INTRODUCTION

Since the development of the transistor, continuous research in the field of semiconductors has provided many additional semiconductor devices. Some of these devices have been adopted to applications that were formally impossible. These devices, now considered as innovations in military and commercial equipment, may become as commonplace as the junction transistor is today. Indications are that development of and application for solid state devices will continue to expand. In all cases, where other devices were previously used, the solid state devices are smaller, more efficient, less expensive, and more reliable. Two of these devices, the unijunction transistor, (UJT), and the silicon controlled rectifier, (SCR), will be discussed in detail during this lesson. The S.C.R. (Silicon Controlled Rectifier) and the U.J.T. (Unijunction Transistor) are classified in the family of electronic switches called thyristors. The electronic switch is faster, less expensive and lasts longer than the conventional manual switch. They have no arc or spark and are therefore, explosion proof. Thyristors are used wherever large amounts of power are being controlled. A thyristor is a four-layer, PNPN device. This PN sandwich now has a total of three junctions. This device has two stable switching states, the ON state (CONDUCTING) and the off state (NON-CONDUCTING). Therefore we have a switch either ON or OFF.

The S.C.R.

The most common thyristor you will encounter as a technician is the silicon controlled rectifier. It is widely used because it can handle larger amounts of current and voltage than any other type of thyristor. Presently, S.C.R.'s can control currents greater than 1500A and voltages greater than 2000V. The schematic symbol for the S.C.R. is shown in figure 1A. Notice that the schematic symbol is like a diode in that it conducts in only one direction, and also must be forward biased from anode to cathode for conduction. It is unlike the diode in that it has an extra element called a gate which turns the device ON (CONDUCTING). The S.C.R.'s switching operation is best understood by visualizing its PNPN construction, as shown in figure 1B.

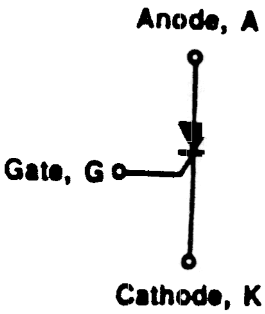


FIGURE 1A

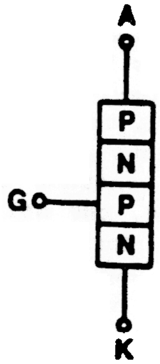
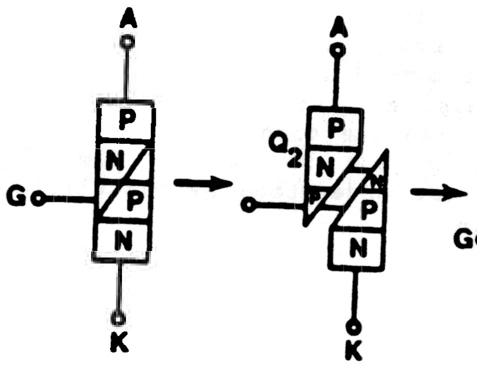


FIGURE 1B

If we slice the middle PN junction diagonally, as shown in figure 2A.



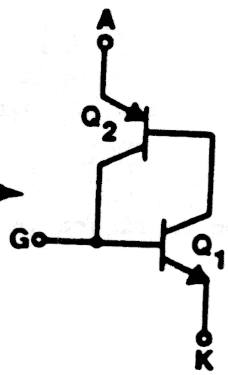
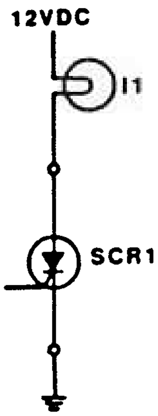


