Wave-Shaping Circuit Action

How waveforms are shaped electronically and interpreting their results—good and bad— on an oscilloscope

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Wave-shaping circuits are extensively used in most areas of electronics. This article illustrates how they work and what they produce, using an oscilloscope, when they're operating properly and when there's a defect that distorts the trace. Such information will be especially important to electronics technicians in many fields since it will take some of the mystery out of vertical-sweep functions and malfunctions.

Perhaps the simplest example of these is the peak clipper shown in Fig. 1. Clipping action occurs in such a circuit because the shunt resistor has a value that is much less than the reverse resistance of the diode but is much greater than the forward resistance of the diode.

If the diode in Fig. 1 develops junction leakage, the output waveform is incompletely clipped. If the diode is shorted, no clipping action occurs. Note that this is an example of a *nonlinear* wave-shaping circuit.

Now observe the parallel diode clipper circuits shown in Fig. 2. Clipping action occurs in these circuits because the series resistor has a value that is much less than the reverse resistance of the diode but is much greater than the forward resistance of the diode. As in the series-circuit arrangement, if the diode develops junction leakage, the output waveform is incompletely clipped. Too, if the diode is shorted, zero output is obtained. This is another example of a nonlinear wave-shaping circuit.

Reverse-biased diode clippers are

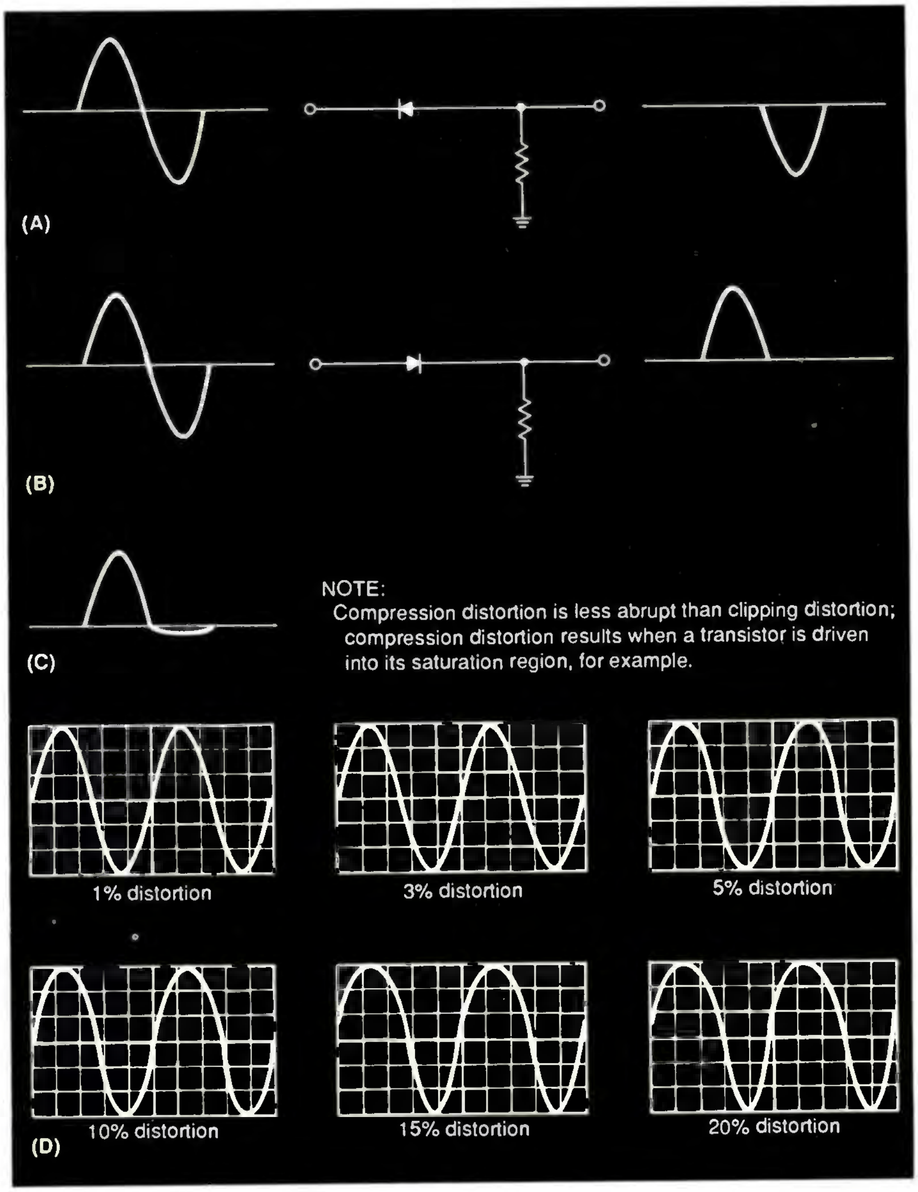
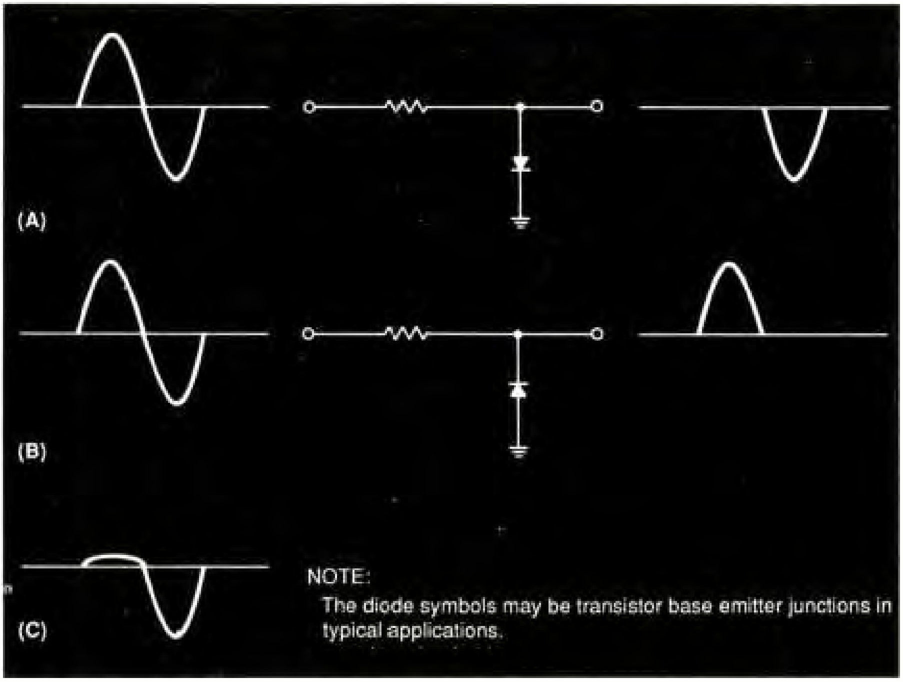


Fig. 1. Series-diode peak-clipper circuits: (A) positive and negative (B) peak-clippers; (C) distorted output waveform from negative peak clipper resulting from junction leakage; (D) peak compression waveforms with different percentages of distortion. In (D), compression distortion is less abrupt than clipping distortion and results when a transistor is driven into its saturation region, for example.



NOTE:
The diode symbols may be transistor base emitter junctions in typical applications.

Fig. 2. Parallel-diode clipper circuits: (A) positive and (B) negative-peak clippers; (C) distorted output from positive-peak clipper due to junction leakage. Diodes in (A) and (B) may be transistor base-emitter junctions in actual circuits.

used for partial peak clipping, as illustrated in Fig. 3, which shows basically parallel diode-clipper circuits. The clipping level is determined by the value of the back-bias voltage. If the diode junction develops leakage, the clipping level is shifted, as illustrated in (C). Note that junction leakage also results in attenuated output. If the diode is shorted, the output voltage is 0. if the diode is open-circuited, the output voltage is not attenuated and no clipping action occurs.

