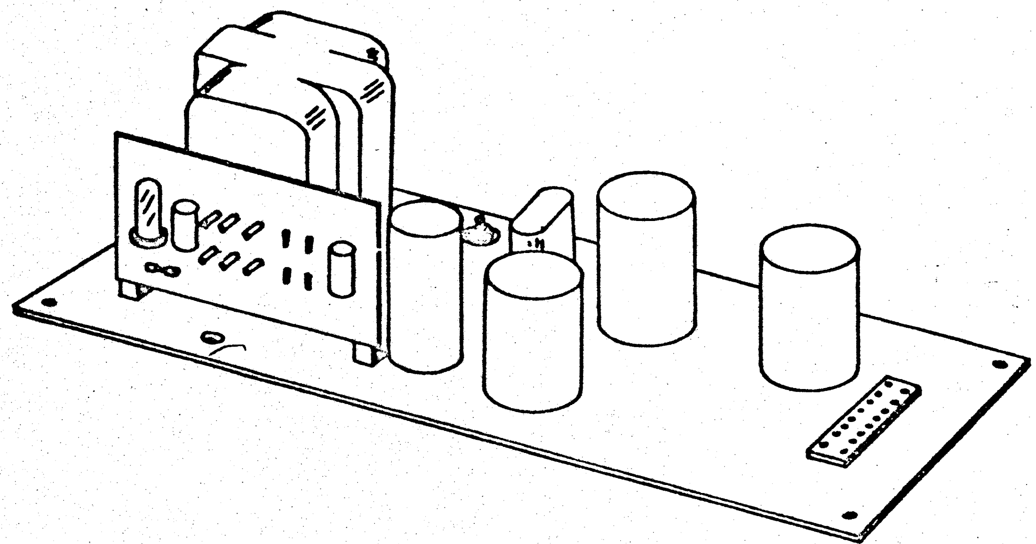
# 2816 POWER SUPPLY
# INSTRUCTION MANUAL



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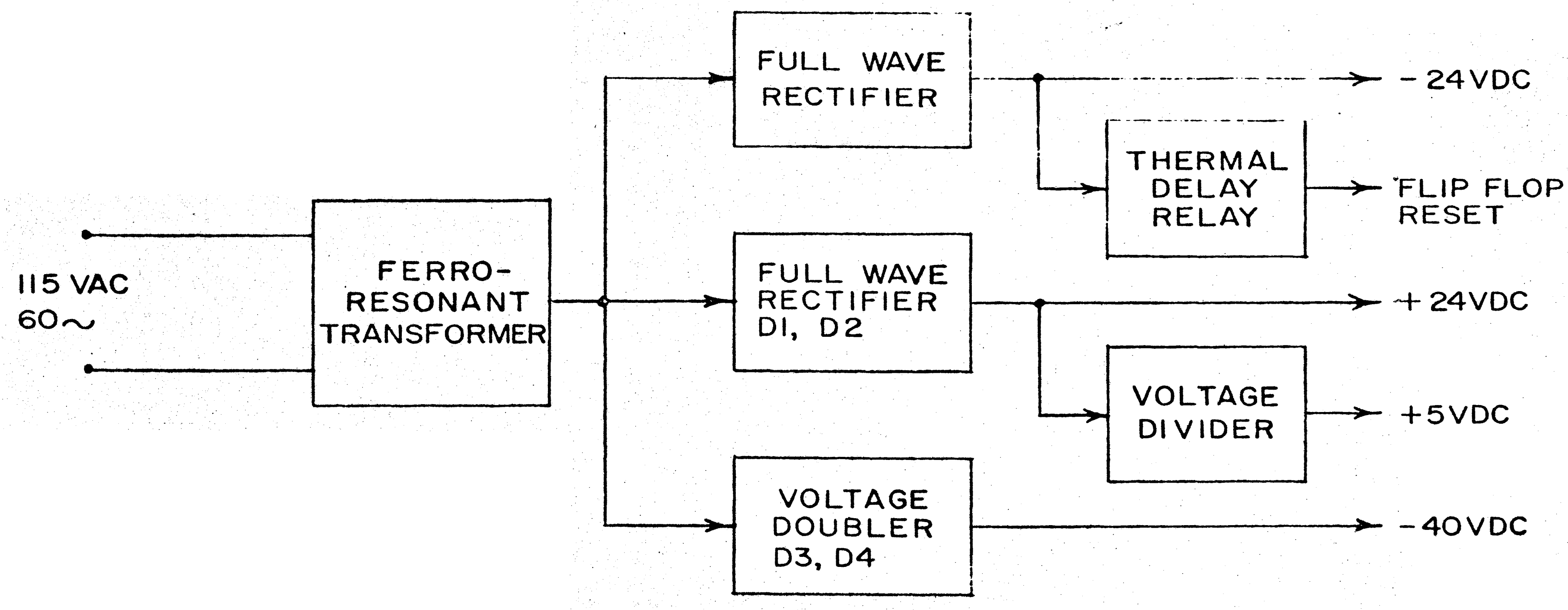



BLOCK DIAGRAM
FIGURE VII-1

## A. INTRODUCTION

The 2816 Power Supply (referred to as PS-1 in the diagrams in the 2816 Service Manual) furnishes 4 DC voltages for operation of the Readers, Punches, Input-Output Unit and the Control Unit, and also a Flip-Flop Reset level for use in the Control Unit. The Power Supply is mounted in the Control Unit console.

A Block Diagram of the Power Supply is shown in Figure VII-1. It consists of a Ferroresonant Transformer, two Full Wave Center Tap Rectifier circuits, a Voltage Doubler circuit, a Voltage Divider and a 3 second Thermal Delay Relay. The +24 volt Rectifier circuit, Voltage Doubler, Voltage Divider and Thermal Relay are mounted on a Printed Circuit Board.