FIGURE 2A

FIGURE 2B

We have formed two transistors (one PNP and one NPN) connected back to back as shown in figure 2B. A forward-biased voltage between the gate-to-cathode leads turns on transistor Q1. Transistor Q1 conducts and its collector voltage begins to decrease. This decrease in collector voltage is also decreasing the base of Q2, actually increasing Q2's base/emitter bias, which turns Q2 on. With Q2 conducting the emitter to collector current flow also provides the base of Q1 with a current path to LATCH Q1 and Q2 on. This regenerative process only takes microseconds to complete which drives both transistors into saturation immediately. The regenerative action is termed LATCHING CURRENT because the transistors continue to conduct even if the gate-to-cathode voltage is removed. The S.C.R. can handle large amounts of power efficiently in that when it is in the off state it has no current flow thru the S.C.R. because the gate-to-cathode junction has not been forward biased. When in the "on" state, the fact that both transistors go to saturation their resistance is minimum and therefore voltage drops are minimum. We can see that regardless of the current flow thru the S.C.R the voltage drop is one volt or less. Figure 3 shows a S.C.R. in series with a light. The circuit uses a 12V power source. When the S.C.R. is "gated-on" current will flow through it and the lihgt (I1) will illuminate. Assume 50ma of current flows when S.C.R.1 conducts and that the S.C.R. drops 1V. Applying OHMS LAW, we see the majority of the power is developed by I1 and very little by the S.C.R.



$P = I \cdot E$

$P_{I1} = I_{I1} \cdot E_{I1}$

$P_{I1} = 50mA \cdot 11v$

$P_{I1} = 550mw$

$P = I \cdot E$

$P_{scr} = I_{scr} \cdot E_{scr}$

$P_{scr} = 50mA \cdot 1V$

$P_{scr} = 50mw$

FIGURE 3

The distinct advantage here is the ability to supply large amounts of power to the load using a small amount of energy at the gate. A good example of this is the PC 52A circuit card in which a small gate voltage will turn-on the S.C.R. and complete the current path for I1, which will at that time illuminate.

Another way of causing current to flow thru the S.C.R. is when the bias voltage is increased high enough to cause a forward breakdown condition. This is caused when the voltage potential across the S.C.R. becomes so high that it forces the electrons thru the S.C.R. without any potential being applied to the gate. As soon as a voltage is applied to the S.C.R., a small amount of current will begin to flow, this small amount of current is caused by leakage between the three junctions. As the voltage on the anode and cathode is increased, the current will continue to increase slightly. As the anode cathode voltage is increased it will reach a point that will allow current to increase rapidly. This point is called the forward breakover point. At this point the current increases rapidly and the resistance of the SCR will decrease. Notice on figure 4, when the forward breakover point is reached, the voltage drop across the SCR also drops. At this point, the SCR becomes a conductor and if some type of protection is not placed in series with the SCR to limit the amount of current passing thru the SCR, it will be destroyed.

