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ferristors,* their use and application

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CONTENTS

* "FERRISTOR" IS THE TRADEMARK APPLIED TO SATURABLE REACTORS MANUFACTURED BY THE BERKELEY DIVISION OF BECKMAN INSTRUMENTS, INC.

INTRODUCTION TO THE FERRISTOR

Reliability is an ever-growing problem for the electronic design engineer today. In evidence are hundreds of published articles specifying long-life requirements for military and commerical utility and communication systems. Berkeley's contribution toward meeting such requirements-- the culmination of several years research and development-- is the FERRISTOR, a tough new component designed to replace the fragile, short-lived vacuum tube in many applications. "FERRISTOR" is the Berklely trade name for a miniature saturable reactor which will operate at high carrier frequencies. Consisting simply of two windings of fine wire on a tiny iron core, all encased in epoxy resin, the FERRISTOR offers the design engineer reliability that is all but absolute. FERRISTORS do not deteriorate with use or age and cannot be damaged by shock, vibration or moisture. Virtually the only thing that can damage a FERRISTOR-- aside from a sharp blow with a hammer-- is excessive current in the windings, and this solitary possibility is quite remote because FERRISTORS are operated at only a small fraction of rated current. Lastly, as a bonus in reliability, the life span of associated components is also prolonged because FERRISTORS do not generate abundant heat as do vacuum tubes.

CIRCUITS YOU CAN BUILD WITH FERRISTORS

FERRISTORS may be used in two distinct ways. Used in the first way, current in one of the windings controls the reactance of the other winding. If a carrier current is flowing in the other winding, it will be modulated linearly in response to the small controlling current. When the modulated carrier is demodulated, the result is an amplified replica of the controlling current. This elementary amplifier may be modified by simple feedback arrangements to produce an impressive array of familiar circuits such as oscillators, free-running multivibrators, one-shot multivibrators, and current discriminators (the magnetic counterpart of the familiar Schmitt trigger circuit). Two amplifiers may be combined to produce a balanced amplifier or a differential amplifier. And, by adding several input currents to obtain the controlling current, a coincidence gate can be built.

The other way of using FERRISTORS takes advantage of the fact that when the inductive reactance of the controlled winding equals the capactive reactance of the circuit in which it is placed, a resonant circuit is formed which passes so much carrier current that the FERRISTOR saturates and "latches" in this condition. This phenomenon is called "ferro-resonance". A ferro-resonant circuit has two stable states ("latched" and "unlatched") each of which will persist indefinitely in the absence of an input signal. From 2 to 20 of these circuits can be connected in a ring in which the particular circuit "latched" will revolve around the ring in response to successive input pulses, thus forming a ring counter.

Most of the circuits described in the section entitled "Detailed Examples of Magnetic Circuits" are similar-- if not identical-- to those used successfully in Berkeley equipment. This information is offered with the thought that an engineer contemplating magnetic design may wish to construct experimental circuits in order to acquaint himself with their advantages and possibilities.

ELEMENTARY CIRCUITS USING FERRISTORS*

THE BASIC AMPLIFIER

Figure 4 is a schematic diagram of a magnetic circuit which is comparable to a vacuum tube amplifier. The Ferristor itself consists of two windings of fine wire on a tiny iron core, all encased in resin. The essential characteristics of the Ferristor arise from the fact that the small core can be saturated by minute currents in either winding. For this reason it is sometimes called a "saturable reactor" --abbreviated "SR". With no current the carrier winding has the relatively high inductance of a iron-core inductor. But, when the sum of the currents in both winding increases beyond a certain point, the core saturates and the inductance of the carrier winding falls greatly. Operated as an amplifier current in the control winding is used to vary the inductance of the carrier winding. If the carrier winding is energized by a carrier supply (an a-c voltage source), its changing inductance will cause changes in the carrier current flowing in it. Since the carrier current variations are much larger than the control current variations, the Ferristor amplifies. In Figure 4 the a-c carrier current is drawn through Cl. The voltage developed across Cl is the carrier frequency modulated in accordance with control current variations. This signal is rectified and filtered to produce a demodulated output.

Notice that this circuit is roughly analogous to a vacuum tube amplifier. Control current corresponds to control grid voltage; carrier supply voltage, to B+ supply; carrier current, to plate current; and load impedance, to plate load. The main differences are that the controlling quantity is a current rather than a potential and that a carrier frequency must be introduced, modulated and finally removed.

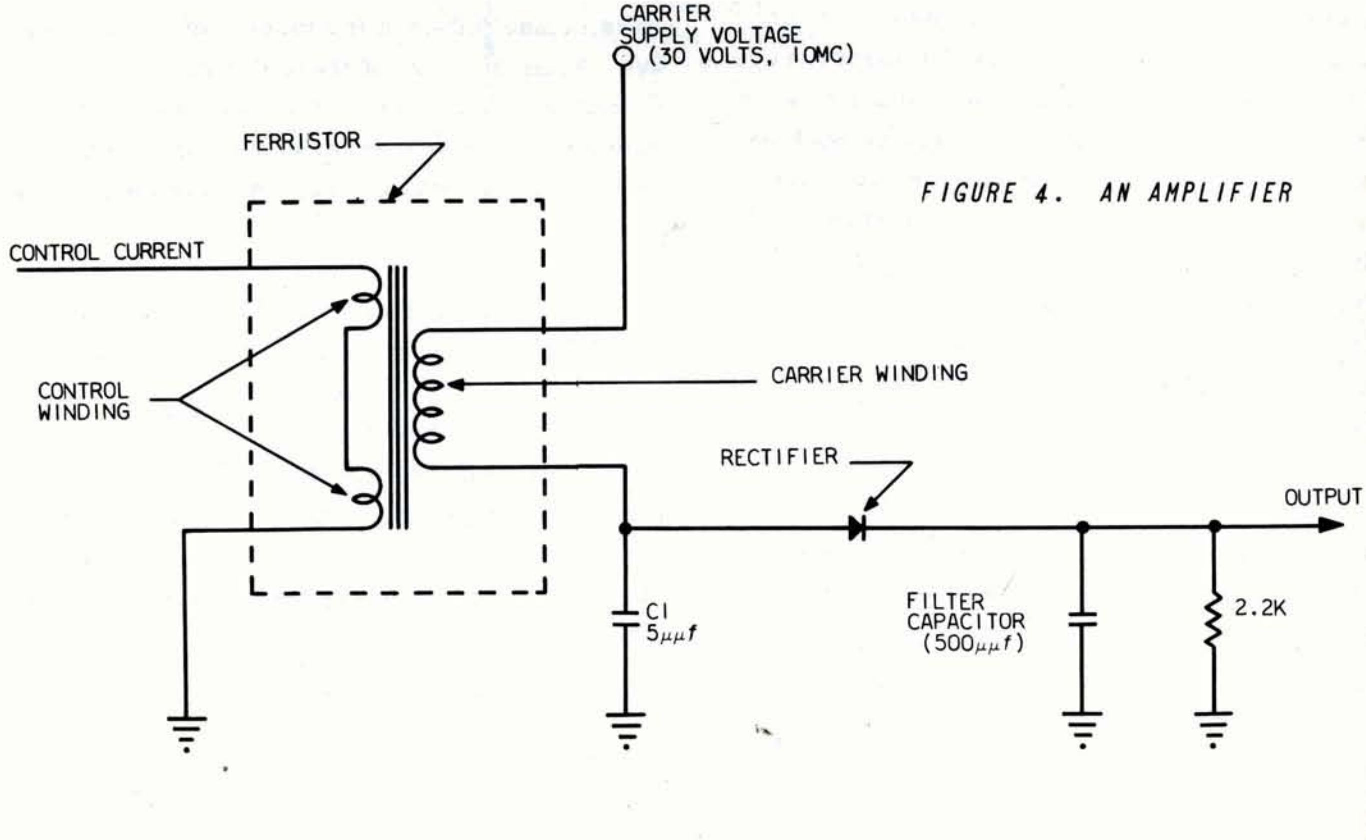


FIGURE 4. AN AMPLIFIER

The transfer characteristics of this amplifier are diagramed in Figure 5. This figure shows how carrier winding inductance and output voltage vary with input current. The inductance is nearly constant from zero current until saturation begins. This range will be called the "non-saturated" region. From the beginning of saturation until the Ferristor is fully saturated the inductance falls rapidly. This will be called the region of "partial saturation." Beyond full saturation the inductance stays nearly constant again

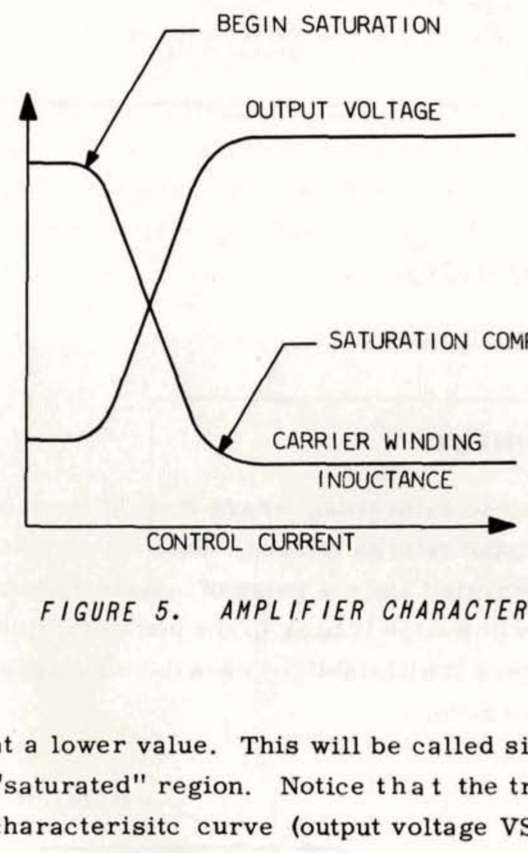


FIGURE 5. AMPLIFIER CHARACTERISTICS

at a lower value. This will be called simply the "saturated" region. Notice that the transfer-characterisitc curve (output voltage VS control current) is analogous to that of a vacuum tube. The point at which saturation begins corresponds to cut-off and the full saturation point corresponds to plate saturation. The gain is appreciable only when the control current varies within the region of partial saturation. The amplifier will have nearly the same characteristics if C1 is removed. In this case the carrier current is predominately pulsating d-c.

A CURRENT DISCRIMINATOR

Figure 6 shows an amplifier circuit which has been converted to a current discriminator by adding positive resistive feedback. This circuit is the magnetic equivalent of the well-known Schmitt trigger vacuum tube circuit. The output voltage E_o draws current through the control winding and feedback resistor in a direction that re-enforces the input current. As the input current rises from zero to the point where saturation begins, the output voltage remains almost constant. When the Ferristor begins to saturate, the gain from input to output rises sharply. At a certain point the feedback loop gain becomes greater than one and the control current and output voltage increase rapidly in a regenerative circuit until the Ferristor is fully saturated. At this point the gain from input to output decreases again to nearly zero and further increases in input current have no effect. When the input current decreases to a value slightly lower than that at which sudden saturation occurred, the total current in the control winding becomes too low to maintain saturation. At this point the output voltage begins to drop, and a reverse regenerative action returns the circuit to the original unsaturated state. Due to this action the circuit switches rapidly back and forth from one to another of two comparatively constant states as the input current rises and falls. Because the state it assumes depends only upon whether the input current is above or below a certain value, it is called a "current discriminator". The difference between the input current value at which the Ferristor switches from non-saturation to saturation and the lower value at which it switches back from saturation to non-saturation is called the hysteresis of the circuit. In electronic counters this circuit is used mainly to generate sharp pulses from slowly varying waveforms.