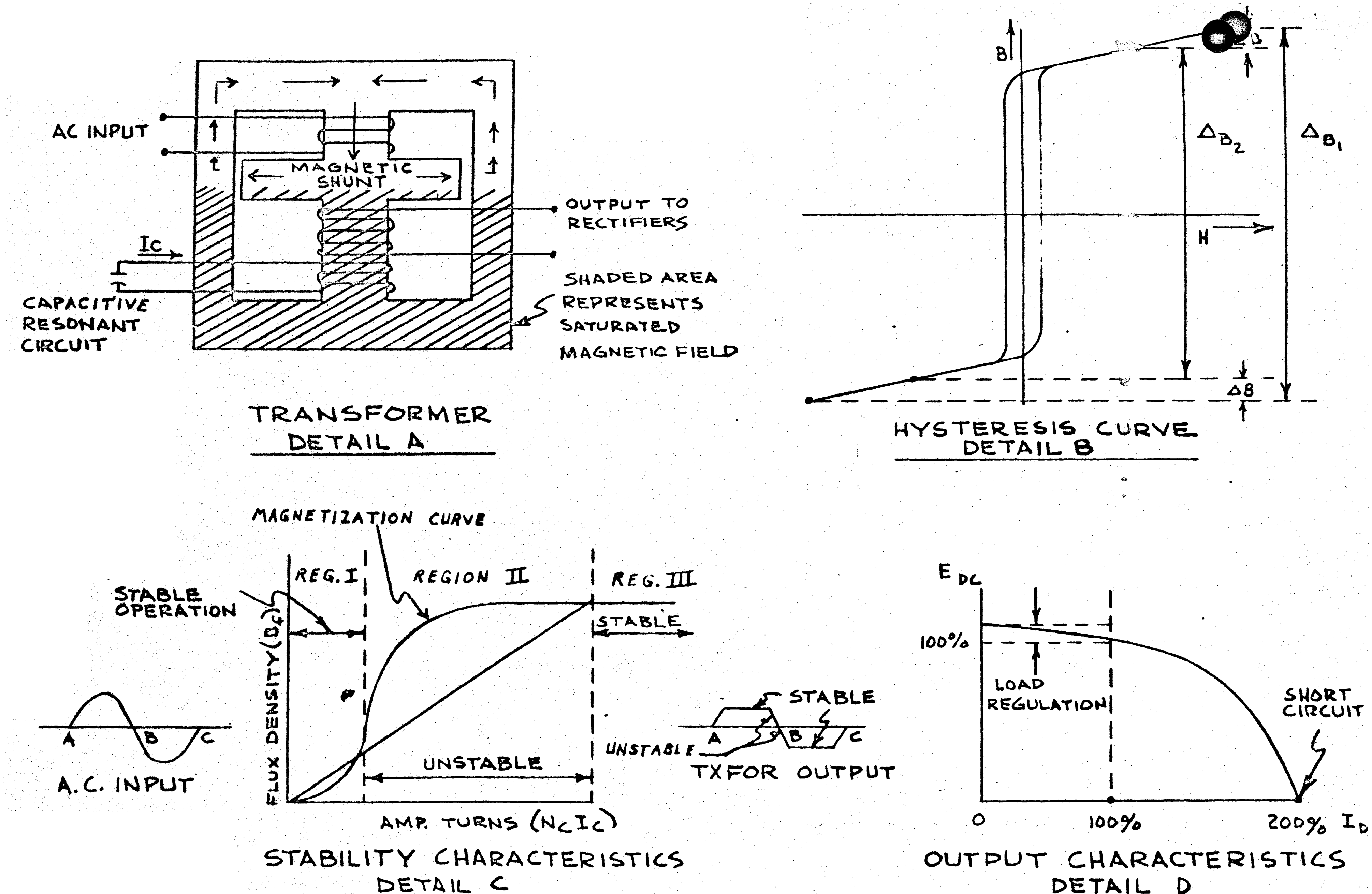
The Ferroresonant Transformer is wired for use with 115 VAC, 60 cycle line voltages. This transformer provides good regulation against AC line voltage changes and also load changes. The voltage on the secondary windings is held within ± 5%.

The two Full Wave Rectifiers and the Voltage Doubler are connected to the same secondary windings of the Ferroresonant Transformer. The Rectifiers furnish -24 VDC and +24 VDC; a Voltage Divider off the +24 VDC line furnishes +5 VDC. The Voltage Doubler furnishes -40 VDC. All voltages are referenced to a common ground.

The Thermal Delay Relay causes all the Flip-Flops in the Control Unit to reset when the System is turned on.

The Power Supply Printed Circuit Board layout, Components Location, and the Schematic are at the end of this section.

The connections from the secondary windings of the Transformer are to terminals on Terminal Board (TB) 2. This board is beneath the Chassis. The connections to and from the circuits on the P. C. Board are on the 10 connections on side of this board. The outputs from the P. C. Board are connected to terminals on TB1. The outputs from this board are connected to printed circuits on the Master Board in the Control Unit.




FERRORESONANT TRANSFORMER OPERATION

*FIGURE VII-2*

B. FERRORESONANT TRANSFORMER OPERATION

A Ferroresonant Transformer (also known as Magnetic or Constant Voltage) is used as the Power Transformer in the 2816 Power Supply. This Transformer has all of the requirements of a conventional transformer, plus good voltage regulating capabilities. An important advantage is that any input AC line voltage fluctuations are dampened by about a 10:1 ratio before the AC is sent to the Rectifiers. Output load variations do not appreciably affect the voltage regulation (unless a short circuit results).

The Ferroresonant Transformer consists of four main parts. These parts are shown in Figure VII-2, Detail A. They are:

1. Input winding
2. Output winding
3. A capacitor connected across a third winding to form a Capacitive Resonant Circuit
4. Magnetic Shunt Core

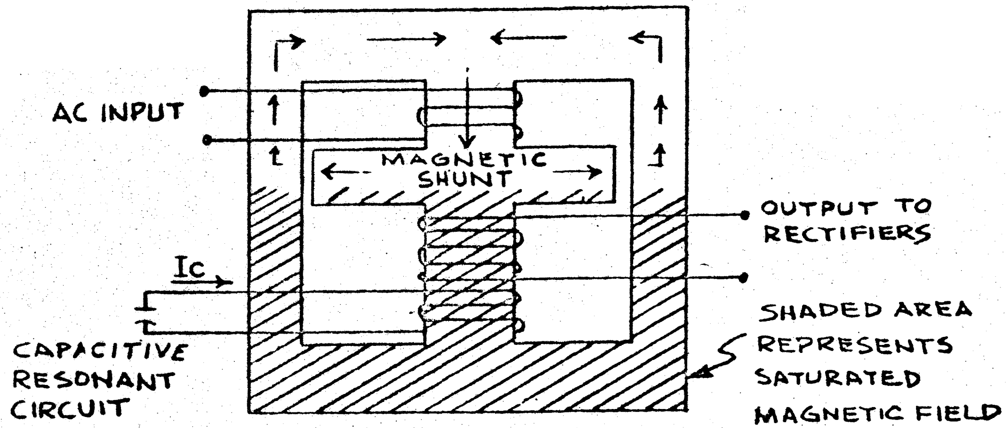
Below is a brief description of the four parts:

1-2. The input winding and output winding function the same as two similar windings in a conventional transformer, so they will not be explained.

