Bootstrapping a phototransistor improves its pulse response

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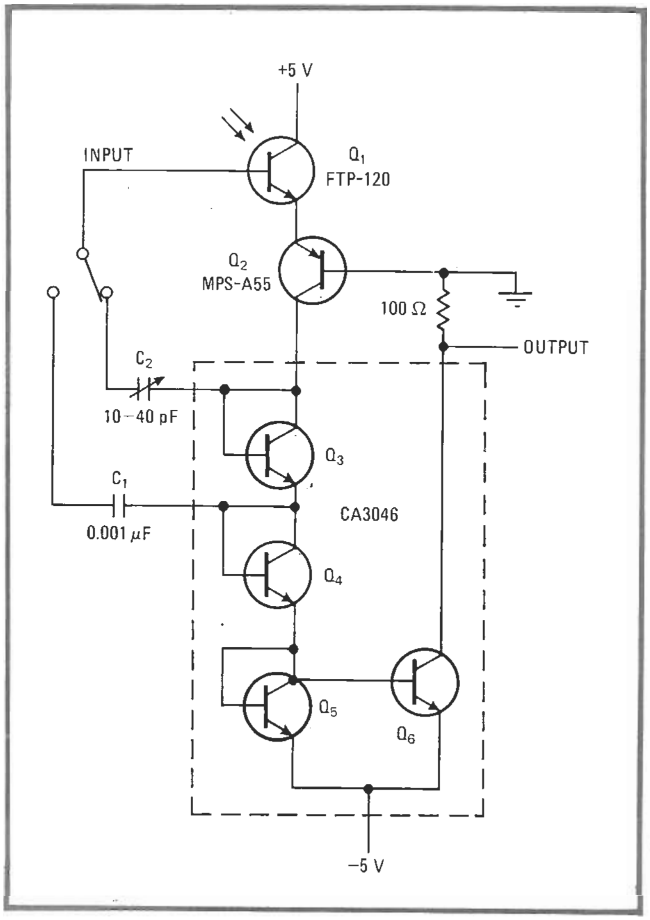
Although the operating speed of a phototransistor cannot be improved simply by connecting a second one in the cascode configuration [*Electronics*, March 2, p. 132, and April 27, p. 154], its response may be improved by employing a standard transistor in a bootstrap circuit in order to reduce the effective value of the phototransistor's junction capacitance. By introducing bootstrap feedback to the base of the input optodevice, the switching speed of a cascode-connected phototransistor can be increased by as much as 10 times over that of a uncompensated one.



Compensation. Junction capacitance of Q_1, which is not sufficiently reduced despite cascode connection (Q_1, Q_2), is greatly lowered by applying feedback to base. This allows a rapid discharge of Q_1's base-to-emitter capacitance during signal conditions, which acts to increase the phototransistor's high-frequency response.

Phototransistor Q_1 and Q_2, a pnp transistor, form the conventional cascode arrangement, as shown in the figure. Generally, when an input signal is detected, the photocurrent step produced begins to charge the capacitance associated with Q_2's base-emitter and base-collector junctions. The voltage across the base-emitter junction has a magnitude comparable to that across Q_2's base-emitter junction, and therefore a way must be found to compensate for the two V_{be} drops produced, in order to ultimately reduce the effective junction capacitance of the phototransistor.

In theory, the V_{be} drops may be cancelled by making use of the pn drops across two forward-biased diodes of comparable transconductance. Here, diode-connected transistors Q_3–Q_5, which are part of the CA3046 transistor array, are available for use. Using the CA3046 ensures that these transistors will be closely matched.

Feedback from Q_4's collector to Q_1's base through C_1 constitutes the normal bootstrap path, supplying an in-phase current to Q_1's base. This causes a rapid charge of the junction capacitance, and therefore the input photocurrent sees a lower value of capacitance than actually exists. Because Q_1 has a β of several hundred, its base-emitter transconductance is less than that of the lower-β devices, Q_4 and Q_5, used in the feedback path. As a result, the amount of feedback is well below unity loop gain (undercompensated condition).

By using Q_3, however, with feedback applied through C_2, an additional pn drop is gained and compensation becomes almost perfect. For a given quiescent photocurrent, C_2 should be adjusted to a value just above that which will cause oscillation in the circuit.

Fairchild's FTP-120 (Q_1) has a typical rise time and fall time of 18 microseconds when used in the typical emitter-follower configuration specified for a 100-ohm load. With C_1-path compensation, the switching time is about 5 μs. With C_2-path compensation, the switching time is about 2 to 3 μs. □

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