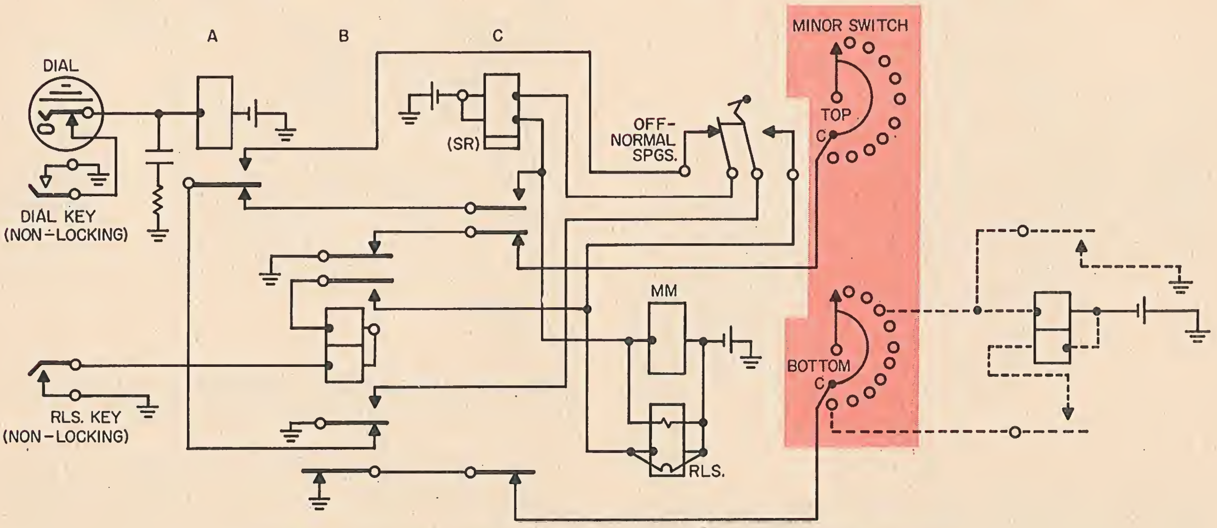
Telephone dial controls rotary stepping switch

Any one of various control functions can be selected by a directly driven rotary stepping switch remotely controlled by a telephone dial.

When a particular digit is dialed, the stepping switch, an Automatic Electric Minor Switch, advances to its corresponding contact. This actuates a control relay connected to that contact, and the relay, in turn, performs the required control function. Although only a single control relay is shown in the illustration, there can be as many relays as there are bank contacts on the stepping switch.

A key is used with the dial to prevent unauthorized dialing. The operation of the dial key closes the circuit to the coil of relay A. This applies a ground to the coil of relay C. The ground is applied through the normally closed contacts of the stepping switch. With relay C energized, the stepping switch's motor magnet (MM in the illustration) is under the control of relay A.

After a digit is dialed, relay A is alternately de-energized and energized as the dial restores. Each time it de-energizes, ground is applied to the holding winding of relay C to keep it energized and to the magnet of the stepping switch to cause it to step once. Each time relay A energizes, ground is removed from the holding winding of relay C and the magnet of the stepping switch. This de-energizes the stepping switch. However,



Rotary stepping switch counts the pulses produced by a telephone dial and actuates a specific control function corresponding to the digit dialed.

relay C is of the slow-release type and remains energized momentarily. As a result, each time relay A is de-energized by the dial contacts, the minor switch is stepped one position.

The dial comes to rest at the completion of the series of pulses corresponding to the digit dialed. At this time, relay A is energized and relay C, after the expiration of its slow-release interval, de-energized.

The stepping switch is returned to its normal, or inoperative, position by operation of the release key. When the key is closed it energizes relay B, which applies ground to the coil of the stepping switch's release magnet.