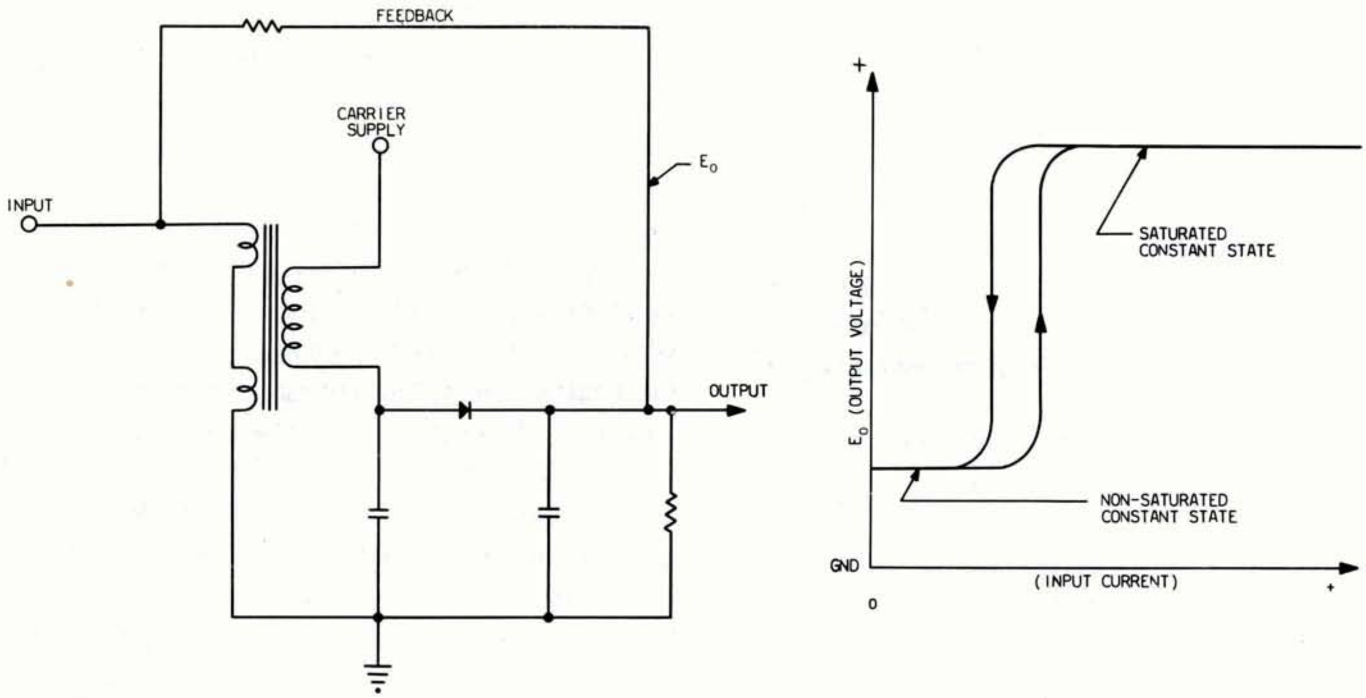


FIGURE 6. A CURRENT DISCRIMINATOR

A CIRCUIT BI-STABLE AT ZERO INPUT

If the value of the feedback resistor in the current discriminator described above is lowered, the hysteresis of the circuit will increase until the transfer characteristic curve assumes the shape shown in Figure 7. This happens because the feedback current in the saturated state becomes so great that it will hold the Ferristor saturated without the aid of any input current, and even when some input current is "bucking" the feedback current in the control winding. In this discussion "positive" input current means current in a direction which aids feedback and "negative" input current means current which "bucks" feedback. Notice that with no input current the circuit is stable in either the saturated or non-saturated state. Due to this characteristic the circuit may be used as a sort of "flip-flop". Starting at zero input current and non-saturation, a pulse of positive current will switch the circuit to saturation, where it will remain when the input returns to zero. With the circuit in the saturated state a pulse of negative input current will switch it back to the non-saturated state, where it will stabilize when the input again returns to zero.

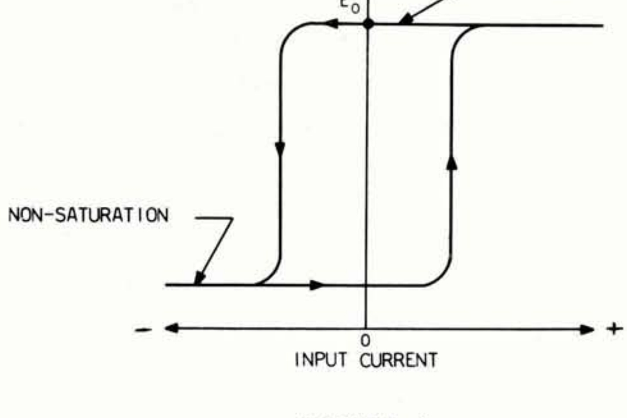


FIGURE 7

voltage the current will decline to the other stable value at point F. On the other hand, if the current is stable at point F and E_{a-c} is reduced to a value below that at point E, the current will drop swiftly to a value below that at point A. If E_{a-c} is then returned to the bi-stable voltage the current will rise to a stable value at point B.

Applying a surge of control current is another way of switching the circuit from one stable state to the other. The total reactance curve shown in Figure 10 is that obtained without control current. If some d-c control current is applied the reactance curve will be shifted to the left as shown in Figure 12. This occurs because the control current now assists the a-c current in producing saturation. Consequently, the carrier winding circuit will reach the point of resonance at a lower value of a-c current. Figure 13 shows the resultant relationship between E_{a-c} and I_{a-c} when control current flows. Note that the circuit is no longer bi-stable at the operating voltage shown in Figure 11. At this voltage it is stable only in the saturated state. If the circuit is operating a point B in Figure 11, a surge of control current will switch it to the saturated state. When the control current declines again to zero the circuit will stabilize at operating point F. Notice, however, that a pulse of control current will not switch the circuit from the saturated state to the non-saturated state.

R1 in Figure 9 was placed in series with L1 and C1 to simplify the circuit. In practice the load resistance is usually connected in parallel with C1. This arrangement will produce the same effect described above if the parallel resistance has the proper value.

REFERENCES

For more thorough descriptions of magnetic circuits see the articles listed below.

(1) "Ferroresonant Flip-Flops" Carl Isborn, Electronics, April 1952.

(2) "An Unstable Nonlinear Circuit" Claude Summers, Elect. Engr., May 1940.

(3) "Critical Conditions in Ferroresonance", P.H. Odessey and E. Weber, AIEE Transactions V. 57, p. 444, Aug. 1938.

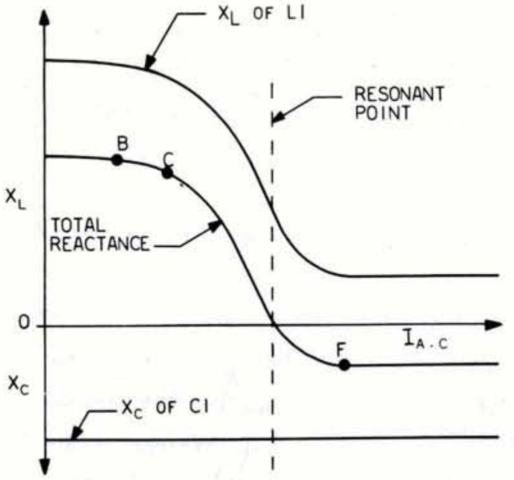
(4) "Non-Linear Circuits Applied to Relays" C.G. Suits, Elect. Engr. April 1933.

(5) "Non-Linear Circuits for Relay Applications" C.G. Suits, Elect. Engr., Dec. 1931.

(6) "Resonant Non-Linear Control Circuits" W.T. Thomson, AIEE Transactions, Aug. 1938.

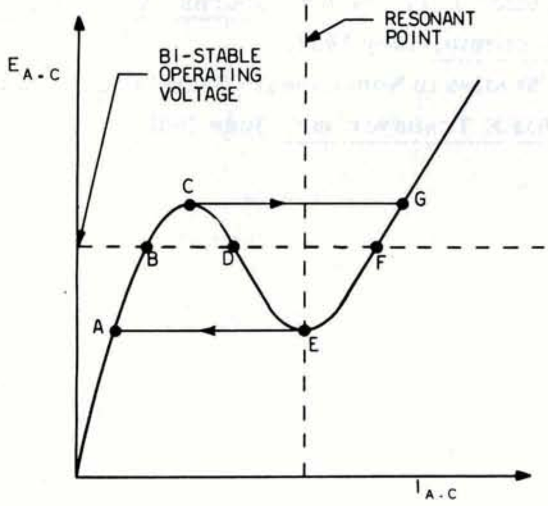
(7) "Resonant Theory Series Non-Linear Circuits" E.G. Keller, Journal of Franklin Institute, May 1938.

(8) "Studies in Non-Linear Circuits" C.G. Suits, AIEE Transactions, June 1931.



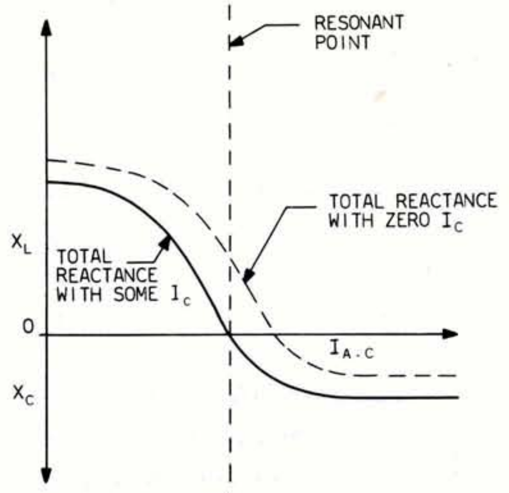
I_{A-C} VS REACTANCE AT ZERO I_C

FIGURE 10.



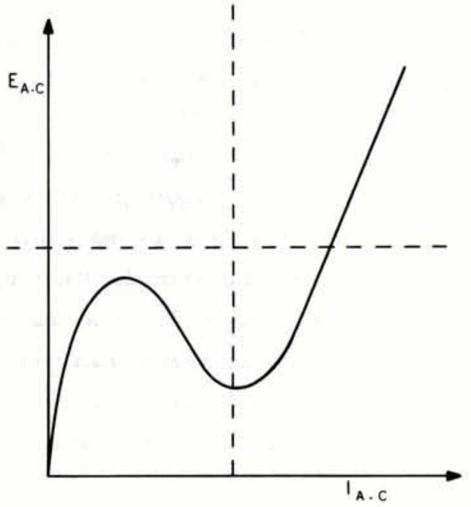
E_{A-C} VS I_{A-C} AT ZERO I_C

FIGURE 11.



I_{A-C} VS REACTANCE WITH SOME I_C

FIGURE 12.



E_{A-C} VS I_{A-C} WITH SOME I_C

FIGURE 13.

A ONE-SHOT MULTIVIBRATOR

Figure 8 shows an amplifier circuit converted to a one-shot multivibrator by adding an R-C feedback loop. The input current to this circuit is usually a series of pulses--in this case, positive pulses. The rising current of each pulse produces a voltage rise at the output. This places a positive potential on the output side of C_f, causing the other side to draw current through R_f and the control winding. If the input pulse has enough amplitude to reach the region of partial saturation, the feedback loop gain will become momentarily greater than one and the conrol current and output voltage will increase rapidly in a regenerative circuit until the Ferristor is fully saturated. At this point E_o stops rising and the control current decreases as C_f approaches a full charge. When the control current re-enters the region of partial saturation a reverse regenerative action rapidly returns the Ferristor to the non-saturated state. The duration of full saturation depends upon the R-C time constant of the feedback loop, becoming longer as the time constant lengthens. This circuit is used mainly to produce uniform amplified pulses with steeper leading and trailing edges. It will also function as a pulse gate if a bias current is used to raise and lower the d-c level which the control current assumes in the absence of input pulses. With a high d-c level, input pulses of correct amplitude reach the region of partial saturation and output pulses are produced. In this condition the gate is "open". With a low d-c level, input pulses do not reach partial saturation, no output pulses occur and the gate is effectively "closed".

