Getting to Know THE SCS

MYRIAD OF USES FOR THE SILICON CONTROLLED SWITCH

BY FRANK H. TOOKER

ONE OF THE MOST useful semiconductor devices on the market today is neglected by the majority of experimenters and circuit designers. That device is the SCS—silicon controlled switch. The neglect is not due to cost since at least one SCS (the 3N84) has a catalog price of only $1.98. More likely, it is due to a lack of understanding of what the SCS is, how it works, and what it can do.

The SCS, shown schematically at (A) in Fig. 1, is actually a simple device. It has a *pnpn* structure, as shown at (B) in Fig. 1, and thus resembles the SCR—with one important difference. It has a fourth connection, called the anode gate, brought out from the third layer of the "sandwich." The more conventional SCR has only a cathode gate. The anode gate gives the SCS a versatility which the SCR does not possess. (For some applications, this fourth lead can be overlooked and then, in fact, the SCS becomes a miniature SCR. In this case, the 3N84, for example, can handle 175 mA with a maximum anode-to-cathode d.c. potential of 40 volts.)

A Convenient Assumed Circuit. Probably the easiest way to understand the SCS is to think of it as an integrated circuit composed of two transistors—one *npn* and one *pnp*—with the circuit configuration shown in Fig. 2. The SCS is not really made this way; but in many cases, it behaves as if it were. Note that the cathode of the SCS is now the *npn* emitter, the cathode gate is the *npn* base and *pnp* collector, the anode gate is the *npn* collector and *pnp* base, and the anode is the *pnp* emitter.

To become acquainted with the SCS, construct the circuits shown in Fig. 3. Before applying power to either circuit, set the potentiometer to maximum resistance. Then with power applied, adjust the potentiometer to produce a gate current reading of 2 mA on the 5-mA meter. In each case note the base (cathode gate) and collector (anode gate) currents. You will find the *npn* has a d.c.

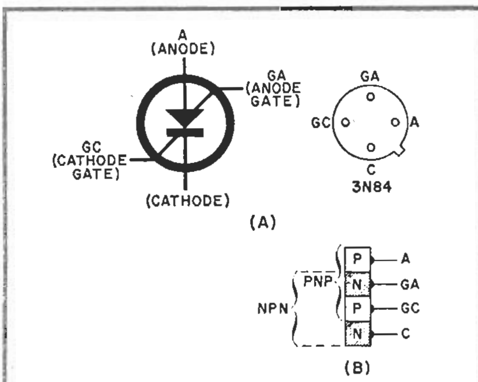


Fig. 1. Lead identification of the SCS including bottom view of the base. Unlike its SCR cousin, the SCS has an anode gate.

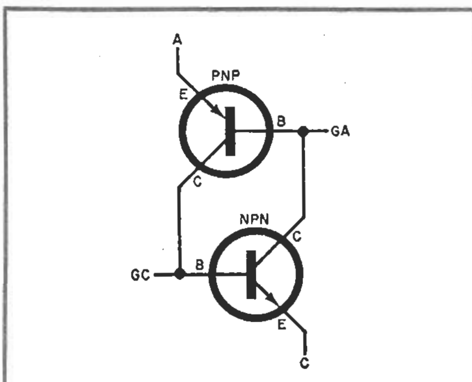


Fig. 2. Equivalent circuit of the SCS shows it to appear to be two conventional bipolar transistors tied in a regenerative-type circuit.

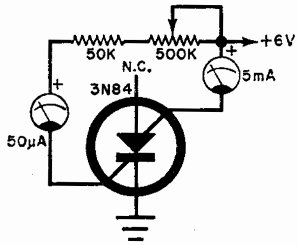
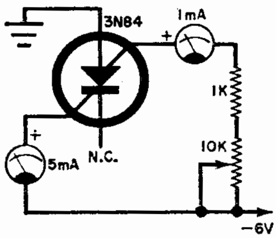


Fig. 3. In (A) above, the pnp section is inoperative. In (B) below, npn section is inoperative. In both circuits, set the pot to full maximum before turning on the power.



current gain of about 40, while that of the *pnp* is only about 1.5 or 2. These experiments will give you a "feel" for what goes on inside the SCS, enabling you to employ it more skillfully in circuits of your own design.

Regenerative Turn-On. The turn-on characteristics of the SCS are highly sensitive because of regenerative action. If you study the circuit of Fig. 2 for a moment, you'll see that the two transistors are connected so that there is a closely-coupled positive feedback. The output at the collector of the *npn* feeds into the base of the *pnp*, while the output at the collector of the *pnp* completes the circle by feeding into the base of the *npn*.

Obviously, if such a circuit is connected to a d.c. power supply and a signal of proper polarity is introduced, a "whirlwind" of amplification and reamplification (regeneration) takes place, ending in a very short time with the circuit locked up in a state of maximum conduction.

This is exactly what happens when the SCS turns on. It goes from what is essentially a no-conduction state between anode and cathode to a maximum-conduction state. In other words, it behaves like a switch, except that the action is electronic not mechanical.