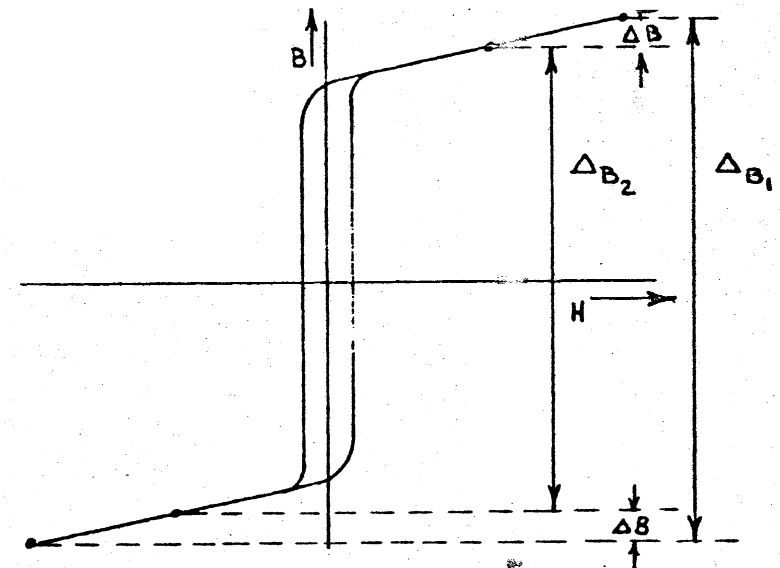
3. The Capacitive Resonant Circuit oscillates at the line frequency; oscillation occurs at only one frequency. This oscillation draws a current which develops a magnetizing force that sets up a magnetic flux to saturate the Transformer core. The core is saturated each half cycle, i.e., twice each AC cycle. The shaded area on the transformer drawing in Detail A represents the magnetic flux field.

4. The Magnetic Shunt Core serves two purposes. First, to isolate the output winding from the input winding so Ferroresonant action can proceed independently of the input. Second, after Ferroresonance has occurred, the Core provides a path (refer to directional lines) for changes in the input magnetic flux caused by changes in the Input line voltage to be shunted out of the path associated with the output winding. Thus, the output voltage stays constant.

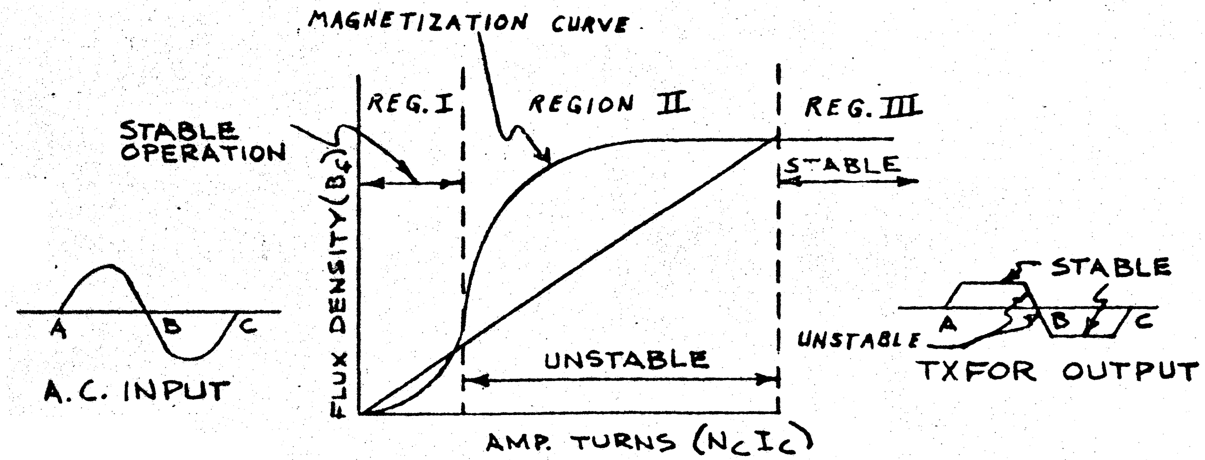
Voltage regulation is achieved by the principle of magnetic saturation. This function is shown by the Hysteresis Curve in Figure VII-2, Detail B. The current ($I_c$ - refer to Detail A) flow through the Capacitive Resonant Circuit winding develops a magnetizing force (represented by H on curve) which sets up the magnetic flux field (represented by B). This field saturates the Transformer. This Hysteres curve shows that the flux density (B) stays relatively constant between the extremes of input line voltages and output load changes. The flux density developed by a high input AC line voltage with no output load is represented by $\Delta$B1. The flux density developed by a low input AC line voltage with a full output load is represented by $\Delta$B2. The flux density change between these two extremes is represented by $\Delta$B. It is seen on the curve that this change is very small. Thus, any increase in