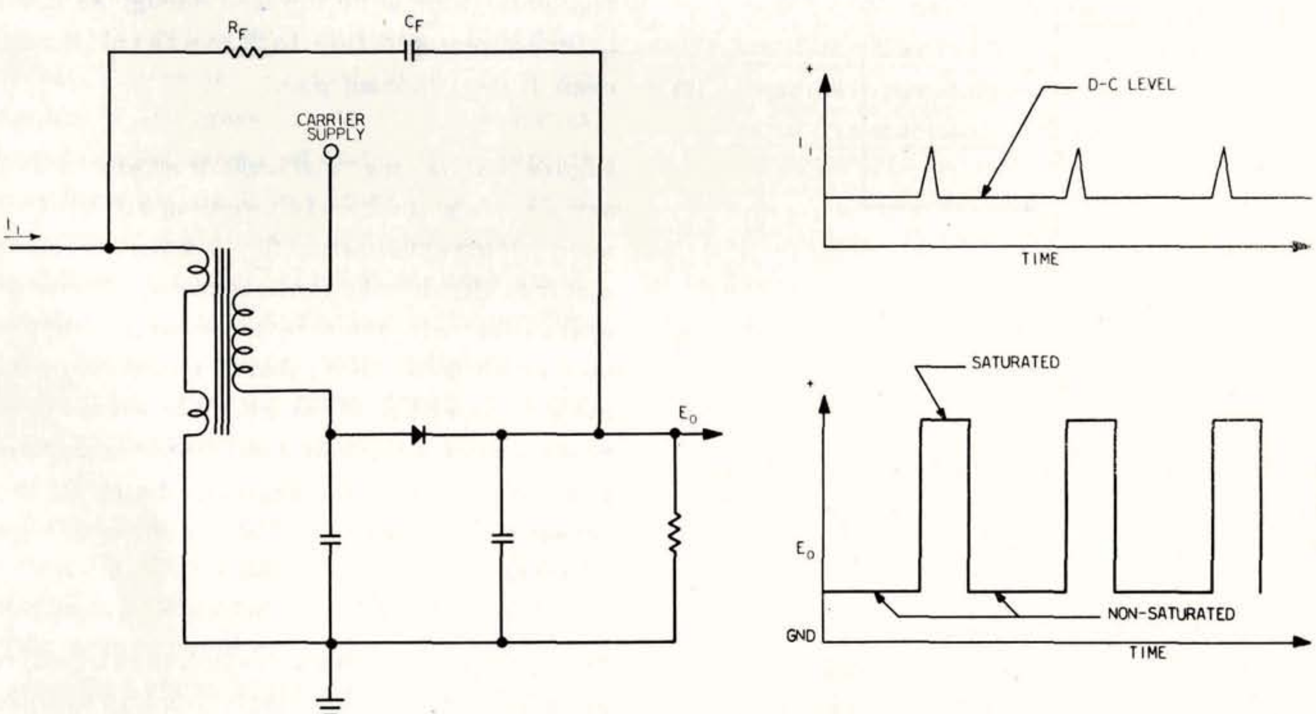


FIGURE 8. ONE-SHOT MULTIVIBRATOR

FERRO-RESONANCE

The amplifier circuits described on the previous pages are built so that the carrier does not have an appreciable saturating effect. This is done by deliberately keeping carrier current comparatively low. However, heavier carrier current can saturate the Ferristor without the aid of any control current. Consider the circuit shown in Figure 9. Cl has a value such that its capacitive reactance equals the inductive reactance of the carrier winding (Ll) at some point near full saturation. At this point the carrier winding circuit becomes series resonant and its total im-

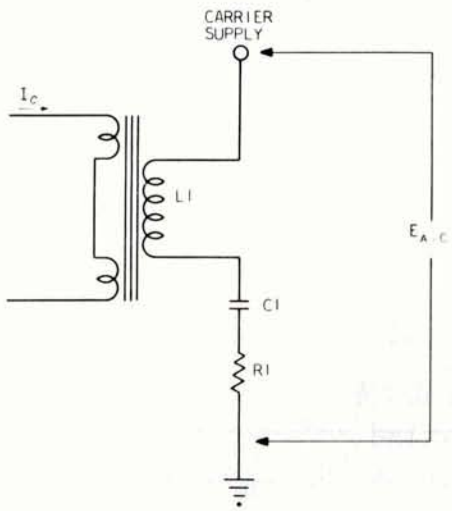


FIGURE 9.

pedance becomes so small that enough carrier current flows to saturate the Ferristor in the absence of control current.

Figure 10 shows how the reactance of the carrier winding circuit varies with carrier current (I_{a-c}) when there is no control current (I_c) whatever. Current and reactance are interdependent. Up to the resonant point an increase in current causes a decrease in reactance which causes a further increase in current producing another decrease in reactance, etc. This mutual reenforcement creates the possibility of a "run-away" regenerative action. When E_{a-c} is initially applied, the current rises and the reactance falls to point B. At this point the circuit stabilizes because increasing current does not cause the reactance to fall rapidly enough to create a "run-away" effect. However, if the reactance is lowered to point C by some device, "run-away" regeneration will occur and the carrier current will increase through the resonant point and beyond. At point F the circuit will stabilize again since the reactance (now capacitive) is increasing with further increases in I_{a-c}. Thus, the circuit has two stable states: a non-saturated state at point B and a saturated state at point F. The circuit may be triggered from non-saturation to saturation by any action which will partially saturate the Ferristor enough to lower the reactance to point C. To switch the circuit back to the non-saturated state the carrier voltage must be lowered enough so that too little current will flow to maintain saturation even at the resonant point.

Figure 11 shows the relationship between the voltage across the carrier winding circuit (E_{a-c}) and the current flowing (I_{a-c}) when the load resistance (Rl) is taken into account. This diagram illustrates the bi-stable characterisitcs of the circuit well. Note that at a certain operating voltage either of two possible values of current can exist: one at point B (non-saturated) and one at point F (saturated). Point D, in the "negative resistance" part of the curve is highly unstable.

Two methods are used to switch the circuit from one stable state to the other. One is to change the operating voltage (E_{a-c}) momentarily. Suppose the circuit is stable at point B. If E_{a-c} is raised to a value above that at point C the current will jump to some value beyond point G. If E_{a-c} is then returned to the bi-stable operating

Method of Obtaining Discrete Stable States. Several of the bi-stable circuits described under "FERRORESONANCE" can be corrected in a ring to form a pulse counting device. Figure 11 is a diagram of a ring made up of three Ferristors which, consequently, has three discrete stable states. It is called a ring-of-three. The carrier winding circuits are connected in parallel through a high impedance (C4) to the carrier supply. For the following reason only one Ferristor can be saturated at any given time. If C4 were shorted-out the voltage across all L-C combinations would rise high enough to cause all the Ferristors to saturate with carrier current alone. However, since carrier voltage is applied through C4, the voltage across all L-C combinations initially rises only until one Ferristor saturates and draws heavy current through its carrier winding. When this happens the voltage across all three is lowered due to the voltage drop across C4. The lowered voltage is high enough to maintain saturation in one Ferristor but not high enough to cause either of the other two to saturate unaided by control current.

Referring to Figure 8, the voltage across one. L-C combination originally rises to that at point C, then falls to a value between that at point C and that at point E. If more than one Ferristor began to saturate the voltage across all would drop below the value at point E and all but one would be forced to assume the non-saturated state. This circuit is analogous to three gas tubes connected in parallel through high impedance to a d-c voltage source. When voltage is applied, the potential across the tubes rises until one breaks down. Once this occurs the other tubes will not fire because their striking voltage is greater than the operating voltage of the tube already lit.

Triggering by Applying Control Current. There are two common methods of triggering the ring from one state to another. One method is to apply a pulse of control current to one of the Ferristors in the ring. Suppose only SR1 is saturated and heavy current is flowing in L1-C1. A large r-f voltage drop appears across C1 but only a small drop across C2 and C3. Since each capacitor is connected to one end of the control winding of the next Ferristor in the ring, a 20-volt r-f signal appears at the SR2 control winding and a much smaller signal at the control windings of SR3 and SR1. The other ends of all control windings are connected through varistors to the input terminal, which is at ground with no input signal. The varistors act like biased diodes. As shown in the characteristic curve in Figure 11, this element passes very little current as long as the voltage across it remains below a certain value, but when the voltage rises above this value its resistance declines severely and current flows freely. When the input is at ground, all varistors are biased "off" with respect to the a-c voltage at the control windings. But when the input voltage rises to +25 volts, the 20-volt r-f signal at the control winding of SR2 draws pulsating d-c current through the varistor charging C5. A moment later when the input returns to ground, C5 discharges through the control winding. This control current switches SR2 to the saturated state in the way described under "FERRORESONANCE". Since only one Ferristor may be saturated at any time, SR1 reverts to the non-saturated state. The next input pulse saturates SR3 and returns SR2 to non-saturation. In this way successive input pulses cause the saturated state to revolve around the ring. If the ring is placed in an initial "reset" condition in which SR1 is saturated, the particular Ferristor saturated after applying input

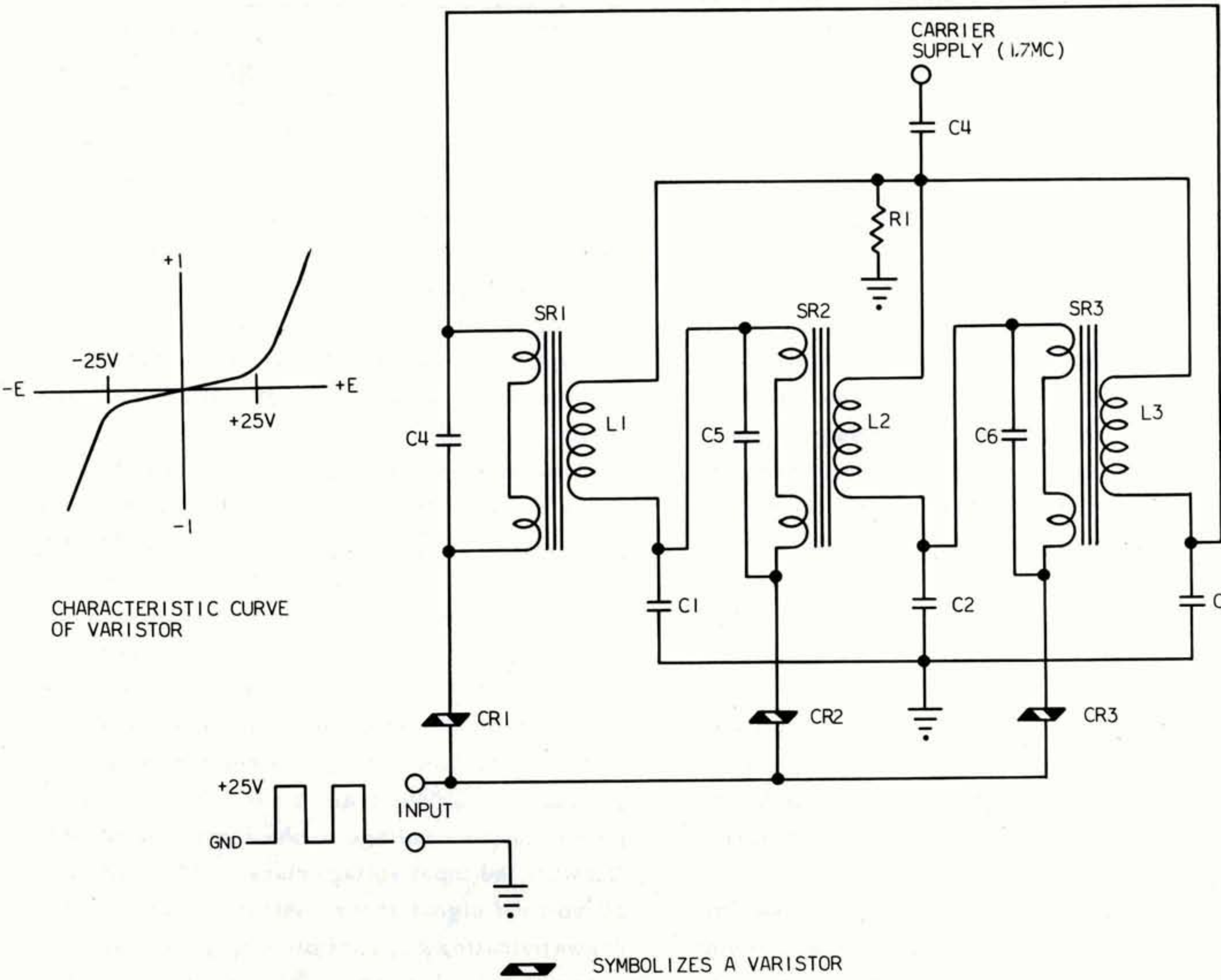


FIGURE 11. A RING-OF-THREE (WITHOUT TRIGGERING FERRISTOR)

pulses will correspond to the number of pulses received. The ring will count: "0" (SR1 saturated) "1" (SR2 saturated), "2" (SR3 saturated) and "0" again (SR1 saturated). If neon bulbs are connected across C1, C2 and C3, a lighted bulb will indicate the pulse score.

Triggering by Reducing Carrier Voltage. Another method of triggering the ring from one state to another is to momentarily lower the carrier voltage. Figure 12 shows a circuit designed to be triggered this way. Suppose SR1 is the saturated Ferristor. Then the high r-f output voltage at the junction of L1 and C1 charges C5 by drawing pulsating d-c current through CR2. The lower r-f voltage at the outputs of SR2 and SR3 is not sufficient to overcome the +5-volt bias on the varistors, so C6 and C4 are not charged. In this condition a triggering current pulse is applied to the input. The current flowing through the control winding of SR4 lowers the reactance of its carrier winding to the point where L4 and

C4 form a parallel resonant circuit at the carrier frequency. The high impedance of this L-C combination momentarily reduces the carrier voltage reaching the Ferristors in the ring, causing SR1 to revert to the non-saturated state. When the input current returns to zero, the carrier voltage rises again and one of the Ferristors must saturate. In this case, SR2 saturates first because it is already partially saturated by current flowing in its control winding as C5 discharges. The next input pulse returns SR2 to non-saturation and saturates SR3. Successive input pulses cause the saturated state to revolve around the ring in the same way described under "Triggering by Applying Control Current".

