

# INTRODUCTION TO OPERATIONAL AMPLIFIER THEORY AND APPLICATIONS

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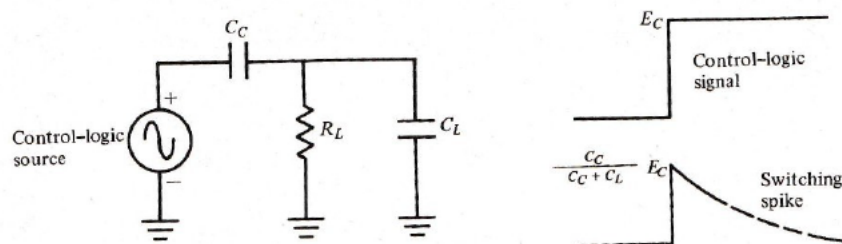


FIGURE 5.2

Turn-on spike (grounded control-signal source, grounded load) due to a switch capacitance  $C_C$ . The dashed lines indicate that the spike will be modified when the switch actually turns ON. Until then (neglecting nonlinear circuit effects), the spike has the form of a decaying exponential with initial amplitude  $E_C C_C / (C_C + C_L)$  and time constant  $R_L (C_C + C_L)$ . For a purely capacitive load ( $R_L = \infty$ ), the exponential becomes a step (based on Ref. 1).

Electronic switching devices such as diodes and bipolar transistors can introduce not only spurious ON and OFF switch impedances, but also *offset voltages and currents* (Secs. 5.3 and 5.4).

If the switch-control circuit and the switched (signal) circuit have common dc impedances, a portion of the switching waveform may appear in the signal circuit, where switching steps give rise to control-voltage-dependent voltage offsets or *pedestals*.

For fast switching, switch-control voltages are usually fast-rising steps or pulses derived from digital logic circuits. Even small coupling capacitances  $C_C$  between the control circuit and the switched (signal) circuit *differentiate* these steep-sided waveforms and create *switching spikes* and/or steps in the signal circuits (Fig. 5.2). Switching spikes may have the full control-voltage step amplitude and constitute very annoying interference which can trip signal-circuit comparators and may even overload amplifiers in low-voltage signal circuits. In capacitive signal-load circuit, switching spikes are integrated into steps (Sec. 5.8).

Reducing the coupling capacitance  $C_C$  will make switching spikes shorter but not smaller. Spike amplitudes can be reduced by increasing the signal load capacitance or by otherwise reducing the frequency response of the signal circuit, if this is compatible with signal-bandwidth requirements.

### 5.3 DIODE SWITCHING CIRCUITS

Figure 5.3 shows a variety of *diode switches (diode-bridge switches)*. Figure 5.4 presents simple diode equivalent circuits in the ON and OFF conditions. Diode switches are perhaps the simplest electronic switches and can be quite fast. It is best to employ modern fast-recovery, low-leakage silicon-junction diodes in matched monolithic sets. The leakage capacitance  $C_{OFF}$  in Fig. 5.4 can be less than 2 pF,  $R_{OFF}$  is greater than 100

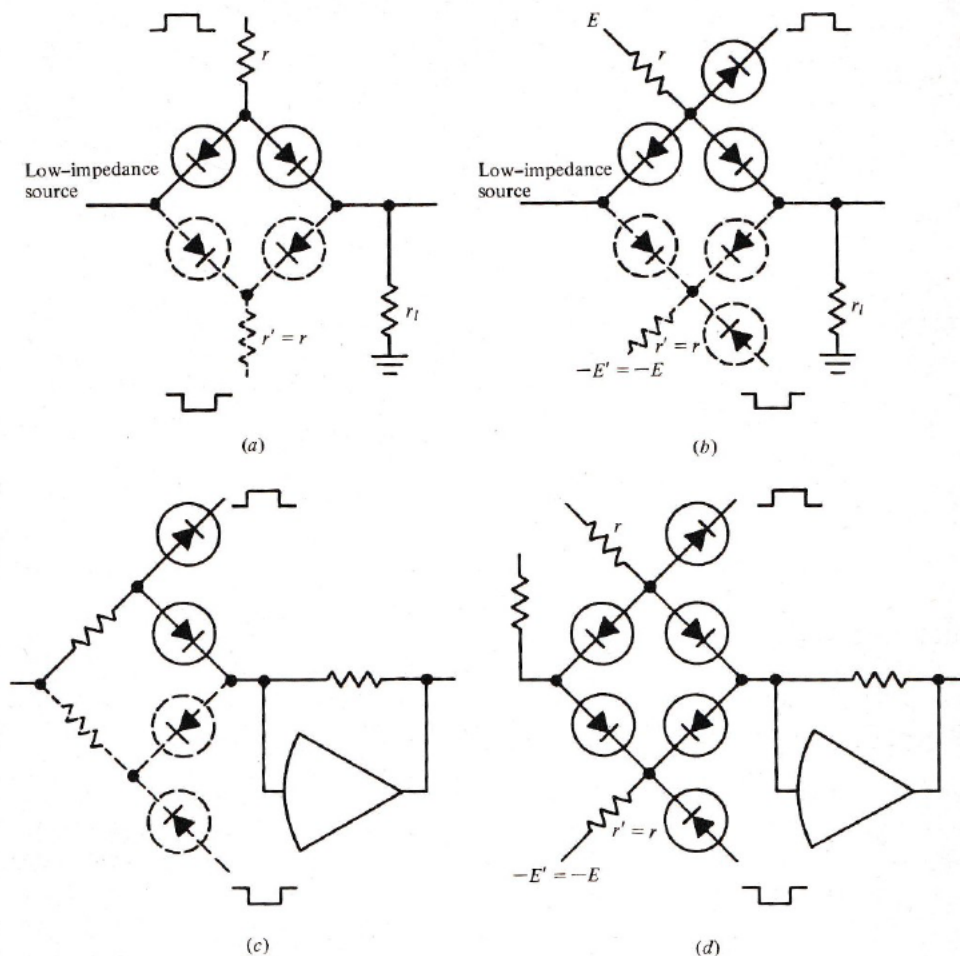


FIGURE 5.3

Diode bridge switches;  $r_L$  can be an operational amplifier input resistor. Circuits (b), (c), and (d) combine shunt and series switching and turn OFF quickly. In (a), (b), and (c), half of each circuit can be used to switch positive input voltages (solid lines) or negative input voltages (dashed lines). But this interferes with pedestal-free control-current returns, and the offset-voltage and leakage cancellation makes the full bridge desirable even with input voltages of one sign. Circuit (d) does not permit half-bridge operation and requires careful balancing of  $E/r$  and  $-E'/r$  to minimize offset in the ON condition (based on Ref. 1).

$M\Omega$ , and  $R_{ON}$  will be 25 to 50  $\Omega$ . Unfortunately, diode characteristics (see also Chap. 4) imply an *offset voltage* of about 0.6 V when the diode is ON and an *offset current*  $I_0$  when the diode is OFF. The offset voltage rises with temperature by 2 to 3 mV/ $^{\circ}\text{C}$  and can be canceled in matched diode-pair circuits. The small leakage current, typically 0.1 to 2 nA at room temperature, doubles every 7 to 10 $^{\circ}\text{C}$ .