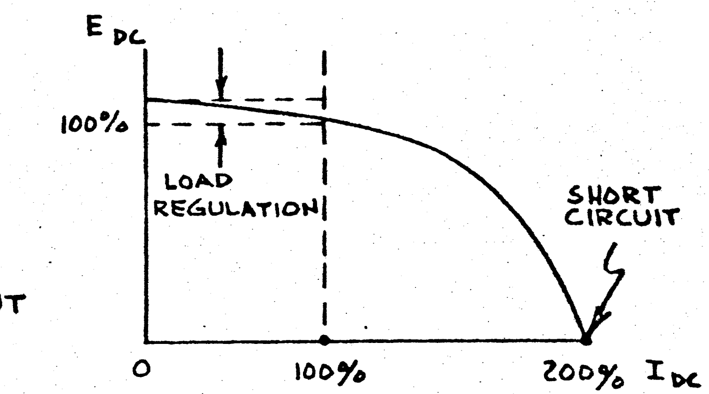

TRANSFORMER
DETAIL A




HYSTERESIS CURVE
DETAIL B




STABILITY CHARACTERISTICS
DETAIL C




OUTPUT CHARACTERISTICS
DETAIL D

FERRORESONANT TRANSFORMER OPERATION

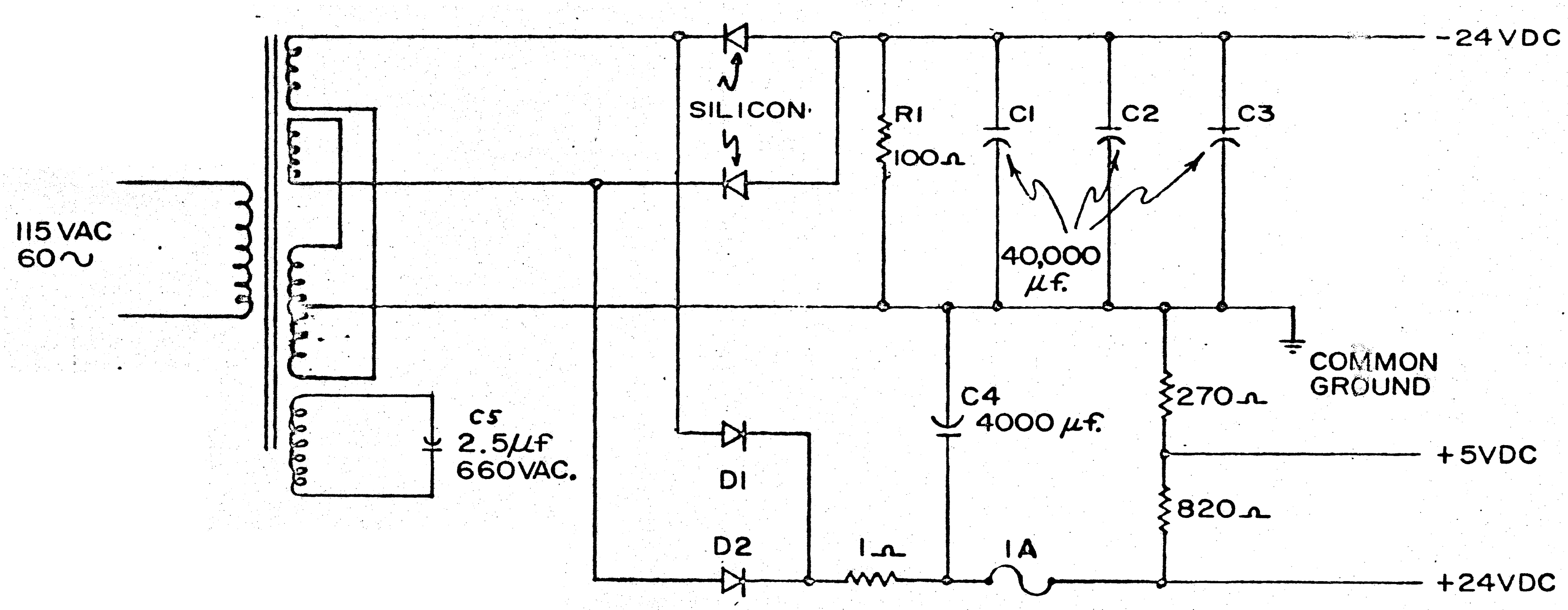
*FIGURE VII-2*

the line voltage will not cause any appreciable increase in the saturated magnetic field, and also any decrease in the line voltage will not cause any appreciable decrease in the saturated magnetic field. Since the magnetic field stays relatively constant, the output voltage stays constant.

The Stability Characteristics for the Transformer are shown in Figure VII-2, Detail C. A stable voltage out of the Transformer is developed from a sinusoidal input voltage. The magnetic saturation causes the stable output. Twice each AC cycle the Transformer is saturated in opposite directions. The Stability Characteristics shows the Ampere-Turns developed by current flow through the Capacitive Resonant Circuit plotted against the Flux Density produced by the current flow. The behavior of the sine wave input upon the Capacitive Resonant Circuit is shown by the Magnetization Curve. If the ampere turns available in the Capacitive Resonant Circuit are more than the ampere turns required to saturate the Transformer then there is a stable region of operation. Regions I and III on the Curve are stable. This is represented by the two flat portions of the Transformer Output waveform. If the ampere turns developed in the Capacitive Resonant Circuit are not sufficient to saturate the Transformer then we have an unstable region of operation. Region II is unstable. This is often called the "jump pnenomenen". It represents the time between half cycles when the capacitor in the Capacitive Resonant Circuit is discharging and then charging to drive the output from one stable state to the other stable state.

The Output Characteristics for the Transformer are shown in Figure VII-2, Detail D. Any output load changes in the 2816 circuits causes current flow back into the output winding. This current builds up a magnetic flux in the Transformer core which opposes the existing flux field. During normal load changes this opposing flux field is not strong enough to cancel the existing flux field. As shown in the Output Characteristics curve, a current change from no load to full load (0 to 100%) causes very little change in the output voltage ($E_{DC}$). If a short circuit occurs in the output, then a large current is generated which develops a large flux. This flux opposes the existing flux field in the Transformer and thus collapses the magnetic field generated by the Capacitive Resonant Circuit. Now the transformer drops out of Ferroresonance and does not furnish an output. It remains inoperative until the short circuit condition is removed. A short circuit current is limited to about 200% of the rated current. This provides short circuit protection to the Transformer and its associated components so they will not be damaged.

The voltage regulation out of the Transformer at its worst case is ± 5%. This regulation is sensitive to frequency and temperature variations.