Sync-Clipper Circuit Action

The basic sync-clipper circuit uses a reverse-biased diode, as shown in Fig. 4. Although it isn't obviously reverse biased, signal-developed bias voltage effectively reverse-biases the diode. When the RC time constant of the coupling circuit is correct, the value of the reverse-bias voltage then provides a clipping level at the "porch" of the sync pulse. In turn, only the sync tip appears in the output. The sync pedestal and any associated video signal are rejected. This circuit action is accomplished as follows.

After several sync pulses have been processed, the "steady state" has been established in the sync separator and the coupling capacitor maintains an average back-bias negative voltage that cuts off the diode except for the duration of the sync tip. Stated another way, the incoming sync pulse "sees" a conducting diode only when its instantaneous voltage exceeds the porch level.

Circuit action in Fig. 4 occurs because diode conduction during the sync-tip passage recharges the coupling capacitor, which partially discharges during the idle time from one sync pulse to the next. Immediately after the sync tip has passed, the coupling capacitor has been charged to the peak voltage of the sync pulse.

Signal-developed reverse bias provides an important advantage when the incoming video signal level is subjected to change from one channel to another. Thus, the peak potential level on one channel might be 2 volts and the peak potential level on another channel might be 0.75 volt.

Despite the prevailing video-signal level, the sync circuitry requires reception of a clean sync tip that is free from spurious components. This requirement is met from a practical standpoint by use of signal-developed reverse bias since the reverse-bias level then "follows" the prevailing video signal.

If a circuit fault develops, such as diode junction leakage, the output waveform will display spurious components, as illustrated in Fig. 4(B). Leakage resistance shifts the clipping level and permits part of the sync pedestal and white video peaks to pass through the clipper. It is evident that if the clipping diodes were to become shorted, there would be no clipping action whatsoever and the input video signal would pass unaltered into the output circuit. The diode in Fig. 4 is more likely to be a transistor to develop gain in the clipper section.

Wave-Shaping and Negative Feedback

Another basic type of wave-shaping circuitry is shown in Fig. 5, which illustrates one method of generating a vertical-sweep waveform, as in a TV receiver. It consists of a gated RC integrating circuit that produces an exponential (semi-sawtooth) waveform.

Since the semi-sawtooth waveform in Fig. 5 is convex, it would compress the image displayed on the TV receiver's picture tube toward the bottom of the screen. Accordingly, the initial waveform must be linearized by some means. Two methods of accomplishing this are commonly employed—negative feedback and predistortion correction.

The basic negative-feedback linearization arrangement is shown in Fig. 5(A). Partial linearization is accomplished by feeding back part of