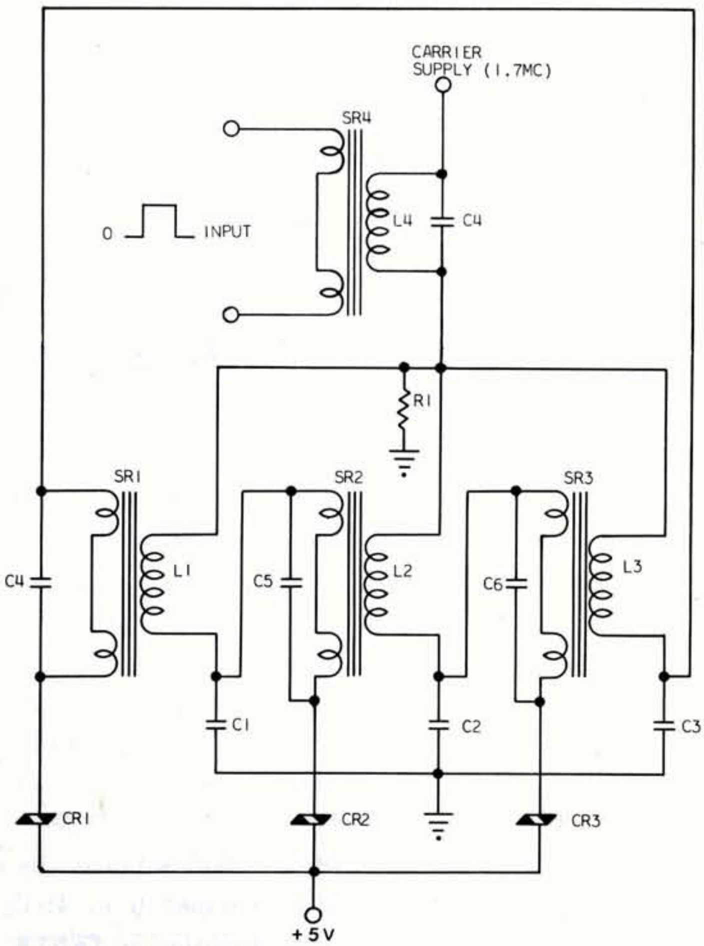
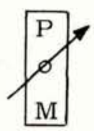


FIGURE 12. A RING-OF-THREE (WITH TRIGGERING FERRISTOR)

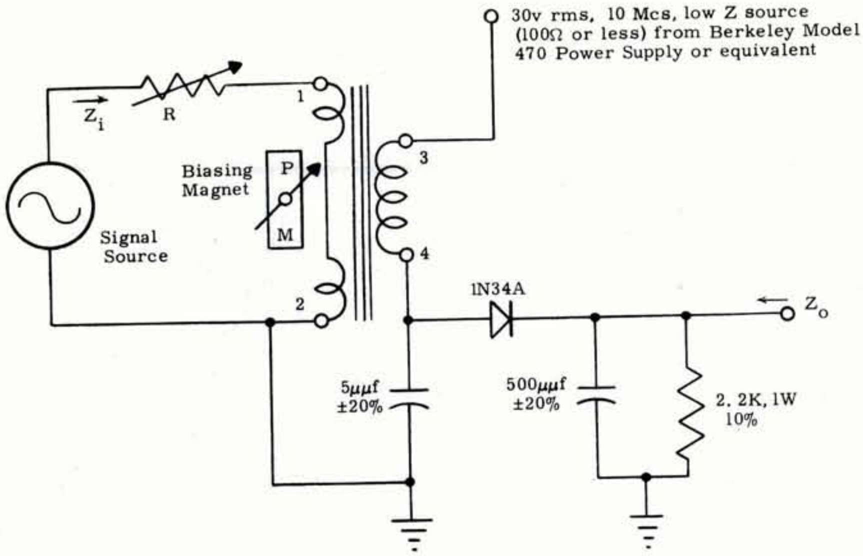
DETAILED EXAMPLES OF MAGNETIC CIRCUITS

Most of the circuits described in the following pages are similar -- if not identical-- to those used successfully in Berkeley equipment. This information is offered with the thought that an engineer contemplating magnetic design may wish to construct experimental circuits in order to acquaint himself with their advantages and possibilities. Component values and performance characteristics listed are merely approximate. It is expected that the engineer will modify the circuits somewhat to achieve desired chacteristics.

In the pages which follow each FERRISTOR is identified by a stock number (i. e. 41-11, 41-12, etc.) labelled on a diagram or in an adjacent table. A small permanent magnet is mounted on some types of FERRISTORS. This magnetic can be rotated to increase or decrease the initial degree of saturation, thus achieving a biasing effect corresponding to grid bias in vacuum tube circuits. FERRISTORS sold with a magnet are stock numbers 41-8, 41-9 and 41-10. These types are otherwise identical to stock numbers 41-11, 41-12 and 41-13 respectively. In the diagrams the biasing magnets appear thus:



SINGLE-STAGE AMPLIFIER



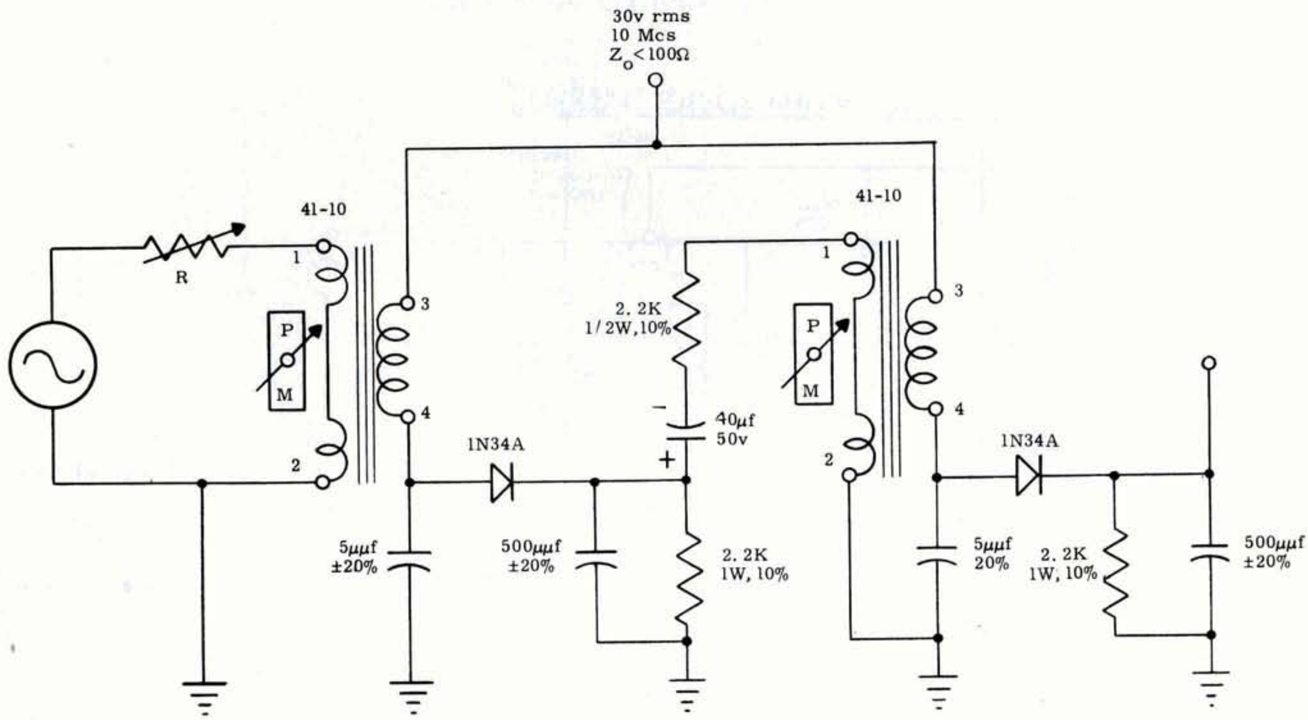
Ferristor Used

	41-8	41-9	41-10
Z_i at 1 KC	R= 1KΩ X_L = 7Ω	R= 1KΩ X_L =12	R= 1KΩ X_L =25Ω
Z_o	500Ω	500Ω	500Ω
Power Gain	10:1	30:1	90:1
Band Pass*	DC to 400 Kcs	DC to 65 Kcs	DC to 30 Kcs
Output Voltage Swing	10v to 30v	10v to 30v	10v to 30v

*For band pass tests
Adjust R to give 1KΩ total input Resistance
Output is 3db down at upper frequency limit.

NOTE: With no input adjust magnet to give maximum output voltage across the 22KΩ resistor, then back down to approximately +18v d-c to achieve best gain and linearity.

TWO-STAGE AMPLIFIER



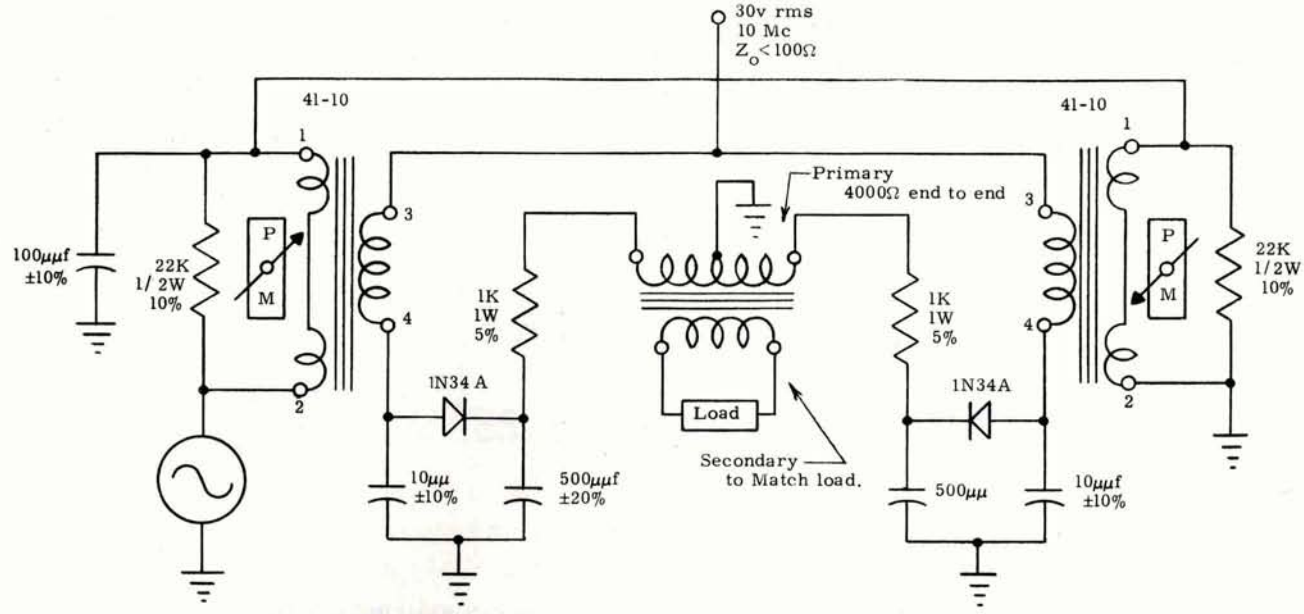
Overall Power Gain:	1000
Band Pass:	15 cps to 35 Kc (See note 2)
Output Voltage Swing:	10v to 30v D.C.

NOTES:

(1) Adjust R to give 1000Ω total input resistance for band pass tests.

(2) The amplifier can be d-c coupled by omitting the 40 μf electrolytic coupling capacitor and readjusting the bias magnet on the second stage to give 18v d-c output with no input.