RECTIFICATION
FIGURE VII-3

## C. RECTIFICATION

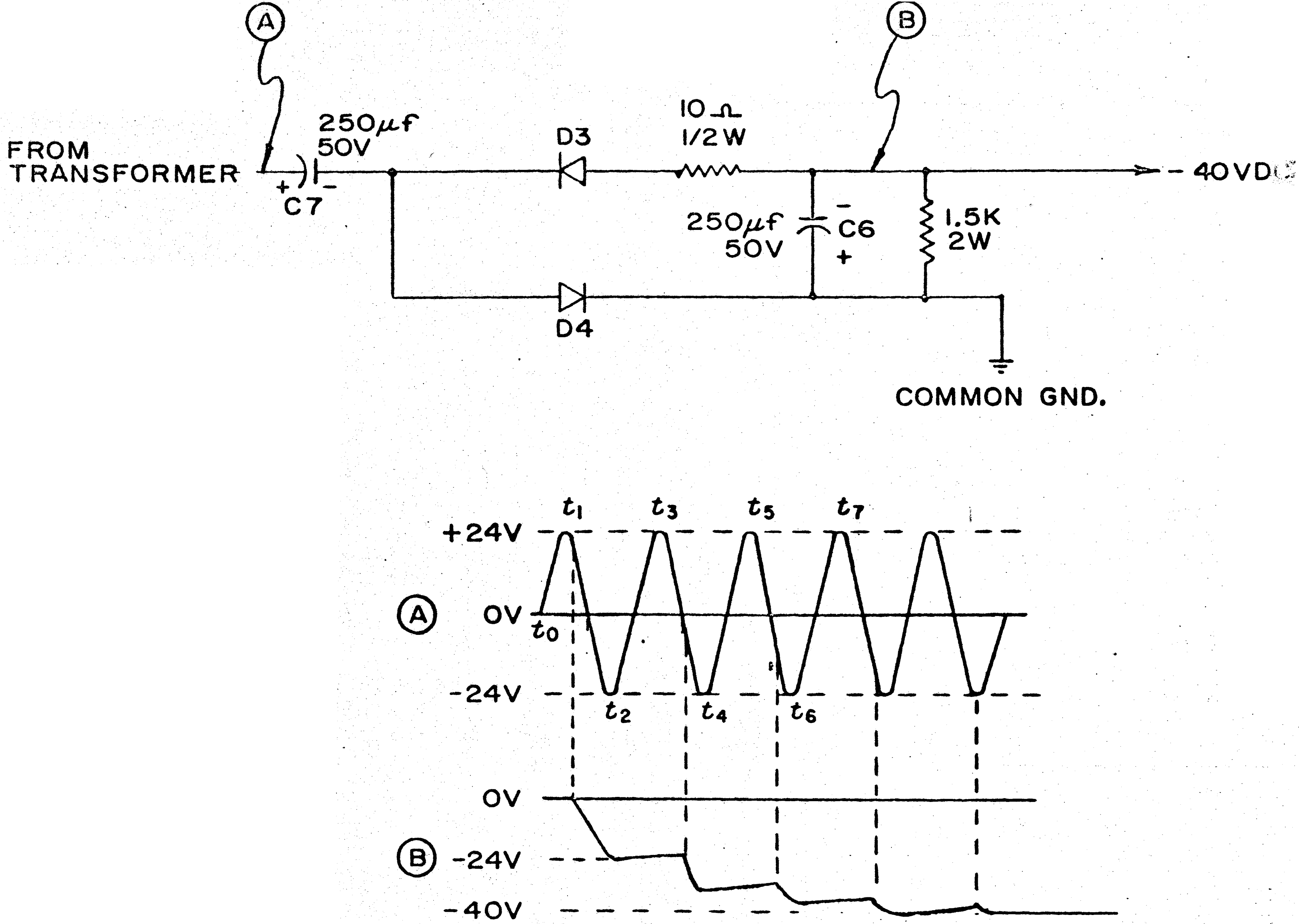
Two Full Wave Center Tap Rectifier circuits are connected to the secondary windings of the Transformer as shown in Figure VII-3. Two Silicon diodes, which are mounted on the base of the Power Supply, are connected together to form a Full Wave Rectifier which furnishes -24 VDC at a maximum of about 2 amps. The anodes of the diodes are connected together to the -24 volt line. The cathode of each diode is connected through a secondary winding to a center tap winding that goes to the common ground.

Diodes D1 and D2, which are on the P. C. Board, are connected together to form a Full Wave Rectifier which furnishes +24 VDC. The cathodes of these diodes are connected to the +24 volt line. The anode of each diode is connected to the secondary windings used by the Silicon diodes. The +24 volt Rectifier circuit is protected by a 1 amp. fuse and a 1 ohm current limiting resistor.

An 820 ohm resistor and a 270 ohm resistor are connected in series between +24 VDC and common ground. This voltage divider furnishes +5 VDC. These two series resistors also form a "bleeder" for discharging Electrolytic Capacitor C4 when the System is turned off.

Electrolytic Capacitors C1, C2, C3 and C4 filter to ground any ripple on the output lines. Resistor R1 is a "bleeder" resistor.

The 2.5 µf Capacitor (C5) is connected across a secondary winding of the Transformer to form the Capacitive Resonant Circuit. This Circuit is used to provide good output voltage regulation. The previously explained principle of "Ferroresonant Transformer Operation" refers to Capacitor C5 across the secondary winding.




VOLTAGE DOUBLER
FIGURE VII-4

## D. VOLTAGE DOUBLER

The Voltage Doubler furnishes -40 VDC for the Punch Strobe and T/W Decode Strobe circuits in the Control Unit.

The Voltage Doubler is shown in Figure VII-4. This circuit consists of two Electrolytic Capacitors (C6 and C7) and two diodes (D3 and D4). Voltage doubler action is achieved by charging Electrolytic Capacitor C6 to about -40 VDC. This charge is built up progressively (refer to waveform B) during the negative half cycles of the first several cycles after the System is turned on. In the waveform shown, (refer to waveform A) a cycle starts at 0 volts but actually the circuit operation could begin at any point on the curve.