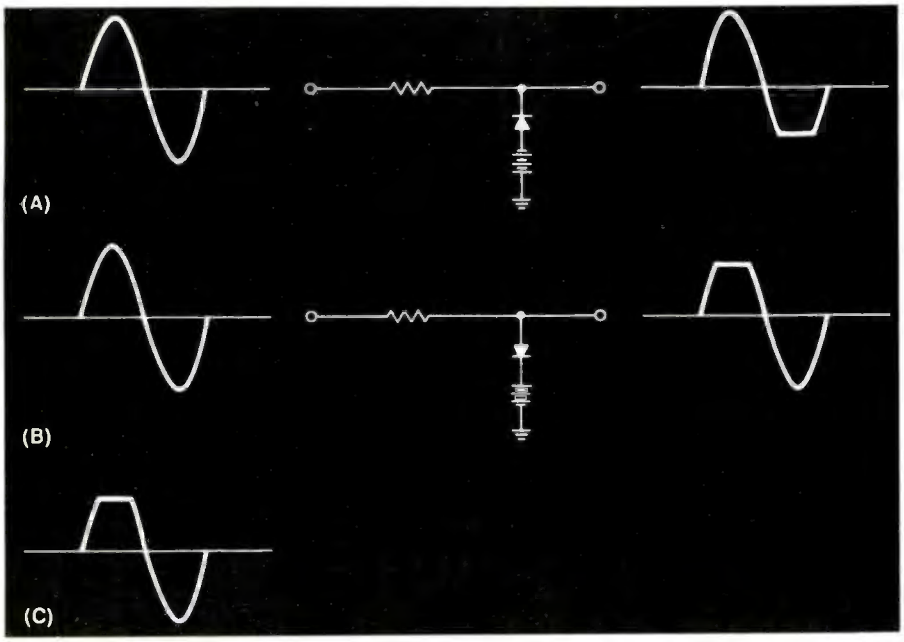


Fig. 3. Reverse-biased diode clipper circuits: (A) negative and (B) positive peak clippers; (C) distorted output (shifted clipping level) from positive peak clipper due to junction leakage.

the output voltage and combining it with the input voltage.

In theory, a semi-sawtooth waveform could be completely linearized by negative feedback. In practice, however, excessive production costs would be incurred, inasmuch as a prohibitively high-powered output amplifier would be required, resulting in a linearization/power tradeoff.

Because of the linearization/power tradeoff, a moderate amount of negative feedback is used in practical circuits. Then the partially linearized sweep waveform is further linearized by means of predistorting circuitry, as shown in Fig. 6. Note here that predistorting circuits are nonlinear wave-shaping arrangements, whereas negative-feedback wave-shaping circuits are basically linear configurations.

Wave Shaping in Predistorting Circuits

Observe in Fig. 6 that the dynamic transfer characteristic for a bipolar transistor is concave at low bias values and is convex for high for high bias values. Thus, if a linearity control biases the vertical driver stage at point R ′, for example, the output waveform will be concave in comparison to the input waveform. Or if the vertical driver stage is biased at point X ′, for example, the output waveform will be convex in comparison to the input waveform. In turn, a partially linearized sawtooth waveform with residual convex distortion can be further linearized by passing it through a driver stage with a low bias setting.

Bear in mind that predistortion wave shaping does not provide complete linearization of the applied semi-sawtooth waveform. This is because the curvature in the dynamic transfer characteristic only approximates the exponential curvature present in the semi-sawtooth waveform. Accordingly, practical vertical driver circuitry typically includes negative feedback to provide optimum curvature in its dynamic transfer characteristic.

As an illustration of the above, a widely used configuration employs appreciable negative feedback from collector to base plus a small amount of emitter feedback. The emitter feedback is further modified by injection of some deflection-coil current.

A common variation on the foregoing wave-shaping circuit uses fixed bias on the driver transistor, with the linearity control in the collector-to-

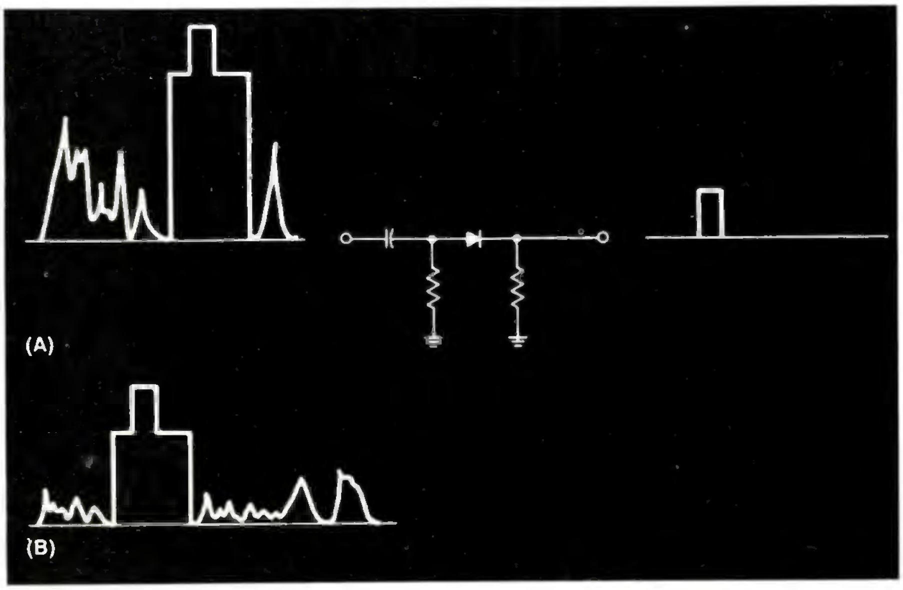


Fig. 4. Sync-separator arrangement with reverse-biased diode type of circuit action: (A) basic configuration; (B) output waveform with spurious components resulting from junction leakage.