In this respect, there is one important point which should always be kept in mind when experimenting with or using an SCS: be sure there is sufficient resistance in series with either the anode or the cathode to limit current flow to a safe value when the SCS turns on. If this is not done, the SCS, acting as a switch, will tend to short-circuit the power supply; and one or the other, or both, will either overheat or burn out.

Controlled Regeneration. Thanks to the availability of the anode-gate connection, it is possible to control positive feedback in the SCS. To study how this works, build the circuit in Fig. 4. It uses the *npn* portion of the SCS as an amplifier with the emitter current of the *pnp* portion controlled by potentiometer *R2*. This resistance introduces negative feedback which acts to offset the positive feedback previously described.

With potentiometers *R1* and *R2* both set at maximum resistance, connect the 9-volt power supply, being careful to observe the indicated polarity. Advance *R1* to obtain a reading of 1 mA on meter *M1*.

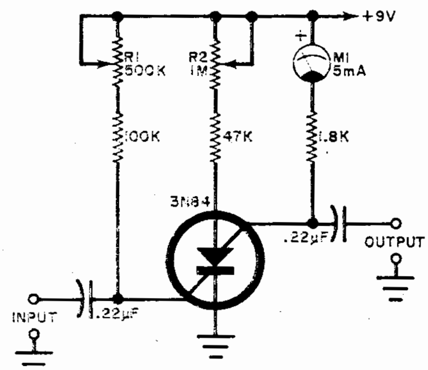


Fig. 4. By adjusting the potentiometers, you can make the SCS act like a conventional variable-beta, bipolar npn transistor.

With potentiometer *R2* set at maximum resistance, the circuit operates as an *npn* transistor amplifier. With *R2* set on minimum resistance, the circuit is simply a turned-on SCS. In between these extremes, the circuit is regenerative, with its gain increasing as the value of *R2* is made smaller.

With *R2* set at maximum resistance and *R1* set for an anode-gate current of 1 mA, advance *R2* and note that, as the setting approaches minimum-resistance in the circuit, anode-gate current rises rapidly to between 4 and 5 mA.

What we have here now is actually a variable-β *npn* transistor amplifier. To see how it works, connect an audio signal

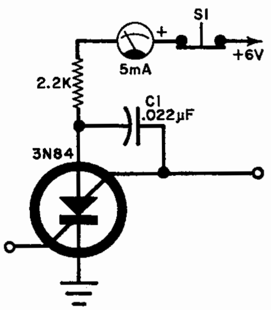
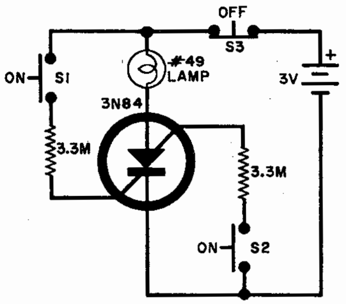


Fig. 5. In (A) above, the gates turn on the SCS switch. In (B) below, the SCS can be turned on by operating either gate switch.



generator to the input terminals and an audio VTVM to the output terminals. Set *R1* for a reading of 1 mA on *M1* and set *R2* at maximum resistance. Set the VTVM on its 1-volt range and feed a 50-mV signal at 1000 Hz into the circuit. The reading of the audio VTVM should be somewhere around 0.25 volts, indicating that the circuit has a signal-voltage gain of about 50.

Now slowly advance the setting of *R2*, observing the VTVM. The meter reading should increase, indicating increasing voltage gain in the amplifier. With care, it should be possible to set *R2* for a full-scale (1-volt) reading on the audio VTVM. With a 50-mV input, the gain of the circuit is now 200! This fourfold increase in gain is due to regeneration provided by positive feedback through the *pnp* section of the SCS.

Simple Switching. Now that we have a good concept of what is inside an SCS and how it works regeneratively, let's study its switching properties. To see how sensitive the SCS is to turn-on at its cathode gate, build the circuit shown at (A) in Fig. 5. With the 6-volt supply switched on, note that the meter reads zero. The SCS is in its off state. Actually, a small current does flow in this condition, but it is only a few microamperes and does not indicate on the meter. For most practical purposes, we can assume that the off current of the SCS is zero.

With your eye on the meter, touch your fingertip to the cathode-gate terminal. Immediately, the meter needle swings up to about mid-scale, indicating a current flow of about 2.5 mA. The SCS is now switched on, and it took no more than the touch of your finger to do it.

Now remove your finger from the terminal and you will note that the reading on the meter does not change. The SCS stays on. To turn it off, momentarily disconnect the power supply by opening switch *S1* (which should be a normally closed pushbutton switch).

To demonstrate turn-on with the anode gate, hold one finger of one hand on any grounded part of the circuit and touch a finger of the other hand to the anode-gate terminal of the SCS. Turn-off is again accomplished by momentarily opening *S1*. In either of these experiments, turn-off may also be accomplished by momentarily shorting the cathode gate to the cathode or the anode gate to the anode.