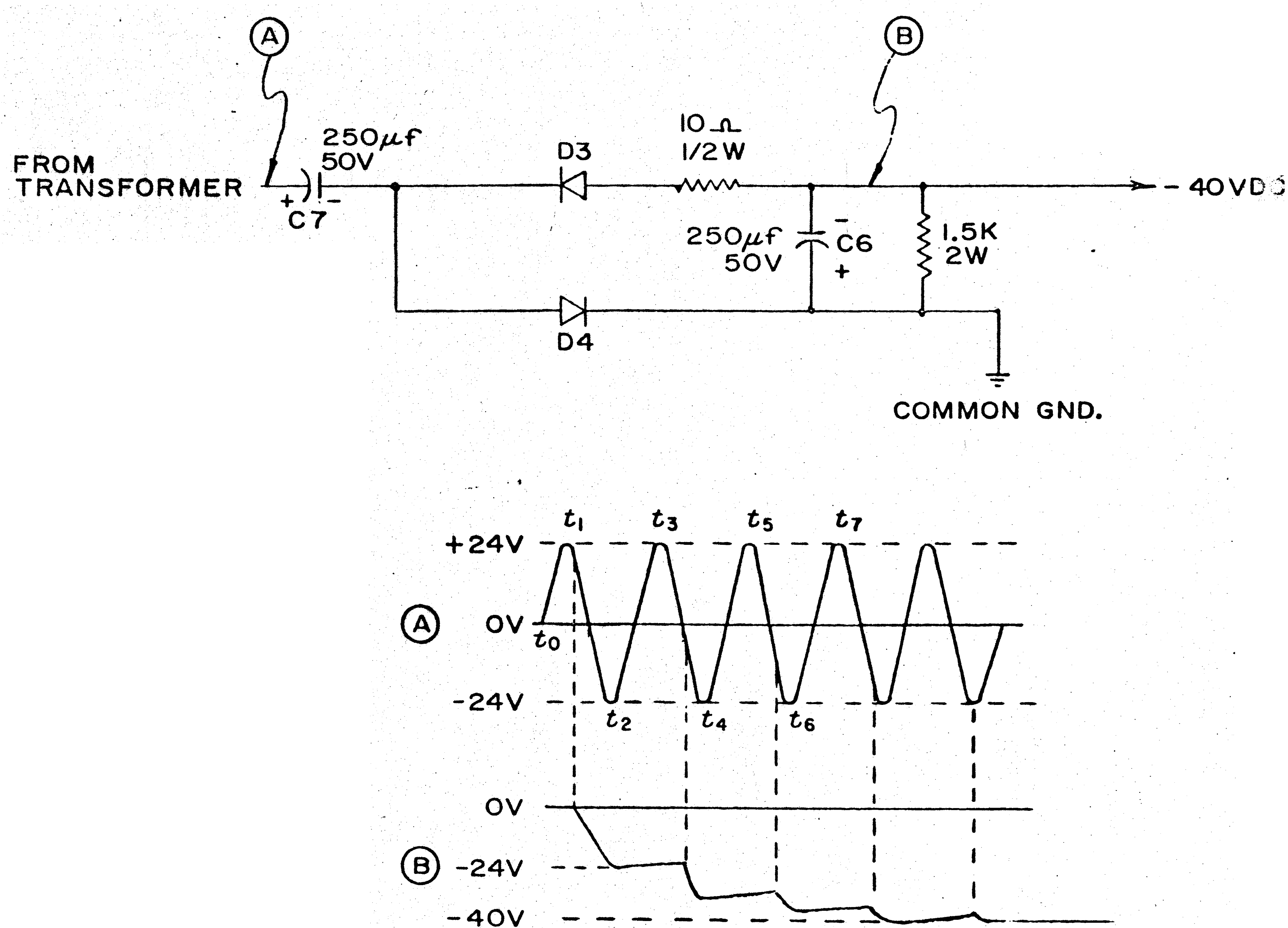
The two Electrolytic Capacitors are equal in capacity, so when both are in a closed circuit each one will take half of any voltage change sent to the circuit. Thus, during the charge time of C6 the two capacitors are in series and each one takes half of any voltage change. During the positive slope of the positive half cycles (refer to waveform A between 0 and +24 volts) Capacitor C7 charges to +24 volts. Then during the following negative slope this Capacitor acts as a battery and furnishes power for charging Capacitor C6. This action allows the 48 volt change between the two Capacitors. Diodes D3 and D4 control the charging of Capacitor C6.

The circuit operation will be explained by reference to time changes (such as $t_0$, $t_1$, etc.) on the sine wave from the Ferroresonant Transformer. Capacitor C6 is charged to -40 VDC as follows: The positive side of Capacitor C7 is connected to a secondary winding of the Ferroresonant Transformer. Between $t_0$ and $t_1$, the positive side of C7 charges to +24 volts. The negative side tries to go positive but this forward biases diode D4 which conducts to put ground at the negative side of C7. Diode D3 is back biased so Capacitor C6 cannot charge.

Between the time $t_1$ and $t_2$ there is a 48 volt (+24 to -24) change on the positive side of C7. This negative change is coupled across C7, back biasing diode D4 and forward biasing diode D3. Now Capacitors C6 and C7 are in series so each one takes one-half of the total change. Capacitor C6 will charge to -24 volts, while Capacitor C7 will discharge its +24 volts. The charge path for C6 is from ground through C6, 10 ohm resistor, diode D3 and C7 to the Transformer. That is, the negative side of C6 goes to -24 volts while the charge across C7 is 0 volts (-24 volts on both sides of C7). Thus, C6 has taken one half of the change (it charged from 0 to -24 volts), and C7 has taken the other half of the change (it discharged from +24 to 0 volts).

Between the time $t_2$ and $t_3$ there is a 48 volt (-24 to +24) change on the positive side of C7, again charging this Capacitor to +24 volts. The negative side tries to go positive, but this forward biases diode D4 which conducts to put ground at the negative side of C7. Diode D3 is back biased (0 volts on cathode and -24 volts on anode), so C6 cannot charge.

Between the time $t_3$ and $t_4$ there is again a negative 48 volt (+24 to -24) change on the positive side of C7. This negative change is coupled across C7. The negative side of C7 goes from ground toward -48 volts; as it goes more negative than -24 volts then diode D3 is again forward biased. Now Capacitors C6 and C7 are again in series, so each one takes one-half of the remaining change (one-half of -24 volts = -12 volts). Thus, C6 charges from -24 to -36 volts.