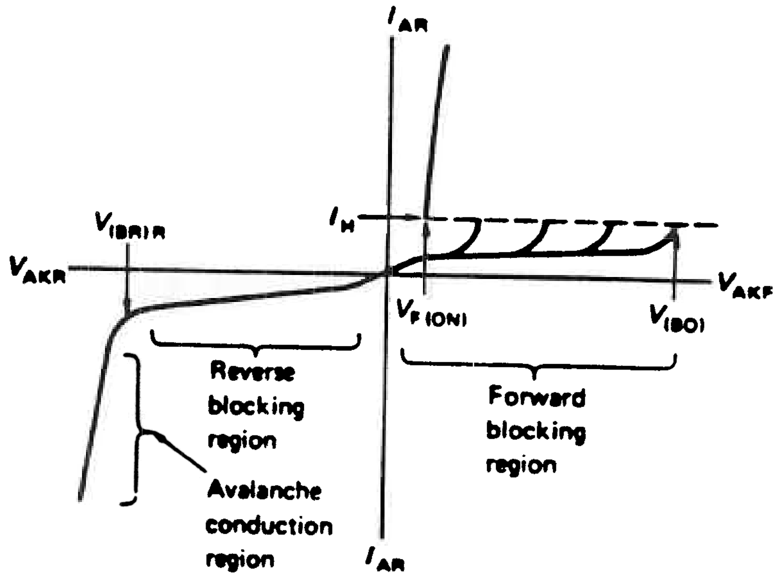


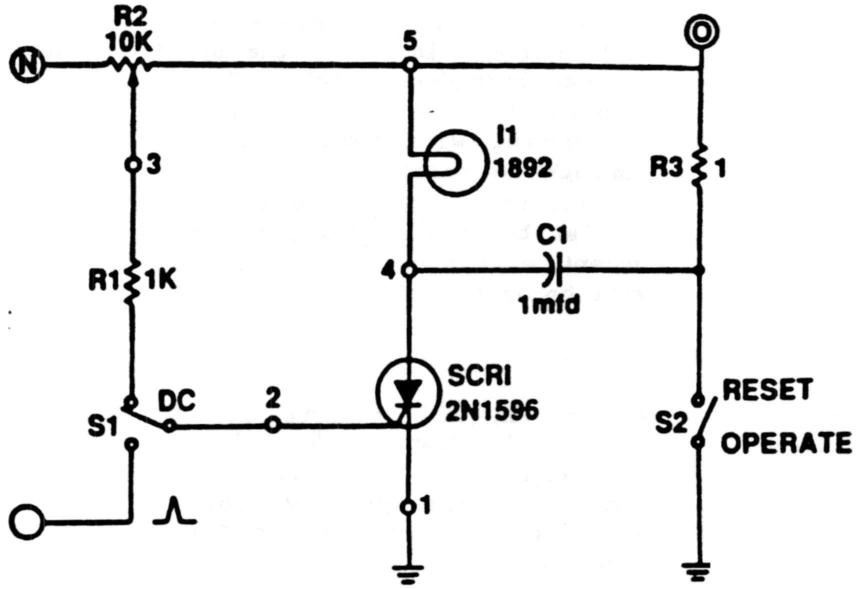
FIGURE 4

Normally, a resistor is placed in the circuit in series with the S.C.R to limit the amount of current.

When the S.C.R. is in the forward breakover condition, a small increase in voltage will cause a large increase in current. The S.C.R. will remain in this condition as long as the current remains constant, but if the current is reduced to a small amount, the S.C.R. will cut off. A point is reached at which the S.C.R. will still conduct that is called Latching Current. This point is the minimum amount of current that can flow thru the S.C.R. and still hold it in the breakover voltage state. The SCR also has a reverse breakdown point. When a reverse voltage or bias is applied across a S.C.R., there will be a small amount of leakage current. This leakage current will remain constant until the reverse voltage becomes high enough to reach the reverse breakdown point. The S.C.R., when reversed bias, will act like a common PN junction transistor. When the reverse bias becomes so high, it reaches a reverse breakdown condition and current will flow. If this condition is allowed to continue, the S.C.R. will be destroyed.

S.C.R. CONTROL CIRCUIT PC 52A

When 12vdc is applied to pin O, -9vdc to pin N, R2 adjusted fully counter-clockwise and S2 in the down (out) position no current flows in the circuit until R2 is adjusted to the right in order to provide the gate with a positive voltage. This positive voltage will forward bias the gate-to-cathode junction and turn on the S.C.R. providing another current path from ground thru the S.C.R., thru I1 to the power supply which will illuminate I1. At this time C1 will charge negative on the anode side of S.C.R.1 and positive on the opposite side. An alternate way to "gate-on" the S.C.R. is with a pulse from a timing current such as our U.J.T. This pulse (providing it has enough amplitude) has the same effect that the DC voltage had on the circuit. To turn off the S.C.R., the latching current thru the S.C.R. must be lowered below the current required to turn on the S.C.R. In this circuit this action is accomplished by placing S2 in the up (reset) position. When S2 is placed in the reset position, C1 discharges thru I1, the power supply, ground, up thru S2 to its opposite plate. This effectively places S2 in parallel with S.C.R.1 and at that time removes the current thru the S.C.R. which turns the device off. R3 is in the circuit for protection of the power supply, to prevent ground from being placed on pin O.



