SCHMITT TRIGGER

In the preceding lesson, you learned the operation of multivibrators. A Schmitt Trigger circuit is a specialized multivibrator that will convert any type of input signal, (sinewave, sawtooth, triangle), to a squarewave.

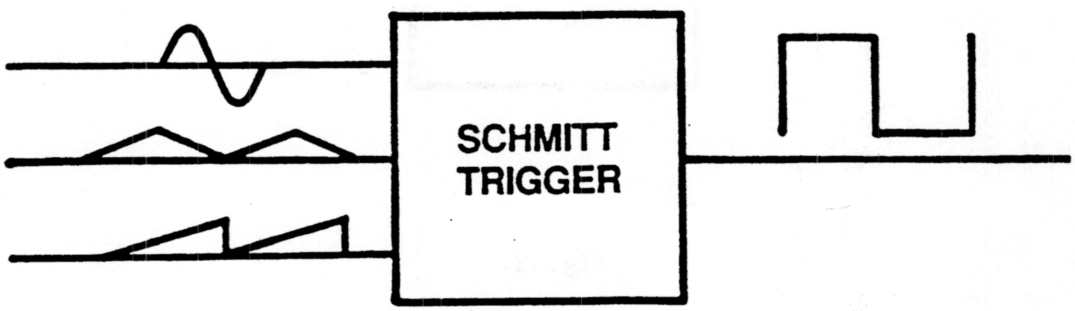

Fig. 1.

There are many circuits in electronic equipment that depend on precise timing signals for correct operation. Frequently, the timing signals become poorly shaped or distorted as they pass through various circuits. To continue to provide accurate timing functions, these signals must be reshaped into sharp rectangular pulses. The circuits that provide the reshaping are often called squaring circuits. The Schmitt Trigger can accomplish this reshaping, and it is sometimes called a Squaring Circuit. See figure 2.

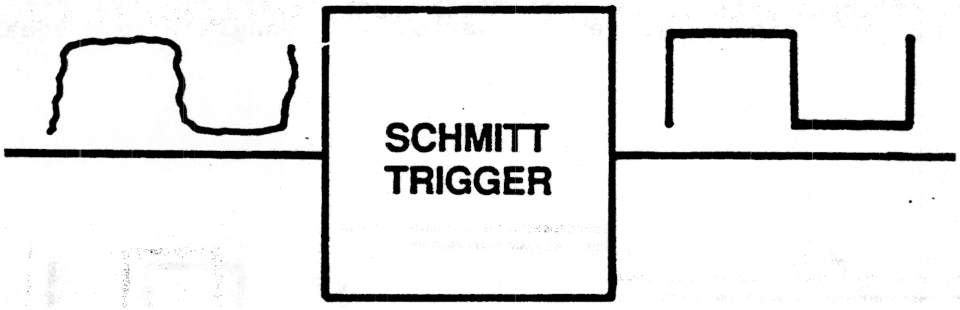

Fig. 2

Some systems use a stable sinewave oscillator, such as a crystal controlled oscillator, to establish a base frequency that will be used to set a time reference for control of the system. The sinewave itself is unsuitable for timing functions because it has no sharp vertical edges. In such cases a Schmitt Trigger is often used to provide a rectangular output from the sinewave input. The rectangular output of the Schmitt Trigger then has both the frequency stability of the oscillator and the rectangular output waveform needed for precise circuit timing.

Another use of the Schmitt Trigger is DC voltage level detection. The Schmitt Trigger can be adjusted to operate when a certain DC level is placed on its input. Due to the design of the circuit, a predetermined DC input will result in the output going either high or low and remaining there until the input voltage is removed.

Schmitt Trigger circuits are easily recognized in that they have their emitters tied together and use a common, emitter resistor. This allows the development of emitter feedback from the output transistor to the input transistor. See figure 3.

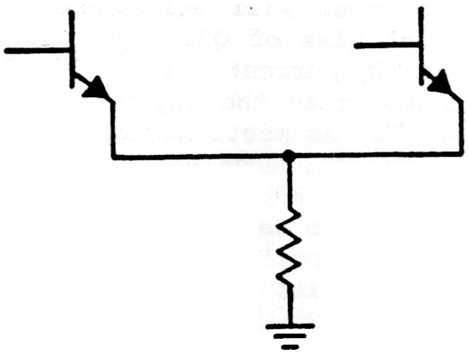

Fig. 3.

A Schmitt Trigger operates similarly to a monostable multivibrator but has certain basic differences. A Schmitt Trigger has two transistors which are always in opposite states of operation. One will be conducting while the other is cutoff. The difference between a Schmitt Trigger and a monostable multivibrator is that the monostable depends on RC time constants to determine output pulse width, whereas the Schmitt Trigger depends on the level of input, DC bias, (sensitivity level), to control the output pulse- width. Figure 4 is a schematic of the Schmitt Trigger card.