AMPLIFIER WITH SINGLE-ENDED INPUT, PUSH-PULL OUTPUT

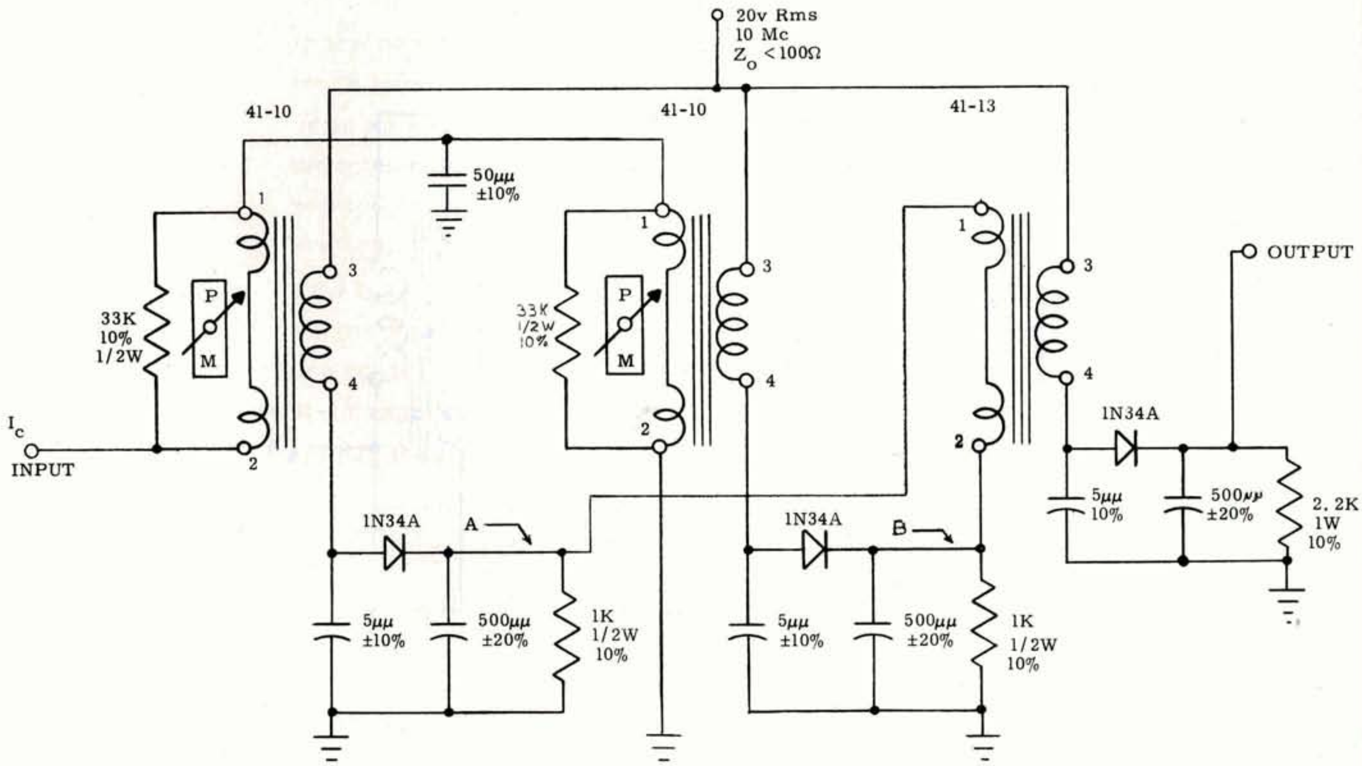


NOTES: (1) Adjust magnetic bias for maximum output voltage then back down to +20v

(2) Audio output power 300 milliwatts

(3) Band pass depends on output transformer. The amplifier itself will pass frequencies high as 20 Kcs.

BALANCED AMPLIFIER



NOTES: (1) Adjust magnetic bias to maximize output, then back down to +10v at A and at B.

(2) This arrangement tends to cancel

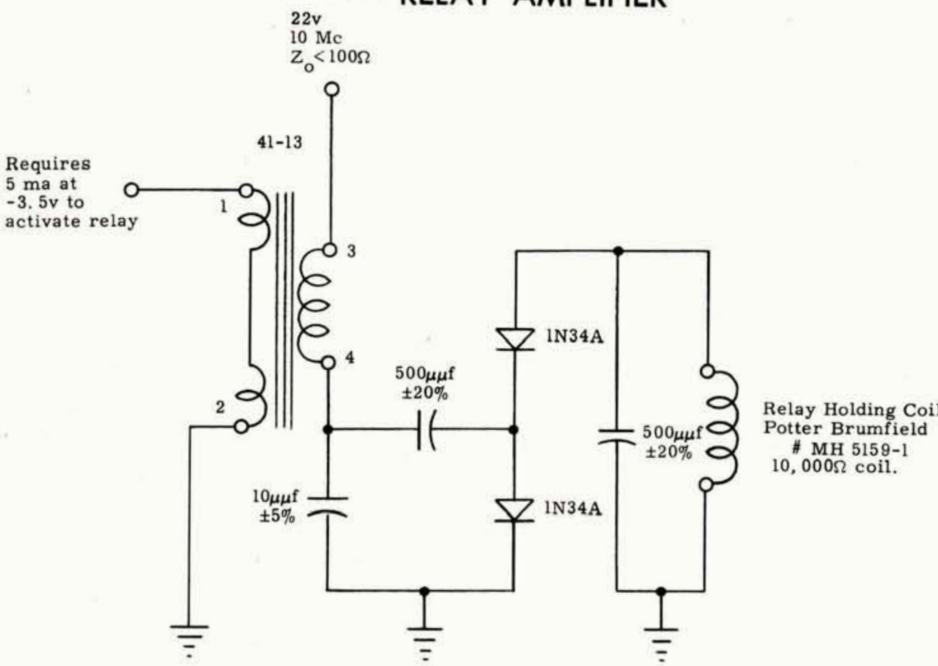
(a) RF voltage variations

(b) External magnetic fields

(c) Temperature drift in components.

(3) Current gain = 25

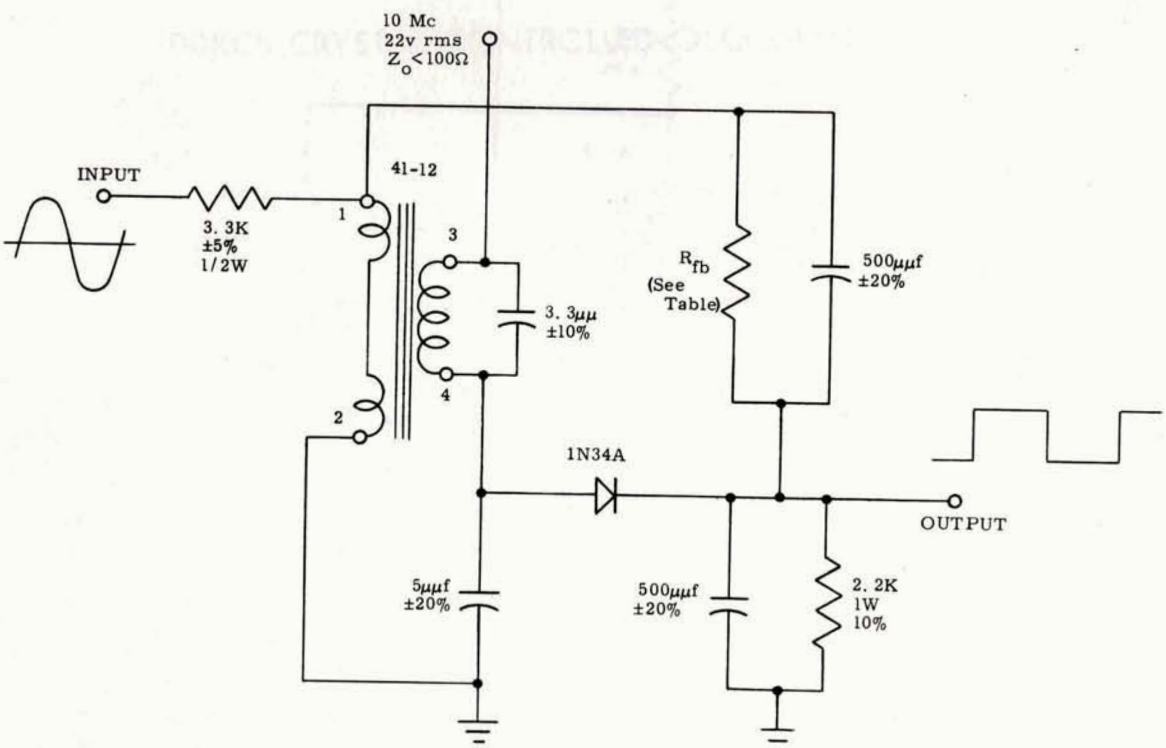
RELAY AMPLIFIER



NOTES: (1) A capacitor feedback of 25μf will cause one shot action and momentary closure of relay with each applied pulse.

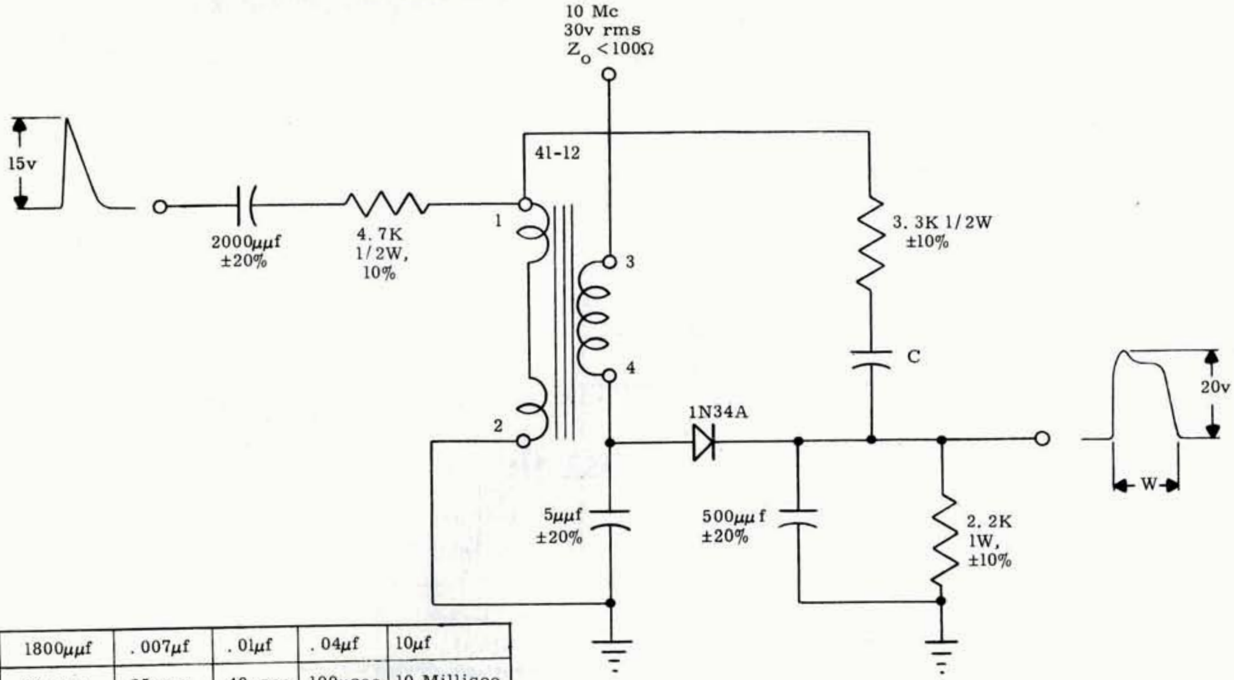
(2) A 4. 7K feedback resistor from junction of the two diodes to the control winding will cause ther relay amplifier to latch and hold the relay contacts closed when a negative pulse is applied to the input.

CURRENT DISCRIMINATOR



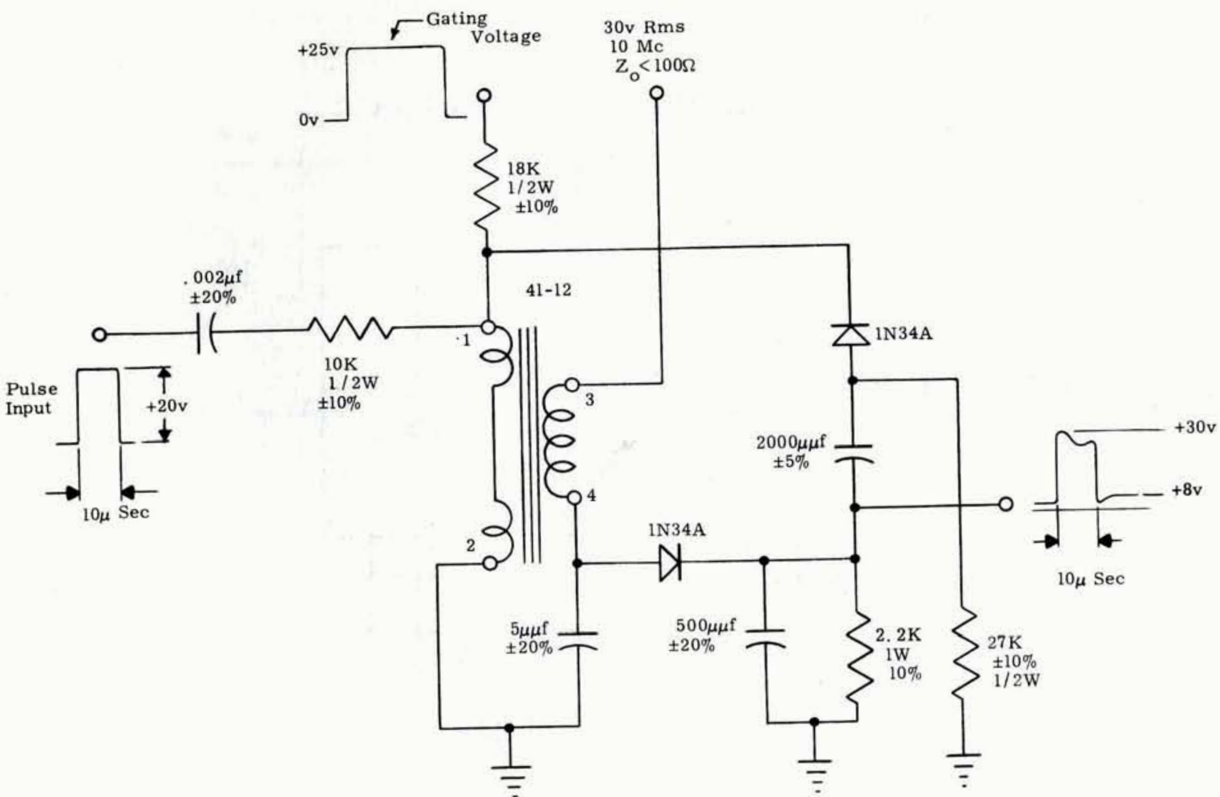
R_{fb}	5. 6K	6. 8K	8. 2K
Hysteresis	130μa	85μa	35μa