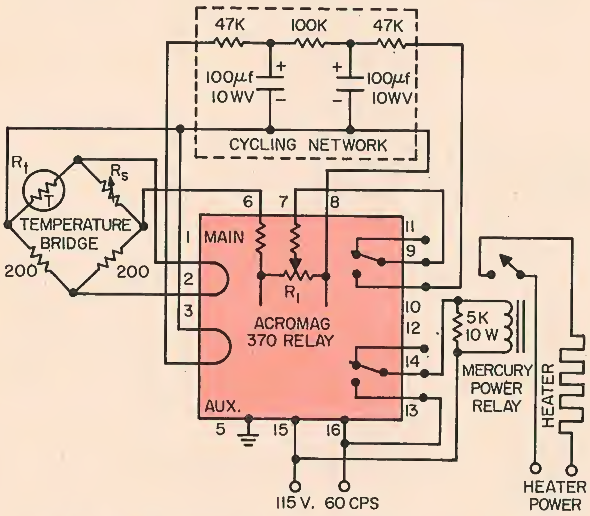
To de-energize the control relay and thus discontinue the external control function, digit 0 is dialed. This causes the stepping switch to stop on the tenth contact, which is wired to the secondary winding of the control relay. When relay C becomes de-energized, ground is applied to the control relay's secondary winding. The resulting magnetic field cancels the field of the primary winding, and the control relay releases.

SOURCE: *Automatic Electric, General Telephone & Electronics*

Ultrasensitive relay forms precise temperature controller

An ultrasensitive, low-level relay incorporating solid-state circuit features can control temperature to within a fraction of a degree. In addition, it accommodates the standard 115 vac, 60 cps power line.

The circuit is basically a Wheatstone



Low-level, solid-state relay, which trips on as little as 50 µv dc, forms the heart of a precision temperature controller system. By adjusting R_s and R_1, the temperature may be controlled to within a fraction of a degree.

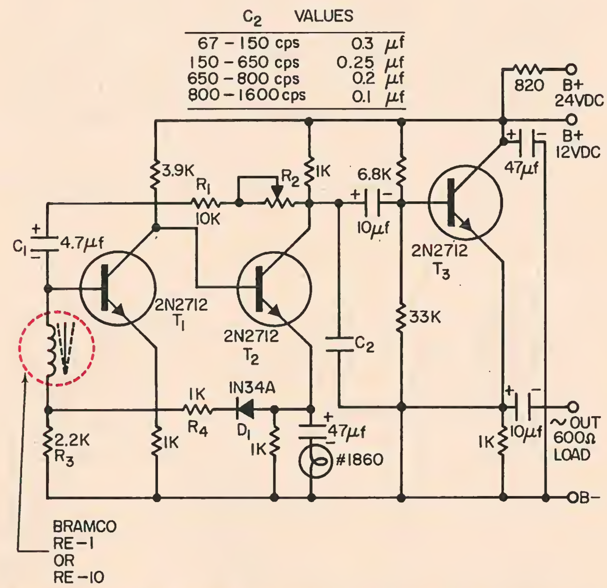
Bridge configuration (see illustration). The relay trips on as little as 50 µv of input. A VECO type-31D38 thermistor and two very-stable, high-precision 200-ohm resistors form the fixed legs of the bridge. The bridge is arranged to be in balance at the set-point temperature. The set-point temperature is selected by adjusting R_s so that its resistance equals the thermistor's resistance. The thermistor changes from 350 ohms at 50°C to 70 ohms at 100°C. Therefore, R_s must cover this span or slightly more.

Adjusting R_1 on the printed-circuit board assists in optimizing the system's dynamics by varying the ON-to-OFF time ratio near the set point. This reduces the oven's temperature variations. In this example, a temperature change as small as 0.02°C operates the output relay. For higher power control, a mercury power relay should be interposed before the low-level relay and the load currents.

SOURCE: *Acromag, Inc.*

Resonant reed stabilizes audio oscillator frequency

Resonant-reed relays can act as accurate frequency-determining elements for audio frequency oscillators. They permit the frequency of a transistor oscillator to be controlled to within ±0.1%.



Resonant-reed stabilized oscillator uses the properties of a vibrating reed to sustain oscillation.

The two-stage feedback oscillator circuit in the illustration has two feedback paths: one path, C_1-R_1-R_2, controls amplifier gain; the other, C_2-R_3, provides a return signal to the reed coil to sustain oscillation. Oscillator frequency is determined by the characteristics of the reed relay. For any particular relay, various frequencies can be obtained by changing the value of C_2. Using Bramco reed relay type RE-1 or RE-10, various values for C_2 and their corresponding oscillator frequencies appear in the table below.

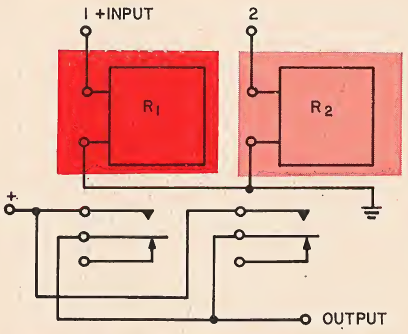
Random noise starts the reed oscillating, and the resulting inductive swing is amplified by T_1 and T_2. Variable resistance element 1860 varies the gain of T_1 and T_2, by varying the amount of emitter bypassing. The oscillator output is coupled to emitter follower T_3, which provides a low-impedance output.