SCR CONTROL CIRCUIT PC 52A

TROUBLESHOOTING

PC 52A

The individual S.C.R. can be checked with the DMM as if you were checking a transistor (High power hold), although the only PN junction that can be verified is the gate cathode junction. The gate anode junction cannot be checked because there is two PN junctions that must be forward biased and our DMM will not supply enough voltage to accomplish the task.

The following is normal static voltages while the S.C.R. is not-conducting.

TP4 DMM 11.6vdc
TP2 DMM -8.8vdc (R2 was adjusted fully C.C.W.)

With S.C.R. conducting.

TP4 DMM .877vdc
TP2 DMM .88 vdc

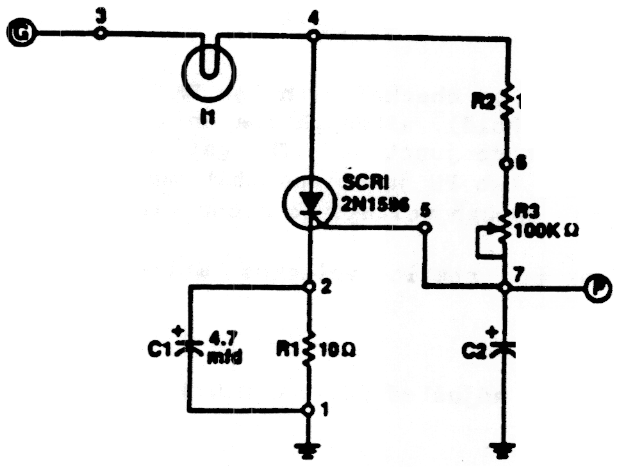
MALFUNCTION 1 I1 does not illuminate!

TP4 DMM 11.6vdc
TP2 DMM .852vdc

Gate has forward-bias applied to it but anode voltage indicated S.C.R. was not-conducting. Therefore S.C.R. must be defective. Resistance check on the gate cathode junction proves it's good. The ANODE therefore has to be OPEN. Recall that there is two junctions that must be biased so we cannot prove this with our DMM.

S.C.R. CIRCUIT PC 52B

The PC52B is operated in the AC mode as a current control circuit. The S.C.R. in this circuit controls the amount of current thru I1 which will control the intensity of the lamp. A 40v pk/pk sinewave is applied to pin G, as the positive alternation is being developed, current flows from ground to charge C2 to the value of the alternation, less any drop across R2 and R3 (notice R3 varies C2's charge time allowing it to charge higher and faster). Once C2 charges to approximately 600mv AC the S.C.R. conducts and we now have another path for current from ground thru the S.C.R. to the power supply which lights I1. During the negative alternation the S.C.R. is reverse biased and no current flows thru the S.C.R. and therefore I1 goes out, I1 will go on and off at the rate of the incoming frequency. C1 prevents any signal from being developed on the cathode and in turn making S.C.R.1 go to saturation much faster.



SCR CIRCUIT PC 52B

PC52B

The following dynamic voltages were present with S.C.R. not-conducting, (R2 adjusted fully CCW). The DMM was used in the AC MODE to measure voltages.

TP4	OSCILLOSCOPE	40v pk/pk
TP4	DMM	14.3vac
TP6	DMM	14.2vac
TP7	DMM	.31 vac

With S.C.R. conducting, (R2 fully CW).

TP4	OSCILLOSCOPE	-20v pk (Positive alternation removed)
TP4	DMM	7.7vac
TP6	DMM	6.1vac
TP7	DMM	6.1vac (Wiper-arm is adjusted to the top)

MALFUNCTION 1 I1 does not illuminate!