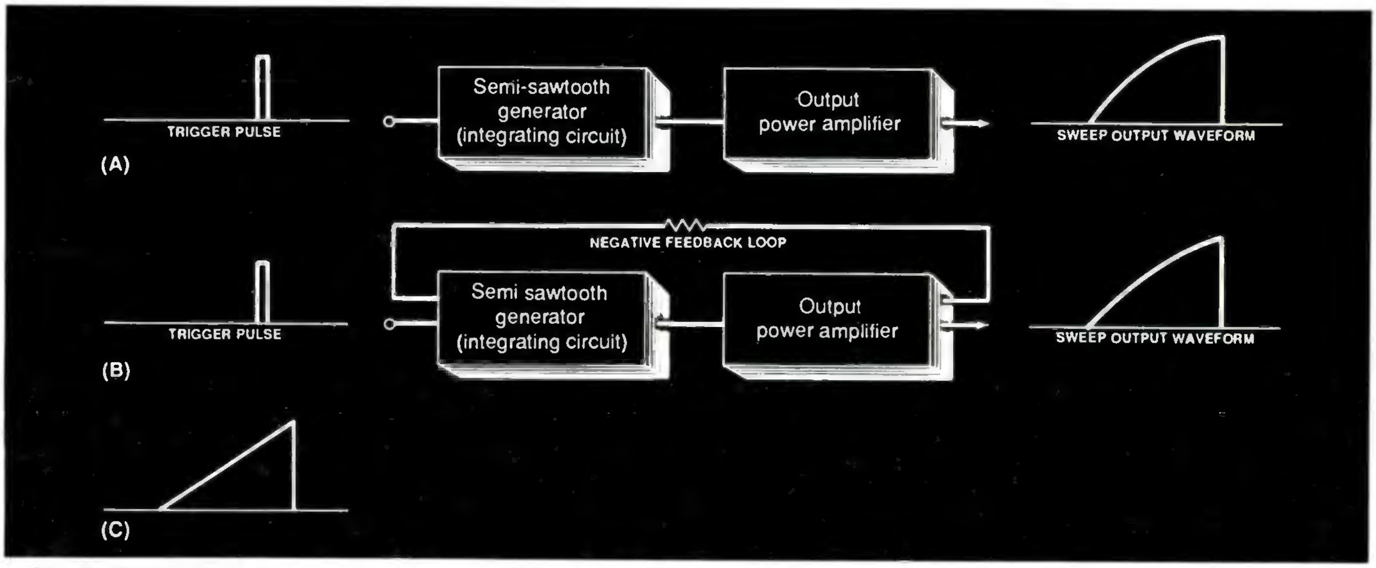