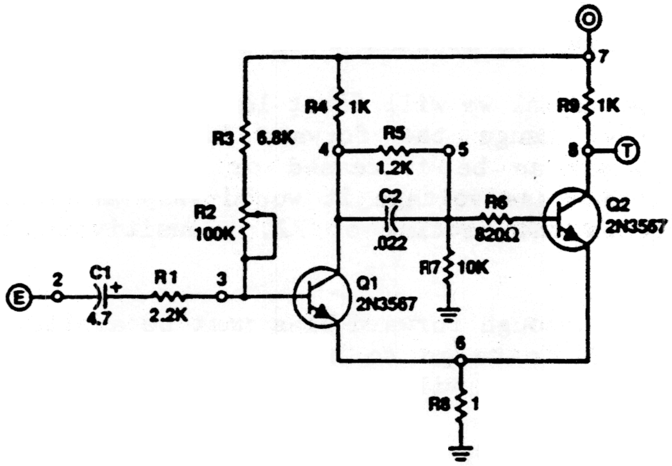

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Fig 4

COMPONENT IDENTIFICATION

The circuit consists of two common emitter amplifiers, Q1 and Q2. R4, R5, and R7 form a voltage divider which will help establish the DC bias of Q2. R6 will determine the actual bias of Q2. R4 also serves as the load resistor for Q1. If Q1 is cutoff, current will still flow through R4, R5, and R7, therefore, TP4 will never read the applied voltage, it will read something less, approximately 10V. As mentioned earlier, R8 is the emitter resistor for both Q1 and Q2. R8 will develop a signal that will be used as a feedback signal from Q2 to Q1. R9 is the collector load resistor for Q2. The output of the circuit will be seen at TP8. R3 and R2 will develop the bias for Q1. R2 is a variable resistor. This allows the DC bias of Q1 to be varied. We will call this bias the SENSITIVITY LEVEL. By varying R2 we set the sensitivity level of the Schmitt Trigger. By increasing or decreasing the sensitivity level, the time at which Q1 changes its conduction level can be controlled. R1 is an isolation resistor that will prevent any distortion of the base signal from being reflected back to the input circuit. C1 is a coupling capacitor which will couple the input signal into the circuit. C2 is a quick change capacitor. C2 allows Q2 to switch conduction levels very rapidly resulting in very sharp leading and trailing edges of the squarewave developed at the output, TP8.

THEORY OF OPERATION

Static Condition

When power is first applied both Q1 and Q2 will start to conduct. As Q1 conducts its collector voltage drops. This decrease in collector voltage is coupled to the base of Q2 and forces Q2 to cutoff. The static state of the Schmitt Trigger is Q1 conducting and Q2 cutoff. It will remain in this condition until an input is applied which will force Q1 to cutoff.

Before applying an input signal we will first look at what varying R2 will do. Adjusting R2 will change the forward bias on Q1, (sensitivity level). The base voltage can be increased or decreased. If an input signal were riding on the base voltage it would vary above or below that base voltage depending on the setting of R2. Sensitivity level and Q1 bias are the same thing.

To saturate a transistor, enough forward bias must be applied to cause the resistance of that transistor to go to near zero ohms. This saturation point is fixed by the circuit and will not vary. Refer to figure 5.

Notice that the saturation voltage is labeled 2V for both 5A and 5B. In figure 5A the sinewave starts at 1.5V and increases to 2V. At this time, the transistor would go into saturation and remain there until the sinewave dropped below the saturation point. In figure 5B the same action takes place but the saturation point is reached sooner because the base voltage has been increased, it takes the input signal less time to reach

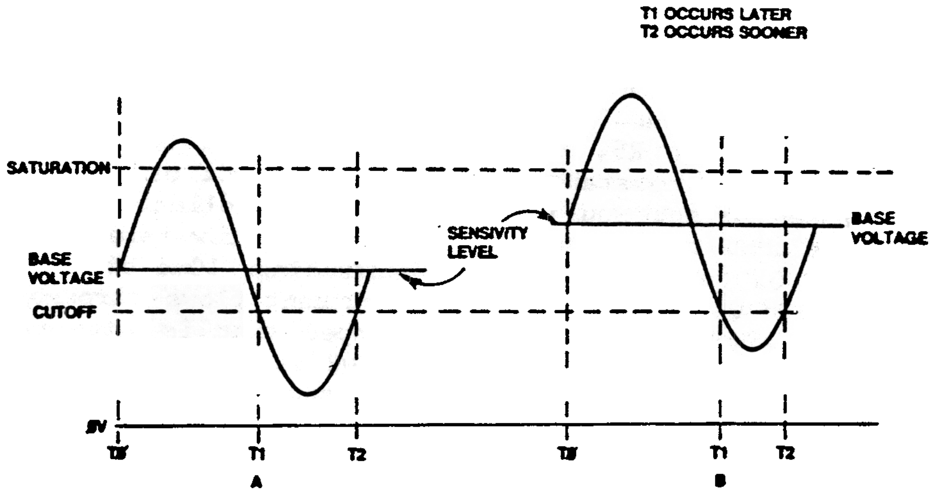

Fig. 5

the saturation point. It should be obvious that by varying R2 you can control when the transistor will saturate. Varying R2 will also determine when the transistor will cutoff. When the sinewave reaches a point where it no longer applies a forward bias to the emitter/base junction, the transistor will cutoff. Notice how both saturation and cutoff times vary in respect to TØ as the base voltage (sensitivity level) is varied.