TP4	OSCILLOSCOPE	40v pk/pk sinewave
TP6	DMM	14.2vac
TP7	DMM	14.2vac

Gate cathode junction has forward bias applied but S.C.R. does not conduct. S.C.R. must be defective. Resistance check on the S.C.R. proves gate-cathode OPEN.

THE U.J.T. (UNIJUNCTION TRANSISTOR)

Although the unijunction transistor is not strictly a thyristor, we consider it here because it is often used to trigger the S.C.R. The U.J.T.'s schematic symbol and construction are shown in figure 5.

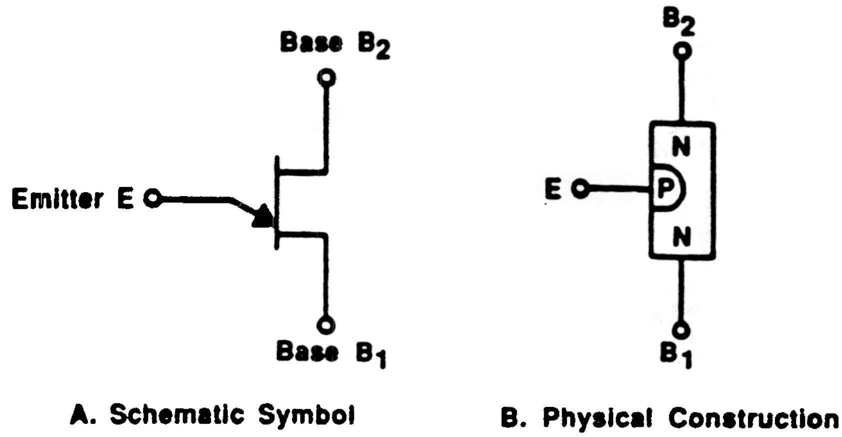


FIGURE 5

The U.J.T.'s physical construction consists of a lightly doped block of N material with a portion of P material fused to its side. Electrically, the U.J.T. is illustrated best by the circuit in figure 6. The three elements of the U.J.T. are called base 1, base 2, and the emitter. The resistance between the PN junction and B1 is designated by RB 1; the resistance between the PN junction and B2 is called RB 2. The PN junction is represented by a diode symbol.

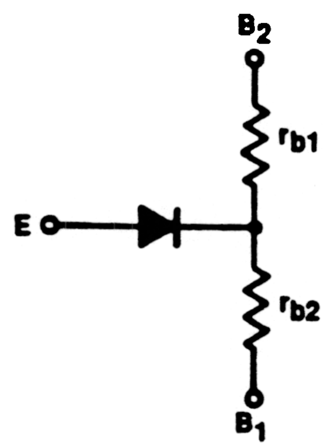


FIGURE 6

In order to turn on the U.J.T. we must raise the emitter voltage 600mv more positive than the junction of RB 1 and RB 2 (considering its constructed from silicon). Naturally we see that the position at which the emitter is fused to that junction is of great importance. Depending on where the P material is fused to the N material determines how much emitter voltage is necessary to turn on the U.J.T. Refer to figure 7.