ONE SHOT MULTIVIBRATOR



C =	1800μμf	.007μf	.01μf	.04μf	10μf
W =	10μsec	25μsec	40μsec	100μsec	10 Millisec

GATED ONE-SHOT MULTIVIBRATOR



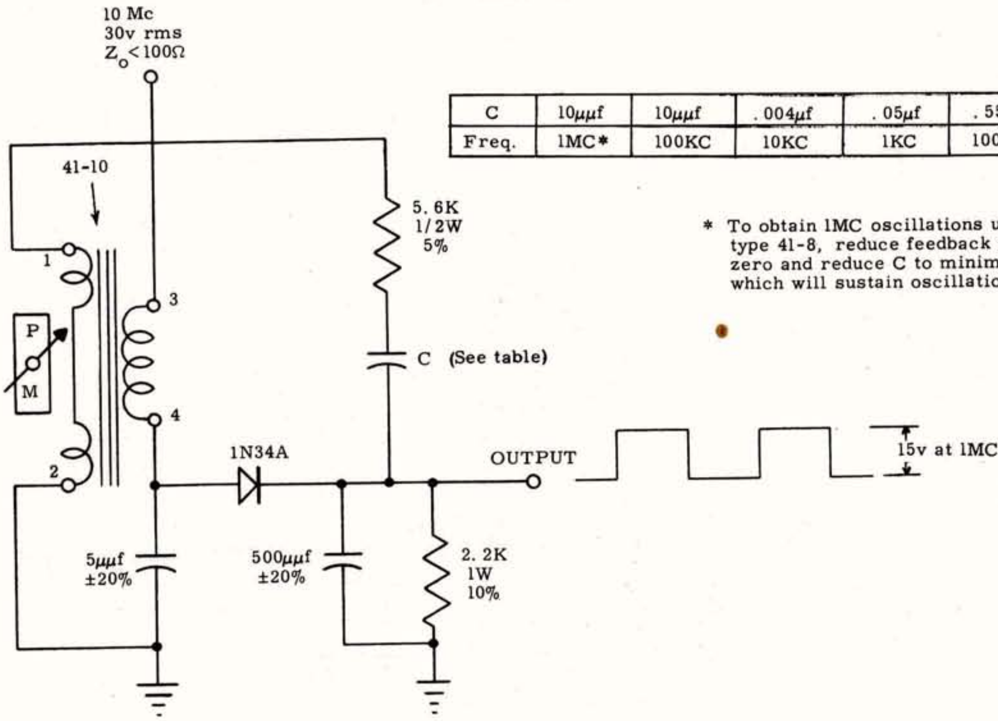
NOTE:

(1) Greater cutoff may be obtained by means of magnetic or current bias. (See transfer characteristic curve). Greater cutoff and greater gating current give more positive gating action.

(2) The 2000μμf feedback capacitor may be increased to give wider action.

(3) The impedance of the gating source and the pulse source should be kept as high as practical since they are shunting the control winding.

FREE-RUNNING MULTIVIBRATOR

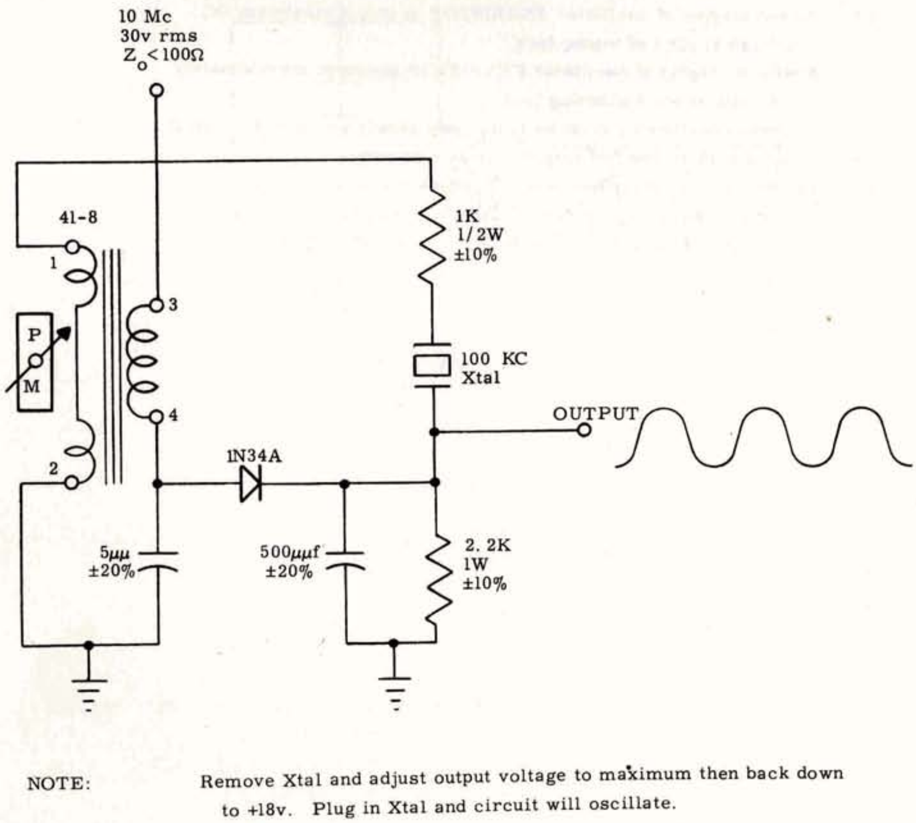


C	10μμf	10μμf	.004μf	.05μf	.55μf	6μf	50μf
Freq.	1MC*	100KC	10KC	1KC	100 cps	10 cps	1 cps

* To obtain 1MC oscillations use Ferristor type 41-8, reduce feedback resistance to zero and reduce C to minimum value which will sustain oscillation.

NOTE: Disconnect feedback capacitor and adjust magnet for maximum d-c output across 2. 2K then back down to approximately +18VDC. Reconnect feedback capacitor and circuit will oscillate.

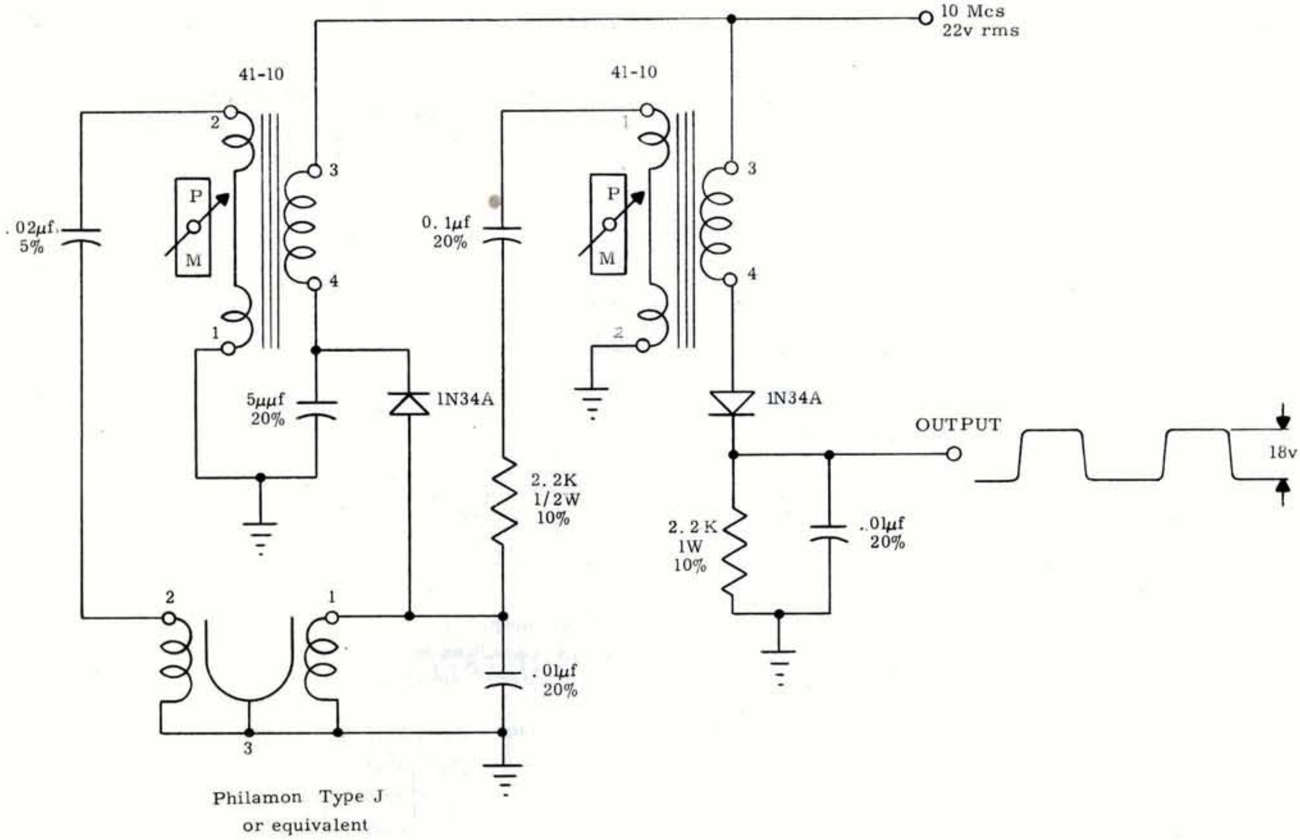
100KCS CRYSTAL-CONTROLLED OSCILLATOR



NOTE: Remove Xtal and adjust output voltage to maximum then back down to +18v. Plug in Xtal and circuit will oscillate.

1KC TUNING-FORK-CONTROLLED OSCILLATOR

WITH BUFFER STAGE



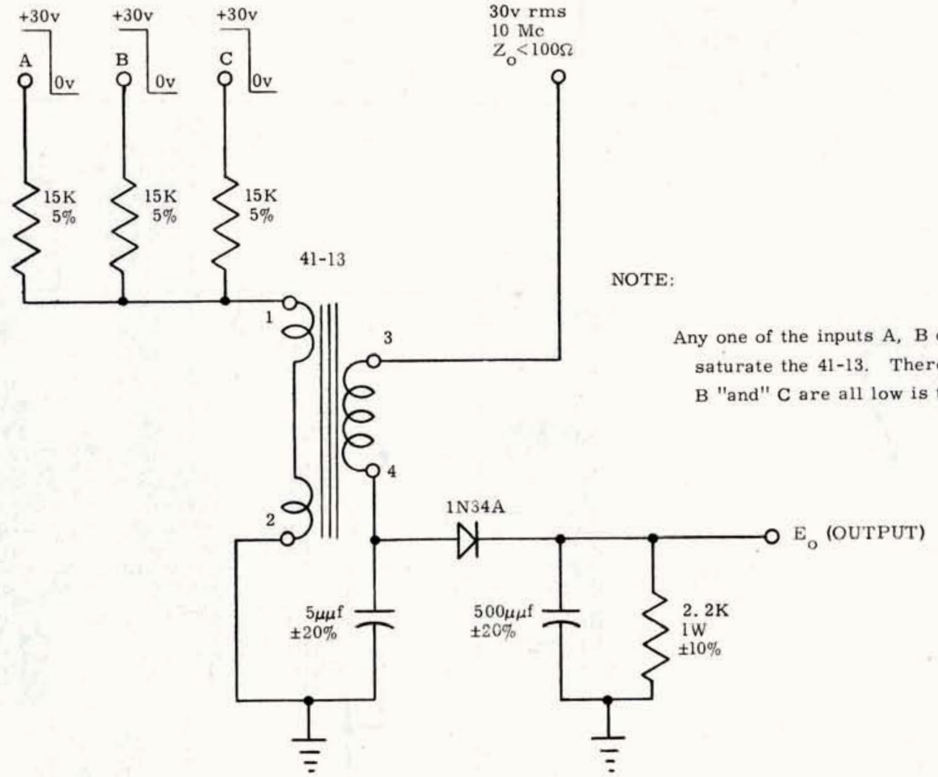
NOTES:

(1) Adjust magnet of oscillator FERRISTOR to obtain maximum DC voltage at pin 1 of tuning fork.