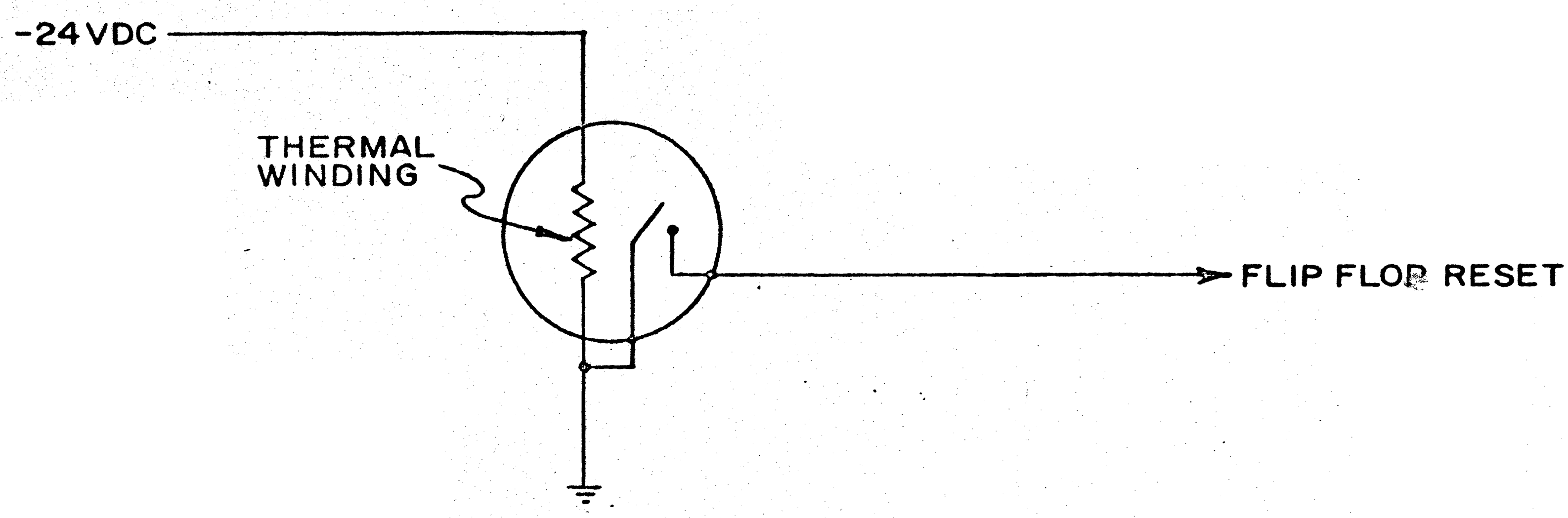

VOLTAGE DOUBLER
FIGURE VII-4

## D. VOLTAGE DOUBLER (Continued)

Between time $t_4$ and $t_5$ there is again a 48 volt (-24 to +24) change on the positive side of C7, again charging this Capacitor to +24 volts. Diode D4 is forward biased to put ground on the negative side of C7. Diode D3 is back biased (0 volts on cathode and -36 volts on anode), so C6 cannot charge.

Between time $t_5$ and $t_6$ there is again a negative 48 volt (+24 to -24) change on the positive side of C7. This negative change is coupled across C7. The negative side of C7 goes from ground toward -48 volts; as it goes more negative than -36 volts then diode D3 is again forward biased. Now Capacitors C6 and C7 are again in series, so each one takes one half of the remaining change (one half of -12 = -6 volts). Thus, C6 charges from -36 to -42 volts.

This cycle repeats itself until Capacitor C6 is fully charged. This charge is about -40 VDC, instead of the theoretical ideal of -48 VDC, due to the partial discharge of C6 between half cycles. The discharge path is through the 1.5K ohm resistor and also the external load. The 1.5K ohm resistor is a "bleeder" for discharging C6 when the System is turned off. The 10 ohm resistor is part of the filtering circuit.