Oscillator buildup time will vary from 0.1 to 60 seconds, depending on the frequency and feedback setting.

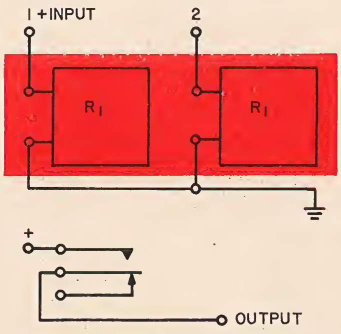
SOURCE: *Bramco Controls Div., Ledex, Inc.*

OR circuits simplified with double-coil relays

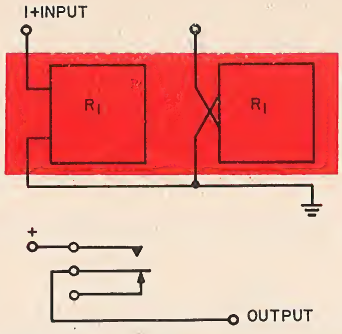
Double-coil relays can greatly reduce the hardware requirements in relay-logic OR circuits. With single-coil relays, the OR function is accomplished by two separate relays having their contacts connected in parallel (Fig. 1). The same OR function can be accomplished with one double-coil relay (Fig. 2). If either coil is energized, the contacts close to produce an output.



1. **Two single-coil relays** are used to make up this OR circuit.



2. **One double-coil relay** can be used for an OR circuit.



3. **EXCLUSIVE OR circuit** will produce an output only when one coil of the double-coil relay is energized.

The double-coil relay can also be used for a simple exclusive-OR circuit (Fig. 3). When both coils are energized, their fluxes buck. Because of this canceling effect, the relay contacts are not transferred. If only one coil is energized, the contacts transfer and produce an output.

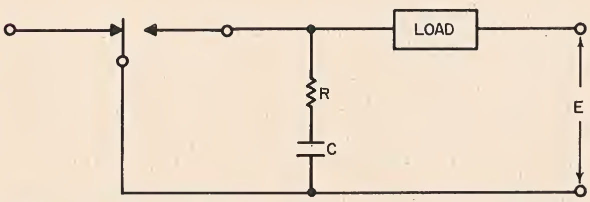
SOURCE: *IBM*

Table speeds RC network design for relay contact protection

A guide for designing RC overvoltage suppression networks can be established by using peak voltage amplitudes as the governing parameter. Although this RC network is commonly used to protect the contacts of mercury relays, it is applicable to general types of relays as well.

Mercury relays typically exhibit a rapid BREAK action. This results in the generation of large, transient peak-voltages across the load. These peaks are particularly dangerous when other than light loads (less than 0.5 amp) are being switched.

The RC network is placed between the load and the contacts (see illustration). It is placed as close as possible to the relay terminals. The design equations are:



RC contact protection network suppresses overvoltage transients

$$C = I^2/10 \quad \text{(in microfarads)} \qquad (1)$$

$$R = E/10I(1 + 50/E) \quad \text{(in ohms)}, \qquad (2)$$

where I is the load current in amperes that was flowing immediately prior to the opening of the contacts, and E is the source voltage (in volts) that existed immediately prior to the closing of the contacts.

The accompanying design table was derived from a test program. Equations 1 and 2 were applied to actual circuits, and the parameters and results were observed. The table is based upon the value of voltage encountered and the minimum safety margin needed to protect the contacts for that value of voltage.

RC contact protection network design

E (volts)	I (amp)	C (μf)	R (ohms)
Less than 50	Less than 2.5	Use calculated value	May be omitted
50 to 70	All other conditions	Use calculated value	3 X calculated value permissible
70 to 100	All other conditions	Use calculated value	Within 50% of calculated value
100 to 150	All other conditions	Use calculated value	Within 10% of calculated value
Above 150	All other conditions	Use calculated value	Use calculated value

Note: for any voltage more than 50, the value of R must not be less than 0.5 ohm.