So sensitive is the SCS to turn-on that even a mild switching transient can accomplish it. In the circuit of Fig. 5(A), the transient response is subdued by capacitor *C1*. To prove this, with the power supply on but with the SCS in its off state, press and release *S1* several times and note that the meter needle remains at zero. Now do the same with capacitor *C1* removed from the circuit. Note that the meter needle promptly swings up to about mid-scale, indicating that even the transient produced by switching the power supply off and on is sufficient to turn on the SCS. The only way to keep it off is to open the switch.

and leave it open. The moment it is closed, the SCS will turn on. Capacitor *C1* prevents this by applying the same potential to the anode and the anode gate simultaneously during the brief interval when the power supply is switched on.

An SCS is always easy to turn on; and as long as it is conducting only a milliampere or two, turn-off is not too difficult. As higher currents are drawn, however, turn-off becomes more of a problem. In the circuit of Fig. 5(B), for example, where about 40 mA is pulled through the 3N84, shorting the cathode gate to the cathode or the anode gate to the anode will not turn it off. On the other hand, opening the power supply circuit is always effective.

The circuit of Fig. 5(B) can be turned on by closing either *S1* or *S2* momentarily. Very little gate current (only a

(*Continued on page* 110)

A SELF-POWERED PULSE GENERATOR

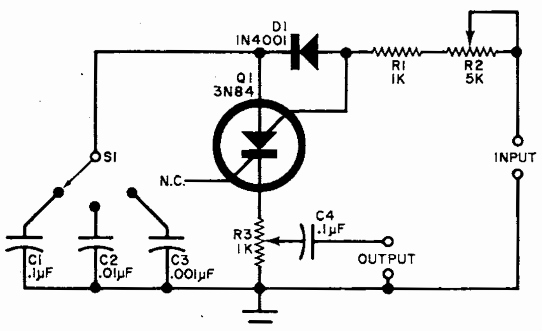
HERE IS a spike-pulse generator using an SCS and operating directly from the output terminals of a sine-wave audio signal generator—and it requires no other source of power! It has a range of 100 to 10,000 pps (pulses per second), producing one positive-going pulse for each cycle of the input signal. The sine-wave input-signal level may be anywhere between 1 and 4 volts r.m.s. You'll find it particularly useful for triggering digital logic circuits.

How It Works. While the sine-wave input signal is going through its positive alternation, diode *D1* conducts and charges up one of three capacitors, *C1*, *C2*, or *C3*, depending on the setting of switch *S1*. Simultaneously, the anode gate of *Q1* is made positive by the input so that the SCS is kept turned off.

When the input signal goes negative, diode *D1* is back-biased and ceases to conduct. At the same time, the anode gate is made negative with respect to the cathode. The SCS is thus turned on and the capacitor (*C1*, *C2*, or *C3*) discharges through potentiometer *R3*. When the sine-wave input signal goes positive again, the cycle repeats.

How to Use. Connect the output of an audio signal generator to the input of the pulse generator. Connect the output of the pulse generator to the vertical input terminals of an oscilloscope. Set the pulse generator's output level control, *R3*, for maximum output (toward the cathode of *Q1*). Set potentiometer *R2* at about midposition.

Set the signal generator at any frequency between 100 and 10,000 Hz and run its output up to about 2.5 volts r.m.s. Observing the trace on the oscilloscope, set switch *S1* to the position which provides the best spike waveform. Then adjust potentiometer *R2* to improve it, if necessary. The largest value of capacitance (*C1*) is best for the lowest frequencies, and vice versa.



This simple self-powered pulse generator can be built directly into an existing audio sine-wave generator. The output pulses can be used to trigger experimental digital circuits or, if accurately calibrated, scope trace times.

If the output pulse is broad, set *S1* at a smaller value of capacitance. If multiple pulses appear, set *S1* to a large capacitance. With each change in the setting of *S1*, adjust *R2* to get the best obtainable waveform.

KNOW THE SCS

(*Continued from page 78*)

microampere) is required for turn-on. If desired, a 100-pF capacitor can be substituted for the 3.3-megohm resistor in either gate circuit. This is a useful substitution when d.c. isolation is required.

Turning an SCS off by opening the power-supply circuit requires a switch in a position to break the full load current

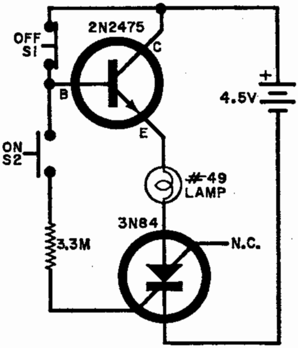


Fig. 6. A conventional npn transistor can be used in place of a power switch to turn the SCS on and off. Any type of mechanical contacts can be used for switches S1 and S2.

flowing through the SCS. This is not always practical if you want to use a very small switch. For such applications, it is better to use a transistor to switch the load current with a small mechanical switch to turn the transistor off and on.

Now to Work. The SCS is such a versatile device that its applications are limited only by your imagination. One typical application is described on page 78.