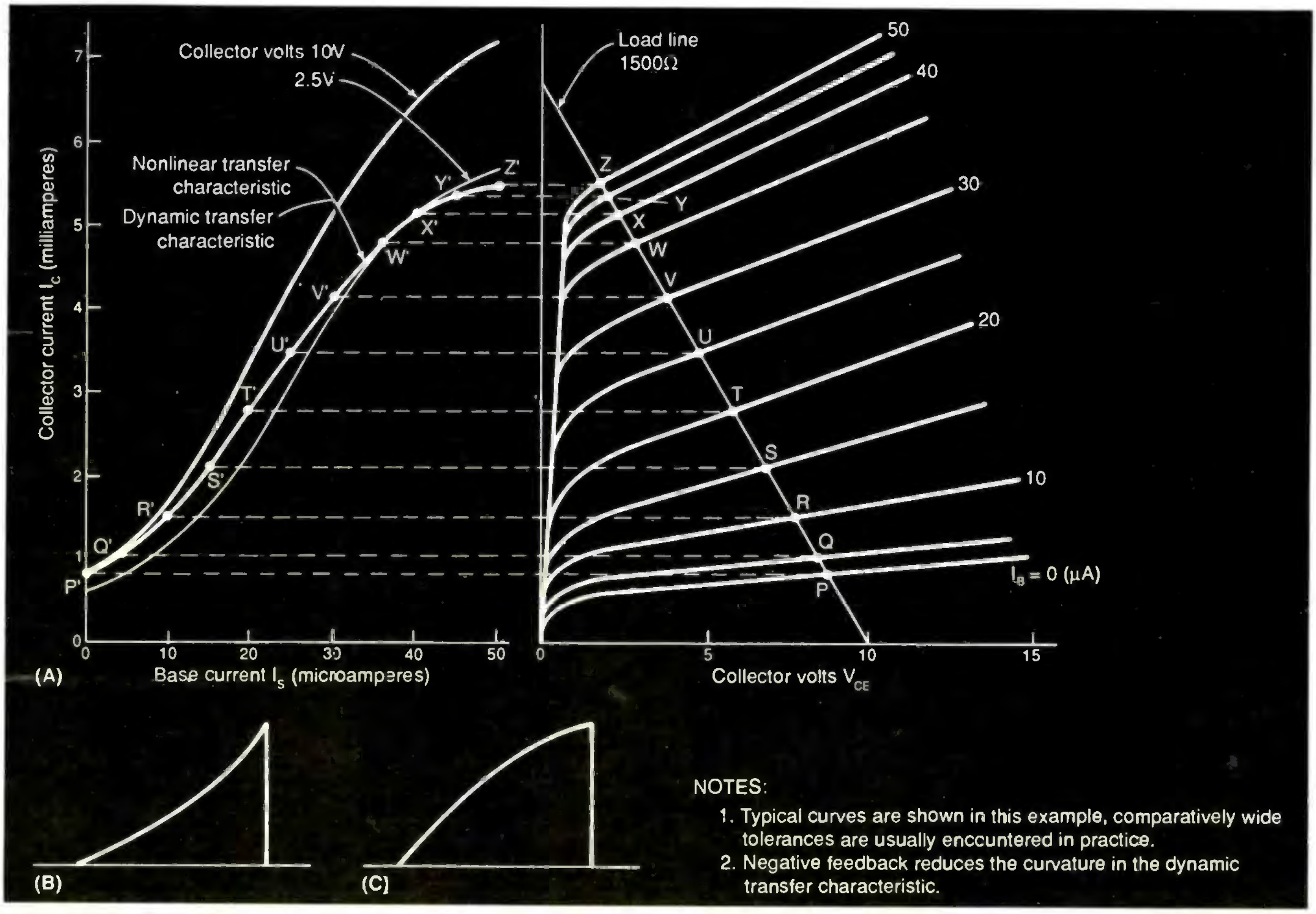