(2) Readjust magnet of oscillator FERRISTOR to obtain approximately -16 volts at pin 1 of tuning fork.
These adjustments must be made very slowly because the high Q of the fork makes for sluggish circuit response.

(3) For proper operating frequency, the fork should be ordered approximately 150 ppm high. The magnet of the oscillator FERRISTOR is used to trim to precise operating frequency.

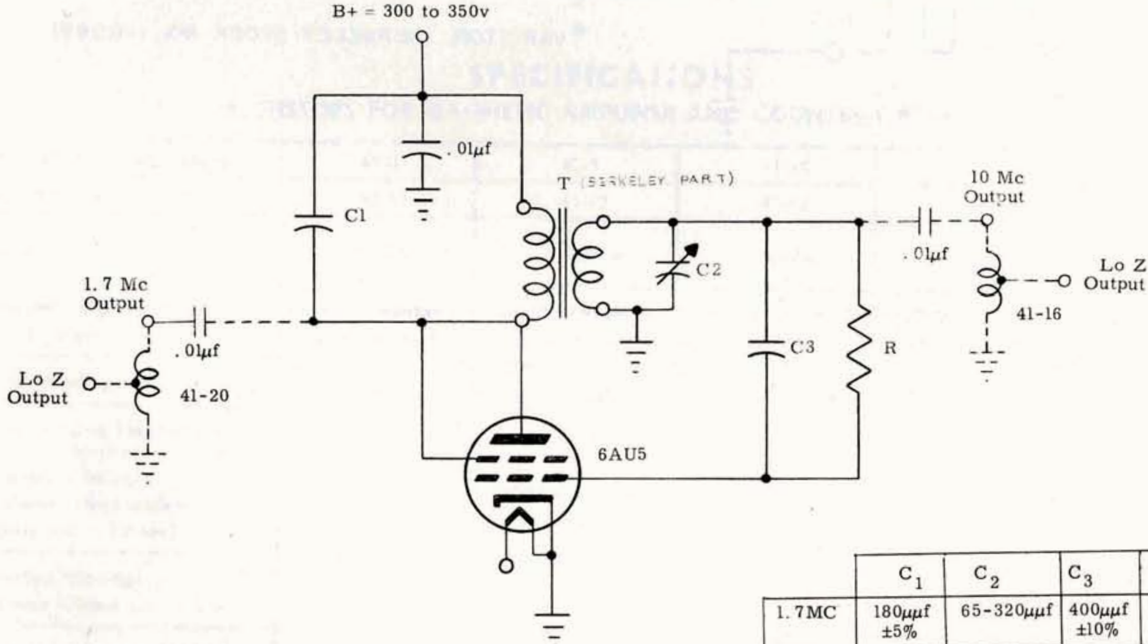
COINCIDENCE ("AND") GATE



NOTE:

Any one of the inputs A, B or C when at +30v is sufficient to saturate the 41-13. Therefore when and only when A "and" B "and" C are all low is the output E_o low.

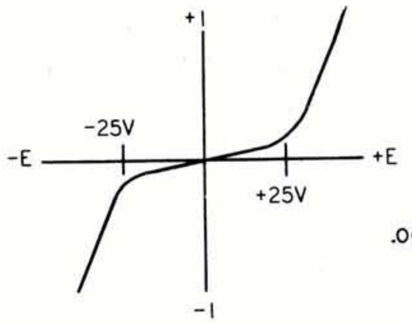
R-F POWER OSCILLATOR



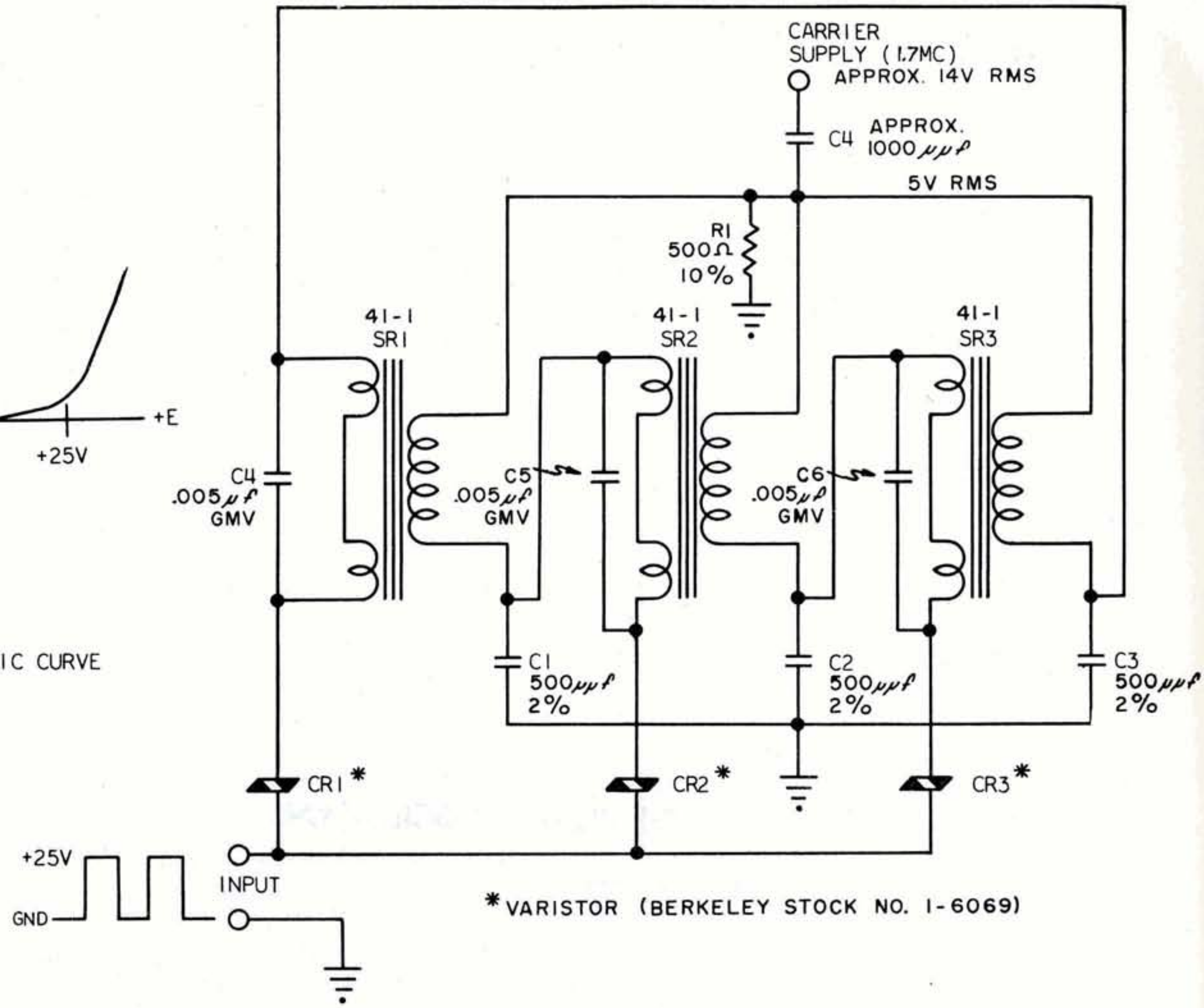
	C_1	C_2	C_3	R	T
1.7MC	180μμf ±5%	65-320μμf	400μμf ±10%	10K 2W 10%	41-5
10MC	75μμf ±5%	65-320μμf	150μμ ±10%	10K 2W 10%	41-6

NOTES: (1) Berkeley Transformer 41-20 Steps the 180v plate voltage at 1.7MC down to 15v Rms.

(2) Berkeley Transformer 41-16 steps the 90v Grid voltage of the 10MC oscillator to 30v and 20v Rms.



CHARACTERISTIC CURVE OF VARISTOR



Counting Rate:	Zero to 10, 000 pulses-per-second. Counting rate may be extended to 40, 000 pulses-per-second by shunting C4, C5 and C6 with 2. 2KΩ resistors which prevent ringing at high frequencies.
Input Pulse Duration:	10 to 30μseconds

Ferristors* are reliable, lightweight, low-power replacements for vacuum tubes. Affected by neither humidity nor temperature, this sturdy epoxy resin encapsulated component is ideally suited for industrial electronics. In Berkeley's new line of long life counter-controllers, Ferristors are used to perform all the functions of vacuum tubes: input amplifier, gate, time base, decimal counting unit, coincidence amplifier, and control circuitry. Consisting of a simple wirewound coil on a ferro-magnetic core, ferristors are immune to damage from shock, vibration, accidental overload.

Berkeley manufactures two general classes of Ferristors:

1. Stock No. 41-8, 9, 10, 11, 12, 13 for high speed magnetic amplifier application.
2. Stock No. 41-1, 2 for counting circuit use.

Every member of the amplifier series is a miniature saturable reactor. One member differs from the other only in the number of turns on the control winding. The controlled winding bears the same number of turns throughout. They are designed to work with carriers in the 1-10 mc frequency range. Higher frequencies are preferred for greater gain and power handling capabilities.

Types 41-8, 9 and 10 have a small permanent magnet which permits application of fixed bias adjustable over a range of ± 12 ampere-turns. No current is required for this bias. Types 41-11, 12 and 13 are identical to types 41-11, 12 and 13, respectively, but have no permanent magnets.

Many different types of magnetic amplifier circuits may be generated from Ferristors. Figure 1 is a plot of inductance (L) vs. control current Ic). A typical amplifier circuit and its transfer characteristics are shown in Figure 2. An output either in or out of phase with the input can be obtained by merely reversing the rectifier diode. The proper operating point on the transfer characteristic is chosen by using a current bias through the control winding or a small permanent magnet.

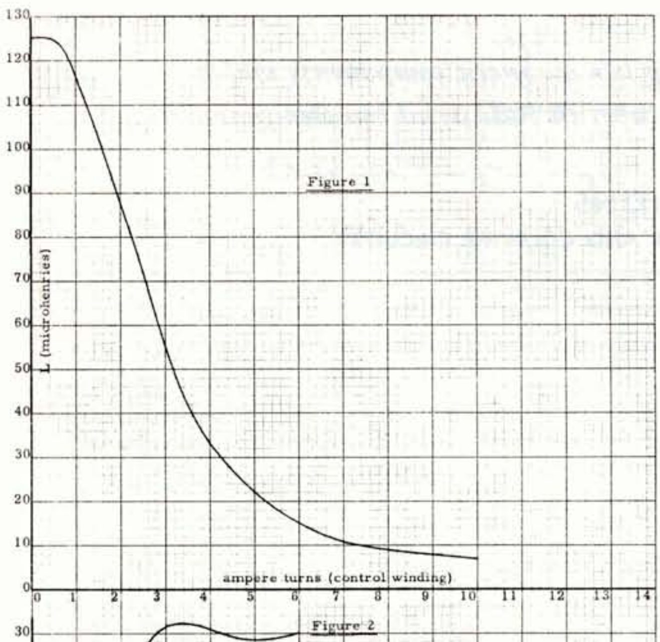
The other series is designed for ferro-resonant counter applications. Combined with the proper size capacitor and connected to an appropriate alternating current source, the 41-1 forms a bistable circuit whose two stable states are:

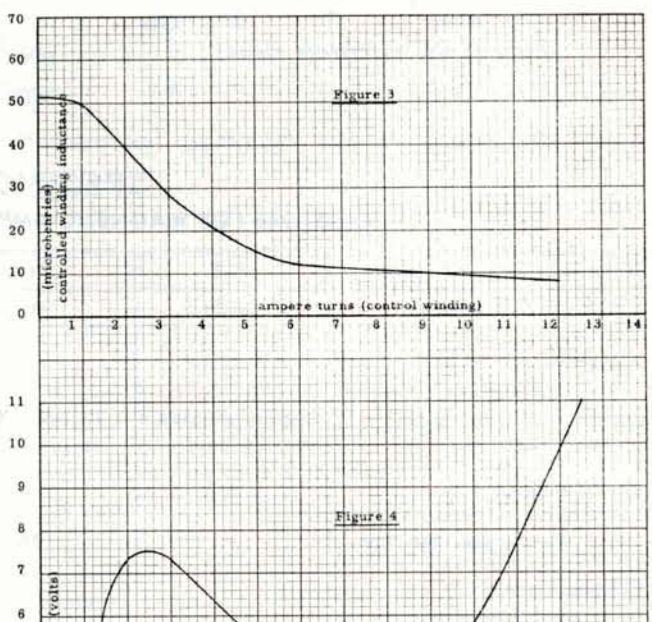
1. An inductive circuit with low circulating current and
2. a near resonance (slightly capacitive) circuit with high circulating current.