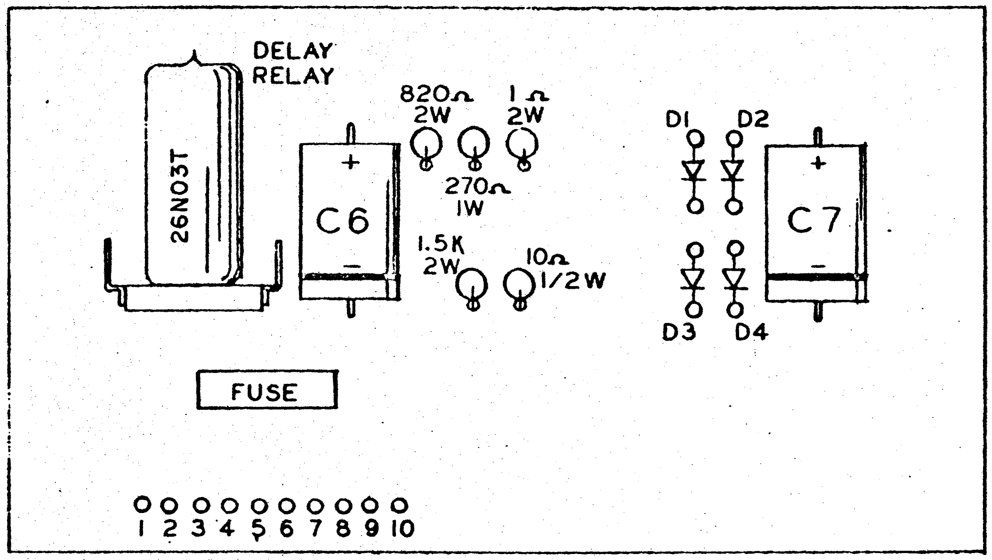



THERMAL DELAY RELAY
FIGURE VII-5

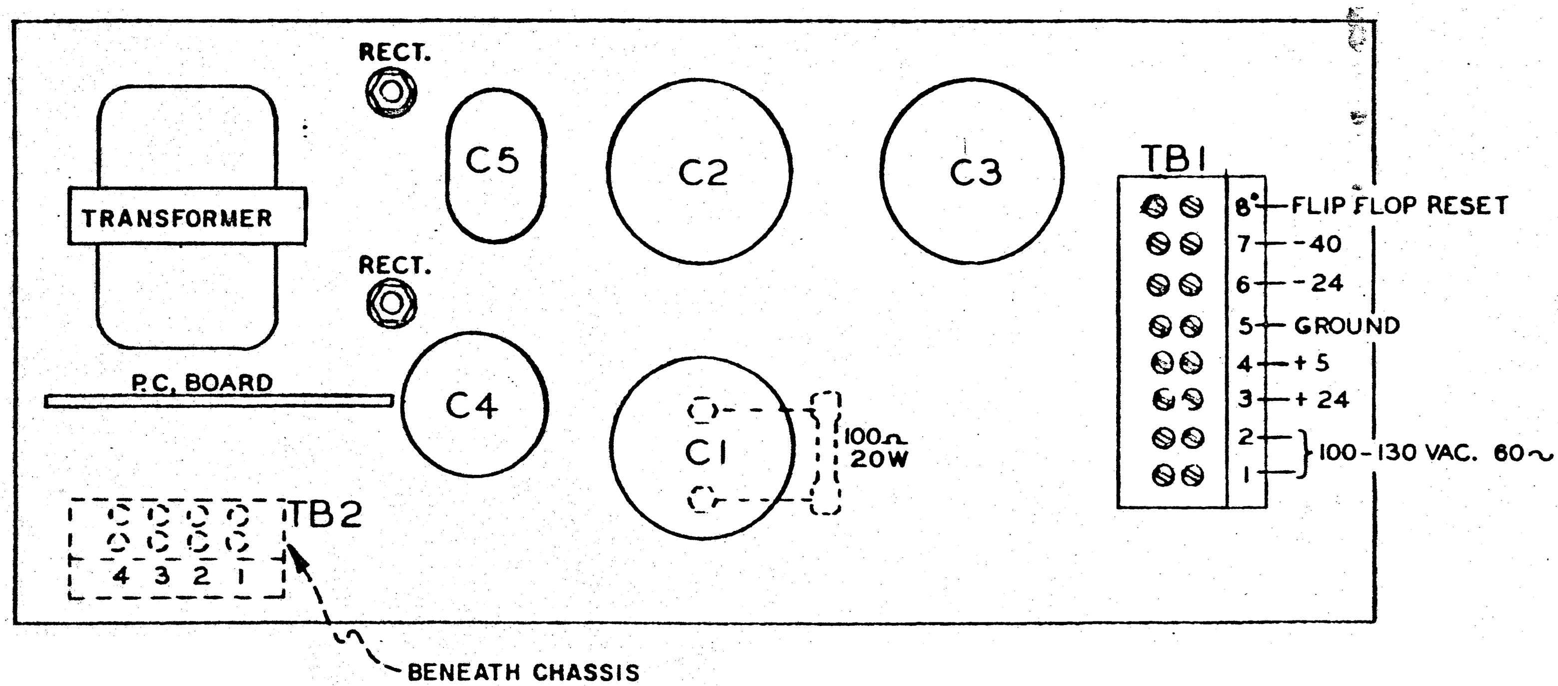
## THERMAL DELAY RELAY

A three second Thermal Delay Relay causes all the Flip-Flops in the Control Unit to reset when the System is turned on. The Flip-Flop Reset line goes to the emitters of all the set transistors in the Flip-Flops. The first three seconds after the System is turned on the Relay contacts are open so the emitters of the set Transistors are "floating". The reset Transistors conduct and thus reset the Flip-Flops.

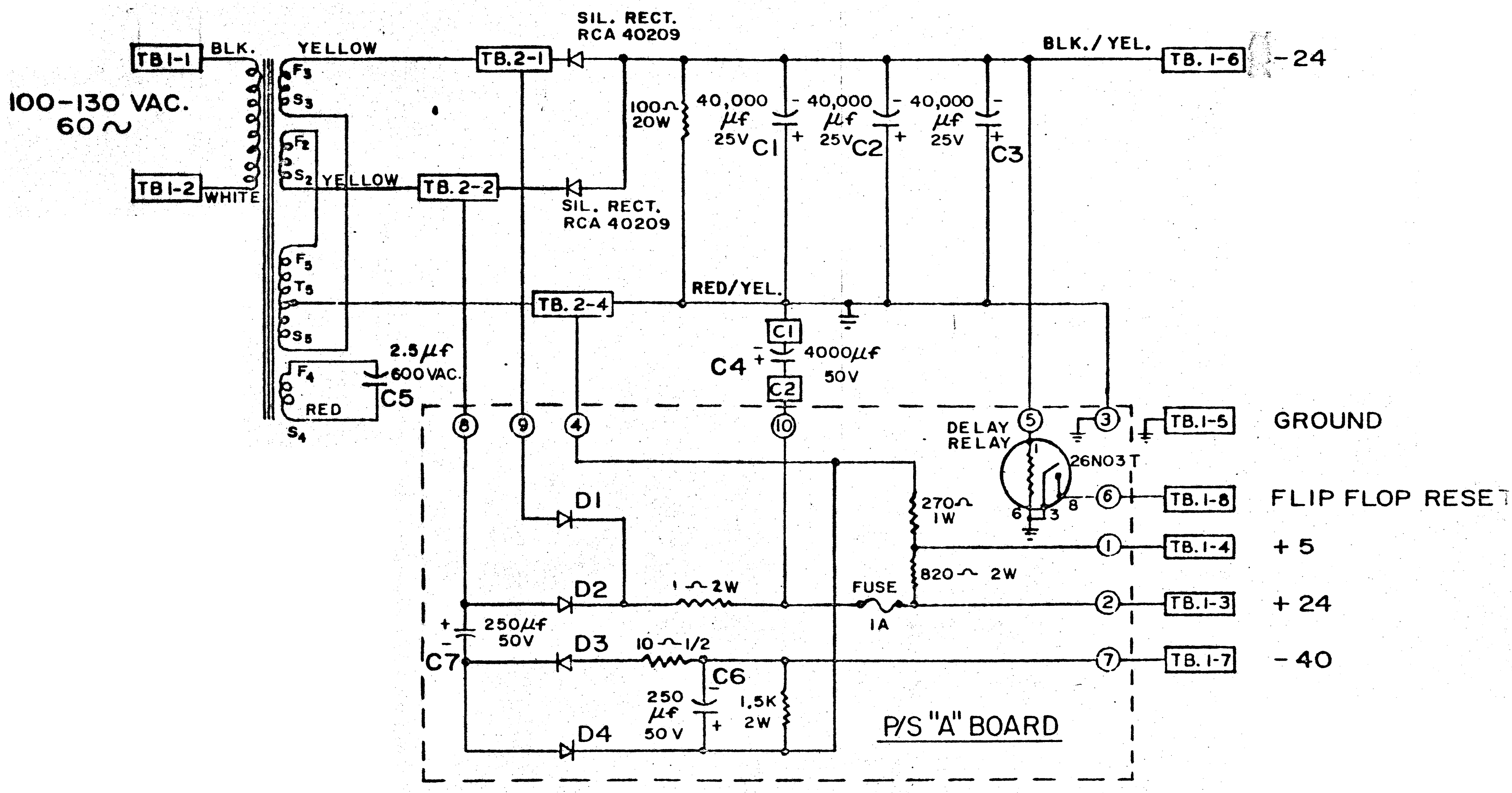
The Thermal Delay Relay circuit is shown in Figure VII-5. When the System is turned on, current flows from ground through the thermal winding to -24 VDC. During the first three seconds the Relay contacts are open. At the end of three seconds the Thermal winding has heated sufficiently to cause the bimetallic strips to pull together, thus closing the contacts. Now there is a complete path from ground through the contacts to the emitters of all the set Transistors. The Flip-Flops can now be set.




PRINTED CIRCUIT BOARD




COMPONENTS LOCATION




# 2816 POWER SUPPLY

## DIAGRAM P.S.-1