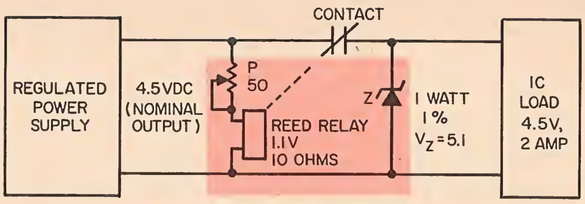
SOURCE: *Adams-Westlake Co.*

Integrated circuit protected by reed relay-diode combination

A reed relay and a zener diode can unite to provide overvoltage protection to integrated-circuit (IC) modules. The relay and diode are placed in a series-parallel configuration to open the IC load circuit.

The widespread use of low-voltage type IC modules has developed a need for overvoltage protection from power-supply defects. A typical industrial IC module has a nominal voltage rating of 4.5 volts and a maximum rating of 5.5 volts. A short-circuit in the series pass transistor (within the supply) can raise havoc with the IC. The supply's output votage will instantaneously double in value and damage the module.

A typical IC load requiring 4.5 volts at 2 amp connected to a series-parallel combination of reed relay and a zener diode appears in the illustration. With a sudden increase in the power supply's output voltage due to a regulation failure—for example, a rise to 9 volts—the zener diode reacts. It is rated at 5.1 volts and thus will immediately clamp the IC load at the safe 5.1-volt level. However, because the zener diode has a low wattage rating, its protection time is limited. This is where the reed relay comes in. Note that the relay will not open its contacts when the power supply voltage is 4.5 volts. However, with the application of a voltage slightly less than the zener diode voltage, the relay will energize and open the IC load circuit. This action removes the overvoltage from the load and cuts off the zener diode.



Combination reed relay and zener diode protect an integrated circuit from overvoltage.

The reed-relay trip point is adjusted by means of potentiometer P, so that the contacts open at a voltage slightly less than the V_z of the zener diode. The reed relay is then supplied with a small current that is below its operating value (under normal supply voltage conditions). It will thus react rapidly to the larger voltage applied during power-supply failure.

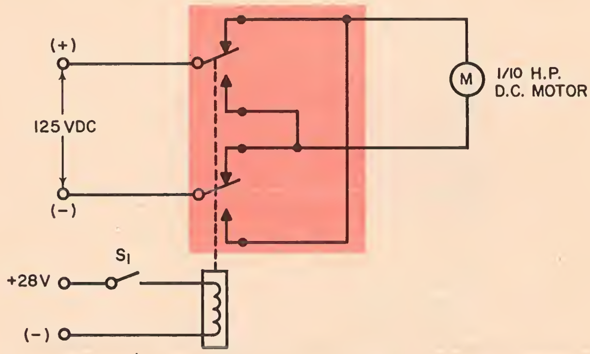
John J. McManus, Senior Project Engineer, Western Union Telegraph Co., New York, N. Y.

Relay provides simple reversal of dc motor

A common, dual-pole relay can be used to reverse a dc motor. It is less expensive than the approach that uses two interlocking relays, and it is far simpler than competing electronic circuitry arrangements.

The circuit (see illustration) reverses the voltage applied to the motor by having the relay contact sets connected in parallel opposition. A reversal occurs each time the coil is either energized or de-energized. Care must be taken to insure that the load current does not exceed the contact ratings. Arc-suppression circuitry may also have to be provided, if the inductive load is large enough to cause severe arcing.

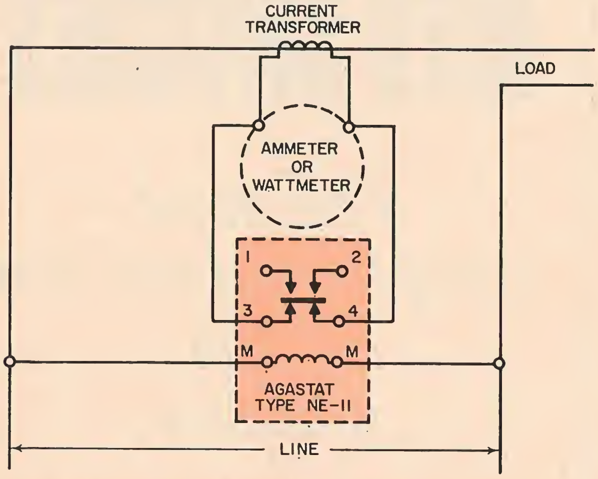
SOURCE: *Leach Corporation*



Parallel-opposition arrangement of relay contacts reverses a dc motor.