Fig. 5. Waveshaping in a vertical-sweep section of a TV receiver: (A) basic arrangement; (B) a sawtooth waveform shown partially linearized by negative feedback; (C) an ideal sawtooth waveform would be generated when an unlimited amount of negative feedback is used in the circuit.



NOTES:

1. Typical curves are shown in this example, comparatively wide tolerances are usually enccuntered in practice.
2. Negative feedback reduces the curvature in the dynamic transfer characteristic.

Fig. 6. Predistortion wave-shaping process: (A) dynamic transfer characteristic for a bipolar transistor; (B) low-bias predistortion; (C) high-pass predistortion. Negative feedback reduces curvatures in the dynamic transfer characteristic.

Fig. 7. Basic peaked-sawtooth wave-shaper (A) and low-amplitude peaking pulse (B) results from capacitor leakage.

base feedback loop. With this arrangement, the amount of concave predistortion is determined by the amount of negative feedback that is used. In either implementation, the amplitude of the sawtooth is determined by the amount of semi-sawtooth drive voltage fed to the base of the driver transistor.

The semi-sawtooth waveform is generally developed by an emitter-follower circuit that has a partially bypassed emitter resistor. This sawtooth-generator maker provides low source resistance, which is an advantage in driving power-type transistors.

It follows that reading oscilloscope waveforms in wave-shaping circuitry can depend considerably on your knowledge of the details in the circuit being investigated insofar as interpreting distorted waveforms is concerned. That is, the same distortion factor that points to incorrect bias in one variation of the basic circuit can be misleading in another variation of the basic circuit.

Sectional interaction can also be confusing when reading scope waveforms. Interaction is most prominent in two-stage systems and may be only a minor factor in three-stage systems. There is always some degree of interaction to be taken into consideration merely because all vertical wave-shaping circuits employ more or less negative feedback.

Peaked Sawtooth Wave Shaping

Current waveforms differ from voltage waveforms in reactive circuits that contain an inductance or/and capacitance. Thus, a sawtooth voltage drives a sawtooth current waveform through a purely resistive circuit, but a pulse voltage drives a sawtooth current through a purely inductive circuit. The vertical-deflection coils in a TV receiver, for example, are both inductive and resistive. As might be anticipated, a combination pulse-and-sawtooth voltage waveform is required to drive a sawtooth current waveform through vertical-deflection coils. This combination waveform is called a "peaked sawtooth."

The basic peaked-sawtooth wave-shaping circuit is shown in Fig. 7. It consists of a series RC branch network in shunt to the output of the driver stage. Observe that during the rise of the input and output sawtooth waveforms, the peaking capacitor charges up to nearly the peak voltage of the sawtooth output.

When the input sawtooth waveform suddenly falls, the output sawtooth cannot instantly fall to ground potential because the peaking capacitor has a terminal voltage that first must drain off to ground via the peaking resistor. Since the time constant of the peaking circuit is comparatively short, drain-off is rapid, and this interval generates a "spike" or peak at the beginning of the next sawtooth waveform.

In a variation of the basic circuit, its equivalent RL configuration is employed. The inductive "kick-back," in turn, generates the spike for the peaked sawtooth waveform.

Blanking-Pulse Wave Shaping

After the peaked-sawtooth waveform has been generated, it is frequently processed to form vertical-retrace blanking pulses. This blanking-pulse wave-shaping circuit has the basic configuration shown in Fig. 8. Note here that the circuit shown is essentially a differentiating circuit that has a time constant that permits passage of the narrow peaking pulses or spikes but rejects the broad ramp portion of the waveform. This is just another way of saying that narrow pulses are built up from comparatively high-frequency harmonics, whereas the ramp is built up from comparatively low-frequency harmonics of the sweep repetition rate.

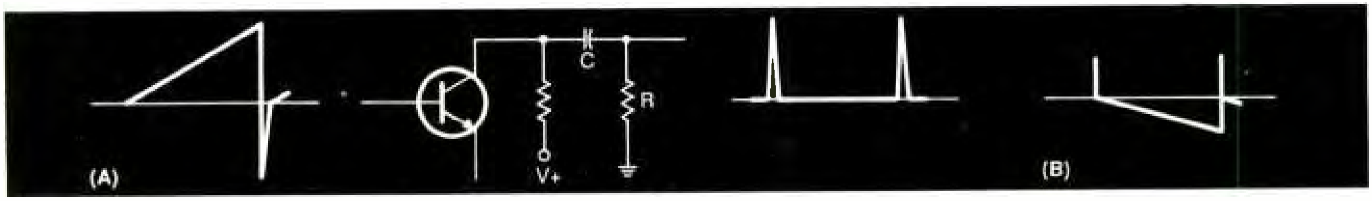


Fig. 8. A basic retrace blanking-pulse wave-shaping circuit (A) and distorted output waveform with attenuated pulse and spurious sawtooth components (B) resulting from capacitor leakage.