With suitable circuitry, these bistable components function as flip-flops or ring-of-N type counters where N may have any integral value from two to twenty.

The 41-2 is similar to the 41-1. A saturable reactor with fewer turns on the control winding and slightly lower inductance on the controlled winding, it is designed for triggering ring-of-ten type counters.

Figures 3 and 4 are characteristic curves for this series.





model 470 FERRISTOR R. F. power supply

FEATURES:

- ✻ **CONVENIENT LABORATORY POWER SUPPLY FOR FERRISTOR* CIRCUIT INVESTIGATIONS.**
- ✻ **SUPPLIES 1.7 MC FOR DECIMAL COUNTING UNITS.**
- ✻ **SUPPLIES 10.2 MC FOR FERRISTOR* AMPLIFIERS, GATES, MULTIVIBRATORS, OSCILLATORS, ETC.**
- ✻ **INDEPENDENT OUTPUT LEVEL ADJUSTMENTS.**
- ✻ **BUILT-IN METER MONITORS OUTPUT LEVELS.**
- ✻ **POWERS UP TO 4 DECIMAL COUNTING UNITS AND 10 POWER AMPLIFIERS.**
- ✻ **COMPACT, SELF-CONTAINED.**
- ✻ **NO OTHER POWER SUPPLIES REQUIRED FOR MOST CIRCUITS.**

SPECIFICATIONS	1.7 MC Output	10.2 MC Output
Output Voltage (adjustable):	2 to 16 V. RMS	3-35 V. RMS
Output Impedance:	18 ohms (approx.)	50 ohms (approx.)
Output Power:	6 watts (max.)	6 watts (max.)
Power Requirements:	105 to 125 V, 50-400 cps, 35 watts	
Dimensions (overall):	6" W. x 8" H. x 7" D.	
Shipping Weight:	10 lbs. (approx.)	
Price:	$95.00 (F.O.B. Richmond, California)	

Prices and specifications subject to change without notice.

EDITION OF AUGUST 1956

A compact, economical laboratory power supply, the Model 470 will aid you in setting up and testing the many interesting circuits using the Berkeley FERRISTOR*, rugged component which can be used in ring counters, amplifiers, gates, pulse generators, oscillators, relay controllers, etc. as a direct substitute for vacuum tubes. The Model 470 is a convenient space-saving source of RF power for these circuits.

At 1.7 MC this dual unit supplies power to operate up to four ring-of-10 Decimal Counting Units; at 10.2 MC, power to operate ten or more medium power amplifiers or similar circuits. Both outputs are available simultaneously which can be individually adjusted to supply just the right amount of power to your circuits. A front panel meter can be switched to read the output voltage of either frequency without affecting performance.

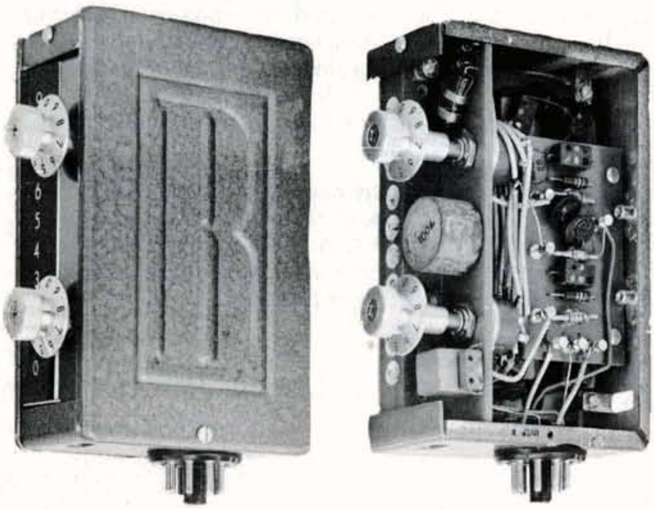
Each oscillator uses a 12AU7 tube in a tuned-grid untuned-plate circuit followed by a power amplifier stage. Variable potentiometers are used to adjust the output level. A crystal diode rectifier and three-inch meter are used to display the output voltages. A self-contained supply for oscillator B-plus and filament operates, from 105 to 125 volts RMS, 50 to 400 cps. The entire unit draws only to 125 volts RMS, 50 to 400 cps. The entire unit draws only 35 watts of power. Output connectors are BNC type.

The Berkeley FERRISTOR has no filament, has high efficiency and generates little or no heat. Potted in epoxy resin, the tiny saturable reactor will operate under adverse environmental conditions and has virtually unlimited life. It is ideal for circuits requiring the utmost in reliability and compactness.

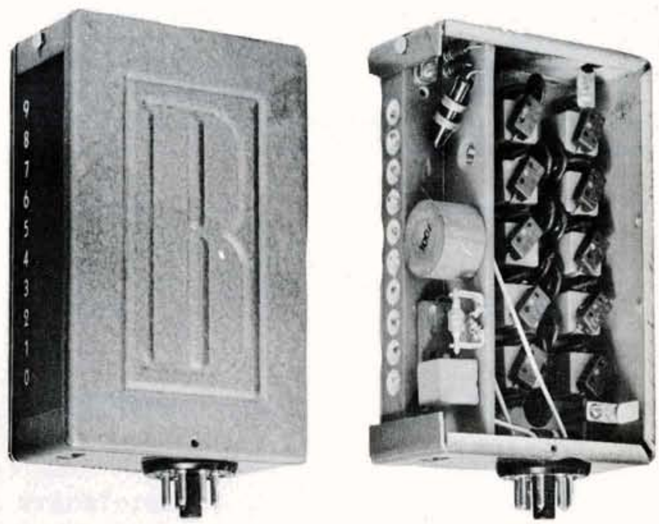
To acquaint you with a few of the literally hundreds of circuit applications of the FERRISTOR, Berkeley has prepared a set of application notes showing detailed circuits, component values and performance figures. Copies of the notes may be had free of charge from the factory or any Berkeley representative.

*TM

magnetic decimal counting units



▲ **models 716 - 717 magnetic dcu**



model 736 dual preset magnetic dcu ▶

Specifications	Models 716 - 717	Model 736
Power Input	165V rms ±10% @ 1.7 mc 1.5 watts per DCU Bias 300V @ 3 ma ±10%	165V rms ±10% @ 1.7 mc 1.5 watts per decade Bias 300V @ 3 ma ±10%
Pulse Input	20 ma peak Duration = 2 to 12 μsec. Rise time = 5 μsec. approx.	20 ma peak Duration = 2 to 12 μsec. Rise time = 3 μsec. approx.
Output Characteristics	±30V Max. output current = 3 ma Rise time = 5 μsec. approx.	±30V; maximum output current = 2 ma Rise time = 5 μsec. approx.
Count Indication	Direct reading decimal presentation	Direct reading decimal presentation
Max. Count. Rate	Model 716—10,000 cps Model 717—40,000 cps	10,000 cps
Resolution of Paired Pulses	Model 716—100 μsec. Model 717—25 μsec.	100 μsec.
Reset to Zero	±20V ±20% into 4,000 ohms Duration > 30 μsec.	±20V ±20% into 4,000 ohms Duration > 30 μsec.
Connector	Standard Octal Plug	Standard Octal Plug
Dimensions	1⅞"x5½"x3½"	1⅞"x5½"x3½"
Weight	13 oz.	1 lb.
Tubes	None	None
Price	$110.00	$130.00

F.O.B. Richmond, California
Prices, specifications subject to change without notice

EDITION OF JANUARY 1956

DESCRIPTION

New Berkeley magnetic decimal counting units (DCU's), Models 716, 717 and 736, are long life, direct reading, high-speed counting devices using tiny magnetic amplifiers (Ferristors*) as the basic component rather than vacuum tubes. They were designed for industrial counting and control applications requiring the utmost in reliability.

Magnetic DCU's are capable of counting up to 40,000 pulses a second. Units may be cascaded indefinitely to achieve a counter of any capacity. Each DUC counts from 0 to 9 continuously presenting an illuminated reading on the front panel. Worthy of note is the reading ease gained by use of larger panel numbers and lights approximately two and one-half times brighter than comparable vacuum tube type decades.

Elimination of vacuum tubes permits an overall size reduction of up to 32% and a weight reduction of up to 59% over other units. Illustrated magnetic DCU's are plug-in units fitting standard octal sockets. Lower heat generation resulting from decreased power requirements permits more compact assembly than vacuum tube types.

CIRCUITRY

Magnetic DCU's are true ring-of-ten type counters that use ten ferro-resonant bistable elements so connected that each incoming pulse advances the count one position on the ring. Each of the ten discrete outputs is connected to a neon indicator light. In the Model 736 Dual Preset Magnetic DCU, output pulses are also connected to ten-position selector switches from which two preselectable outputs may be obtained. Accordingly, by cascading Model 736's and adding proper gating circuitry, two independent outputs at any two preselected counts between one and the full capacity of the instrument may be obtained.

In all units output from the number "nine" element is demodulated and brought out to provide a gating voltage for parallel gated counter operation. This output may be differentiated and the leading edge used to drive the next DCU through an intermediate magnetic amplifier.

Part No.	Description	Price
41-1 41-2	Berkeley Ferristor* for Ferro-resonant bi-stable circuits	$ 20.00 each
41-8 41-9 41-10	Berkeley Ferristor* with Adjustable Permanent Magnet Bias Saturable Reactor	5.75 each
41-11 41-12 41-13	Berkeley Ferristor* Saturable Reactor	5.50 each
41-5	Berkeley 1.7 mc oscillator coil	8.00 each
41-6	Berkeley 10 mc oscillator coil	8.00 each
41-16	Berkeley 10 mc output transformer	3.50 each
41-20	Berkeley 1.7 mc output transformer	3.50 each

For quantities of a signle type, the following discount schedule applies:

Quantities 1 to 24	Zero Discount
Quantities 25 to 99	40% Discount
Quantities 100 to 499	50% Discount
Quantities 500 and above	Quotation on Request

Prices are effective January 1, 1957 f.o.b. Richmond, California, and are subject to change without notice.

*T.M.

Berkeley Representatives

ALBANY, NEW YORK
Edward A. Ossmann & Associates
28-C Weis Road

ALBUQUERQUE, NEW MEXICO
V. T. Rupp Co.
8009 Bellamah, N.E.

ATLANTA 9, GEORGIA
Murphy & Cota
2110 Peachtree St., N.W.

BOSTON, MASSACHUSETTS
Broger Instrument Sales Co.
48 Pearl St.
Brookline 46, Massachusetts

BUFFALO, NEW YORK
Edward A. Ossmann & Assoc., Inc.
43 Greenfield Avenue
Hamburg, New York

CHARLOTTE, NORTH CAROLINA
Murphy & Cota
2036 Norton Rd.

CHICAGO 39, ILLINOIS
Ridgeway Engineering & Assoc.
6100 W. North Ave.

CLEVELAND 28, OHIO
J. R. Dannemiller Assoc.
3955 Lee Road

DALLAS 7, TEXAS
John A. Green Co.
137 Parkhouse

DAYTON, OHIO
J. R. Dannemiller Assoc.
384 W. First St.

DETROIT 38, MICHIGAN
1204 North Woodward
Royal Oak, Michigan
Phone: Lincoln 8-4440

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Gene Piety
2030 Home Rule St.

HOUSTON 6, TEXAS
John A. Green Co.
P.O. Box 6445
(Fairview Station)

INDIANAPOLIS 2, INDIANA
Ridgeway Engineering Assoc.
1606 N. Illinois St.

KANSAS CITY, KANSAS
Norman W. Kathrinus & Co.
1409 Southwest Blvd.

LOS ANGELES 6, CALIFORNIA
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2230 West 11th St.

MIAMI 43, FLORIDA
Murphy & Cota
11375 S.W. 46th St.

MINNEAPOLIS 3, MINNESOTA
Pinkney & Hine
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200 South Main St.,
(Room 822)

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San Mateo, California

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Boeing Field

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308 Merritt Ave.

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Silver Springs, Maryland

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35 Burke St.