Time delay relay protects against inrush currents

In many installations of ammeters and wattmeters, provision must be made to protect the sensitive instrument mechanisms from sudden inrush currents beyond their capacity. "Meter slamming," or driving the pointer beyond the limits of the instrument range, may cause loss of calibration or do permanent damage to the moving elements. This protection is easily provided by a time-delay relay.



Time-delay relay prevents high inrush currents from damaging sensitive instruments.

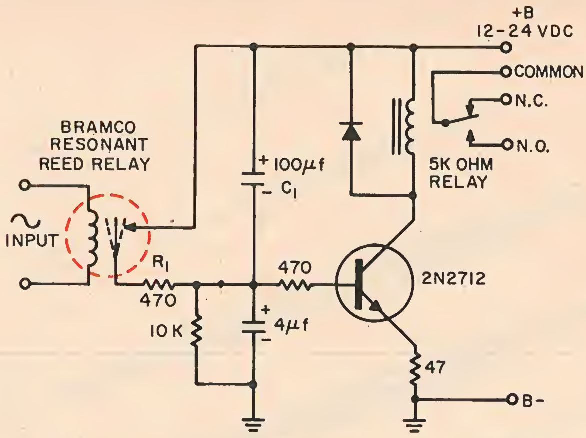
As shown in the diagram, the unit's normally closed contacts (*3* and *4*) provide a short-circuit in the transformer line feeding the instrument, when no current is flowing. When voltage is applied, the coil (*MM*) is energized, initiating a time-delay interval while maintaining the transformer line short. This delay period prevents the high inrush currents from being transmitted through the instrument.

At the end of the timing period, the switch transfers, breaking the circuit between Contacts *3* and *4*. This removes the short from the transformer line and permits the instrument to indicate the normal load value. When the current flow is halted, the relay instantly transfers its switch to the original short-circuit position and is ready for the next voltage inrush.

SOURCE: *Agastat Timing Instruments*

Resonant reed controls timed latching relay

A resonant-reed relay can be used to actuate a timed latching relay circuit. The frequency selective characteristic of the reed relay enables it to discriminate between various input frequencies.



Latching-relay circuit is energized for a predetermined time when the reed relay is pulsed.

The coil of the relay being controlled is in the collector circuit of a grounded-emitter stage. With no input signal to the reed relay, the transistor is biased to cutoff. When the reed relay is pulsed, the reed contacts close intermittently as the reed vibrates. This allows C_1 to discharge through the reed contacts and through R_1. When C_1 discharges, the transistor conducts, closing the secondary relay.

When the reed stops vibrating, the transistor continues to conduct until C_1 again charges up to the transistor cut-off point. At this time the transistor cuts off, de-energizing the secondary relay.

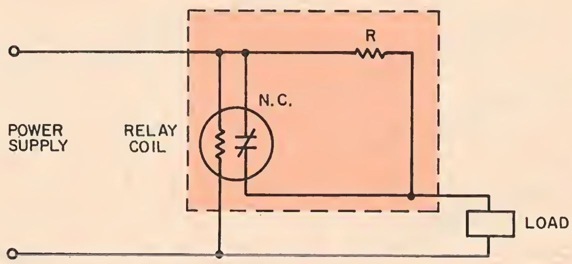
Lock-up time of the secondary relay is determined by the value of C_1. For a 100 μf value, lock-up is approximately 5 to 10 seconds. The diode across the secondary relay protects the transistor from inductive spikes.

SOURCE: *Bramco Controls Div., Ledex, Inc.*

Thermal relay forms simple stepped voltage regulator

A voltage-sensing type of thermal relay can be used as an elementary voltage regulator. Wide variations in the supply voltage being applied to a fixed load may thus be reduced by half.

The relay in the illustration has a set of



Stepped voltage regulation is achieved by the thermal relay-dropping resistor arrangement.