Before discussing the operation of the Schmitt Trigger circuit, we will look at feedback in the circuit and determine its effect. See figure 6.

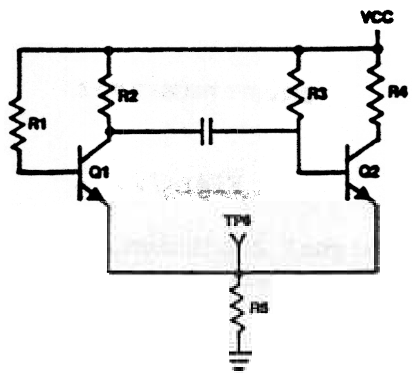

Fig. 6.

Q1 and Q2 are two identical amplifier circuits. They do not necessarily represent a Schmitt Trigger Circuit. If both transistor circuits are identical and will draw the same amount of current when they are conducting, no signal would be developed at TP6 if the transistors conducted alternately. When Q1 saturated Q2 would be cutoff. A certain amount of current would flow through R5; for example, 5ma. If they reversed conduction levels, Q1 cutoff and Q2 saturated, being identical circuits, 5ma would still flow through R5, resulting in no signal being developed at TP6. If the values of resistance in the base circuit of Q2 were reduced so that more base current would flow, then more collector current would flow. Now assume that twice as much current will flow through Q2 when it conducts as when Q1 conducts. With Q2 conducting, 10ma of current flows through R5 and with Q1 conducting, 5ma of current flows through R5. The result is that a signal will now be developed that is the result of Q2 turning on and off. It could be said that Q2 is responsible for driving Q1's emitter more or less positive. This theory, when applied to the Schmitt Trigger circuit, will be responsible for driving Q1 into saturation.

Dynamic Operation

We will now discuss the operation of the Schmitt Trigger circuit when a signal is applied. See figure 7.

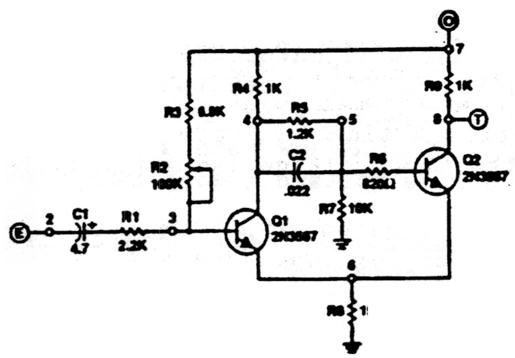

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Fig. 7.

The circuit is in its no signal condition, Q1 saturated Q2 cutoff. As the input signal swings negative it will decrease the forward bias of Q1, decreasing Q1's conduction level. As Q1's collector approaches cutoff the increase in collector voltage will be felt by Q2's base. Q2 will start to conduct. As Q2 increases its conduction level the voltage dropped by R8 will increase. This positive going voltage will result in a further decrease in the bias of Q1 (positive going voltage on the N emitter material). Feedback is being developed from Q2 to Q1. Since the bias on Q1 is being decreased by both the negative going input signal and the positive going emitter voltage, Q1 goes immediately into cutoff. As Q1 cuts off Q2 is driven into saturation. The output of the circuit is observed at TP8. TP8 has gone from a high (VCC) to a low saturation voltage (120mV). Once the two transistors are in this condition (Q1 cutoff, Q2 saturated) they will remain there until the signal allows Q1 to turn back on. As the input signal becomes more positive it will forward bias Q1. At this time Q1's collector voltage will start to decrease reducing the forward bias of Q2. As Q2 decreases its conduction level the voltage drop across R8 will decrease (become less positive or more negative). This increase in bias from both the base and emitter causes Q1 to go into saturation. The quick change of Q1's collector from cutoff to saturation results in Q2 going immediately to cutoff. The output of the circuit now goes from a low voltage to the applied voltage. This constant switching of Q2 from off (cutoff) to on (saturation) produces the squarewave output.

By adjusting R2, Q1 can be made to go into cutoff earlier or later. The result is the output pulse width can be varied by the setting of R2.

TROUBLESHOOTING

Keep in mind, the output of a Schmitt Trigger circuit will be a squarewave if there is an input signal to the circuit. If no signal is present at the output, check the input, TP2. If there is a good signal at TP2, next check TP3. If Q1 is operating, the signal at TP4 should be larger than the one at TP3. If it is not, Q1 must not be amplifying. If an amplified signal is present at TP4, Q1 must be operating. If the Q1 stage is good, the Q2 stage must be bad.

Once the bad stage is identified, use the DMM to isolate the problem to the defective component. Keep in mind the basic idea of how amplifiers operate. If the bias increases, the transistor should move toward saturation. A decrease in bias results in the transistor heading toward cutoff.

SUMMARY: The Schmitt Trigger is a form of multivibrator. In the static state one transistor is saturated and the other is cutoff. The input signal switches the circuit where it will remain until the input signal allows it to return to its static state. The output signal is a squarewave of the same frequency as the input. The Schmitt Trigger may be used as a squaring circuit to reshape or restore distorted pulses.