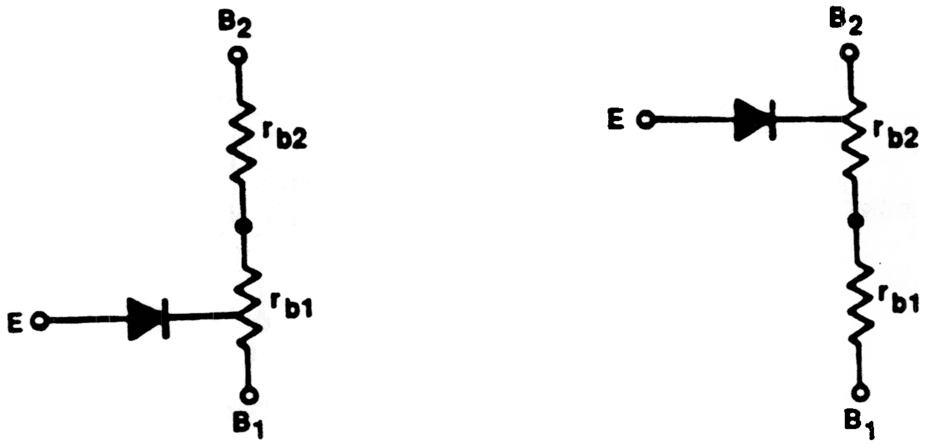
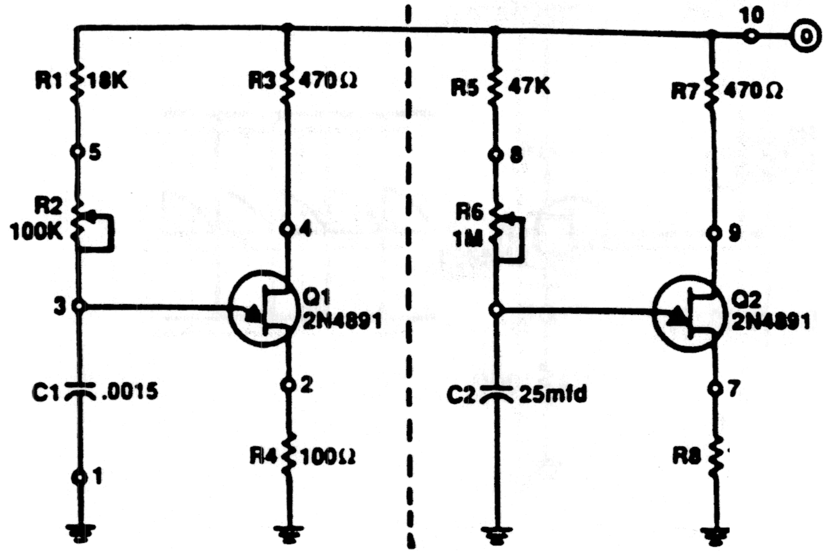


FIGURE 7

Since the U.J.T. is often used in an oscillator, we will discuss that configuration, as shown in figure 8.



UJT OSCILLATOR PC 51

FIGURE 8

When power is applied to the circuit current flows from ground thru R4, Q1, R3, to the power supply developing voltages at TP 2 and TP 4. Recall also that junction of P material to the N material within the U.J.T. C1 begins to charge at a rate determined by R2. If the emitter is fused in the center of B1 & B2 the junction would be 6vdc, so as soon as C1 charges to 6.6vdc the U.J.T. would conduct and C1 would immediately discharge thru R4, B1, emitter and to its opposite plate. At this time the U.J.T. is now off and C1 begins to charge again. Refer to figure 9.

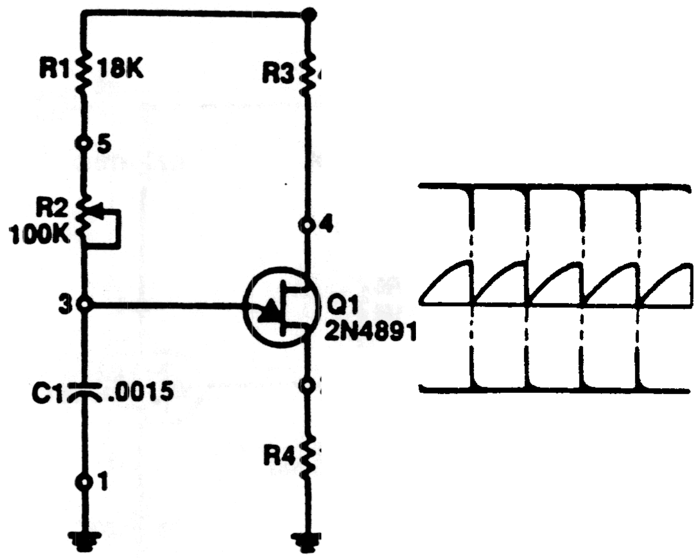


FIGURE 9

The waveform on the emitter is the charge and discharge of C1, as shown in figure 10.