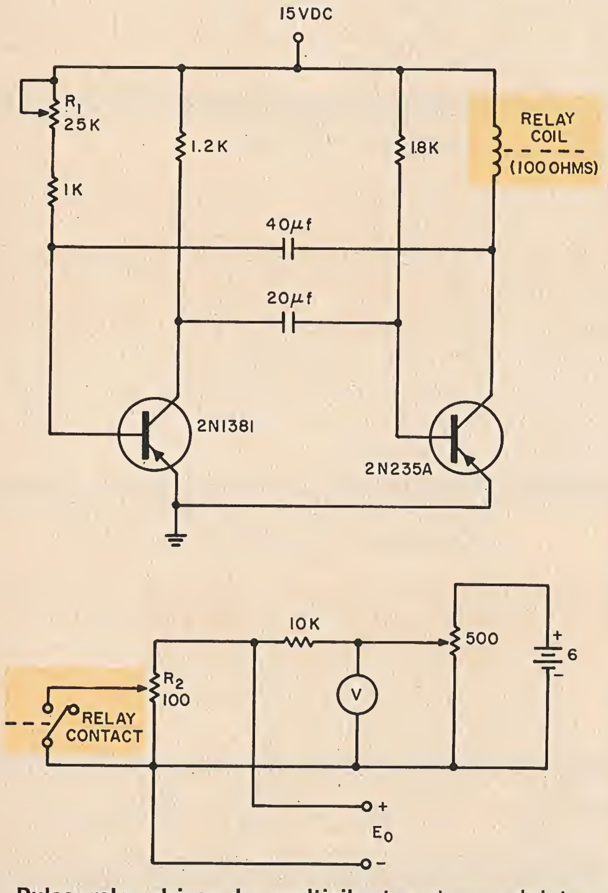
normally closed contacts. When the voltage level reaches one-half of its extreme fluctuations, the contacts open. This inserts a dropping resistor in series with the load. The resistor is selected to produce a voltage drop equal to one-half the total variation span.

For example, if the supply voltage varies between 24 and 30 volts (very common in portable equipment), the relay is set to operate at 27 volts, and the resistor is designed to bear a 3-volt potential. From 24 to 27 volts, the supply is fed directly to the load. Above 27-volt input, the resistor absorbs the excess voltage.

SOURCE: *G-V Controls, Inc.*

Pulsed relay generates low-level step functions

A relay and a multivibrator may be combined to produce a step function waveform to be used to modulate millivolt-level dc signals. Repetitive, low-level steps are generated when the relay's contacts are used to sequentially short out a portion of a voltage-divider network.



Pulse relay driven by multivibrator step-modulates low-level dc signals. Potentiometer R_1 permits the repetition rate to be varied. For the component values shown, output levels up to 60 mv are generated.

In the circuit (see illustration), transistors Q_1 and Q_2 form a free-running multivibrator. The multi's output is used to drive the relay coil. As the multi flips back and forth, the relay's contacts switch the lower half of the R_2 dividing potentiometer in and out of the circuit. This action produces the low-level step voltage waveform.

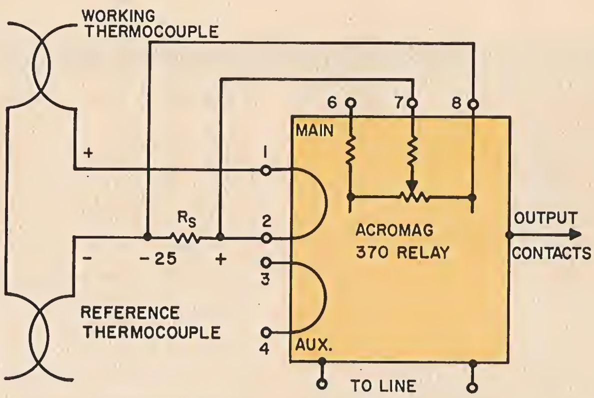
For the component values shown, the repetition rate may vary between 0.1 and 8.0 pulses-per-second (pps). Potentiometer R_1 in the base of Q_1 permits the user to set the desired pps rate. The amount (percent) of modulation may also be varied by adjusting output potentiometer R_2.

The output voltage, E_o, is approximately 0.01 of the monitored voltage, V. E_o varies between zero and 60 mv.

SOURCE: *Portronics, Inc.*

Microvolt dc relay makes inexpensive thermocouple trip

A low-level, solid-state relay can easily and inexpensively function as a thermocouple trip control. It is especially useful for fairly constant ambient-temperature environments.



Thermocouple trip function is inexpensively and simply achieved by ultrasensitive solid-state relay.

A dc-biasing signal is derived from the built-in dc reference in the Acromag Model 370 relay (see illustration). This permits the trip temperature to be adjusted. The circuit is basically a differential voltage comparator that can be adjusted over a range of 0-50 mv. The maximum-temperature trip point is fixed by R_s. For tighter control (lower maximum temperature), R_s should be decreased according to the difference in thermocouples expected and the sensitivity range desired in the comparator.

SOURCE: *Acromag, Inc.*