FIGURE 10

The waveform on base 1 is developed when C1 discharges thru R4. This is an increase in current thru R4 which also increases the voltage drop of R4 and thus a positive spike is generated, as shown in figure 11.

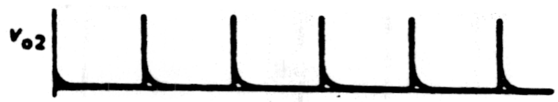


FIGURE 11

The waveform on base 2 is developed when C1 discharges thru R4. The increase in current thru R4 causes the resistance of RB2 to decrease and therefore less voltage dropped by RB2. This is viewed with the oscilloscope as a negative spike. Refer to figure 12.

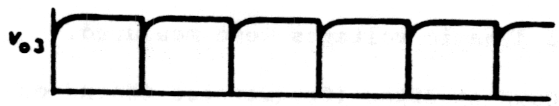
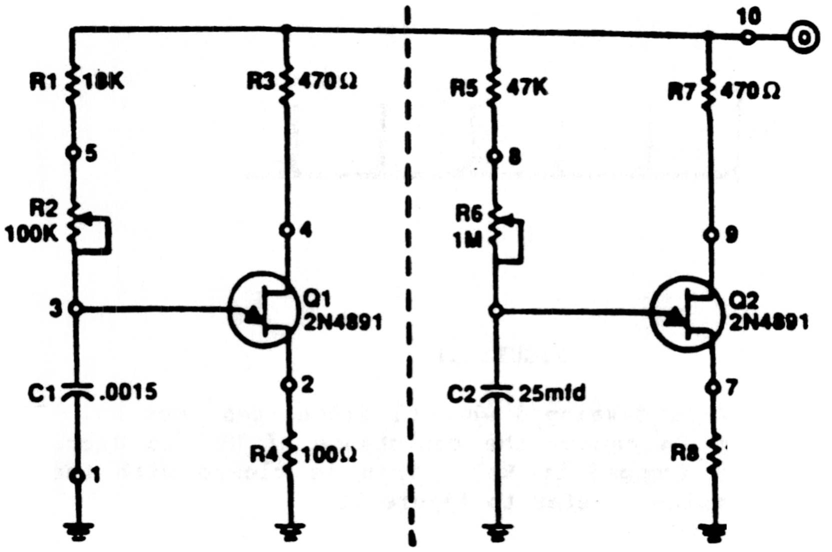


FIGURE 12

The preceding circuit is only one half of the PC 51 card. This card consists of two U.J.T. oscillators with different component values so therefore different RC time constants produce different frequencies out.



UJT OSCILLATOR PC 51

The following static and dynamic voltages were measured

TP3	OSCILLOSCOPE	SAWTOOTH at 25khz (Frequencies depend on R2's setting) with an amplitude of 6v pk/pk.
TP3	DMM	5.01vdc
TP2	OSCILLOSCOPE	POSITIVE SPIKE at 25khz with 2.2v pk
TP2	DMM	.214vdc
TP4	OSCILLOSCOPE	NEGATIVE SPIKE at 25khz with 2.7v pk
TP4	DMM	10.7vdc

MALFUNCTION 1

TP3	OSCILLOSCOPE	no waveform
TP4	DMM	10.7vdc
TP3	DMM	0 vdc
TP2	DMM	.191vdc
TP5	DMM	9.9vdc

C1 SHORTED

SUMMARY: During this lesson we have discussed the characteristics, construction and uses of both the SCR and UJT. The schematic symbols of both were presented to you as well as how to troubleshoot circuits which contained them.