

# Coupling Capacitors

## 1 AC Coupling

AC Coupled signals<sup>1</sup> pass through a classic RC high-pass filter as shown in Figure 1. Some amount of signal degradation also occurs, as shown. The time constant of the RC filter determines the amount of 'decay' in the signal. A design target may be that the maximum signal decay be 10% for a given frequency of operation. The value of R is usually constrained by the construction of the printed circuit board which has a characteristic impedance. The value of R is picked to match this impedance, and it will usually be somewhere near 50 ohms, which is assumed here. This leaves us with the value of C which can be chosen to minimize signal degradation for an expected operational frequency  $f$ .

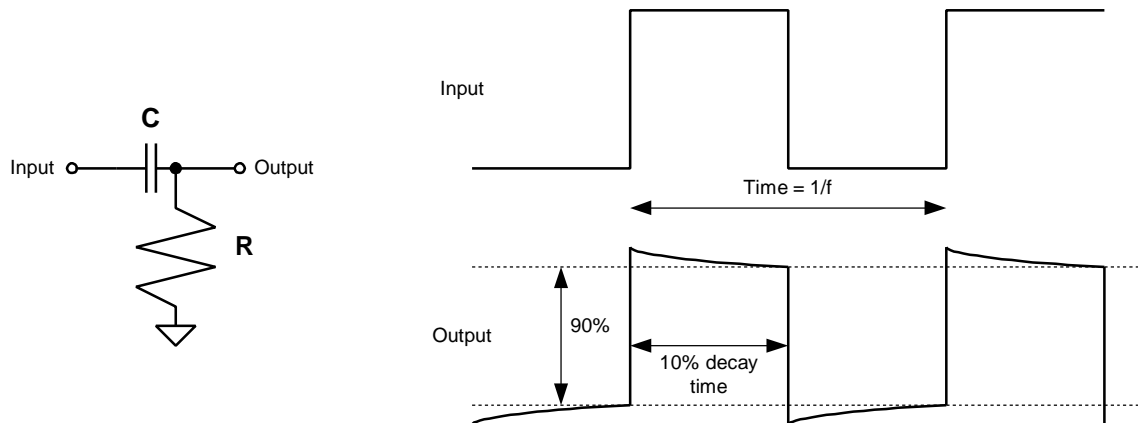


Figure 1: High pass filter defined by AC coupling capacitor and termination resistor.

## 2 Scalability: Capacitor Size Versus Frequency

The chart shown in Figure 2 shows signal decay versus time normalized into time constants. (Note the semi-log scale.) After one time constant, only about 37% of the original signal remains. To achieve the goal of 10% maximum degradation, we need a time constant of 0.1 from the chart.

From Figure 1 again, we see we need to assure this degradation occurs within a half-cycle of frequency  $f$ , so we have  $RC * 0.1 = 1/(2*f)$  which can be solved:  $C = 5 / (f * R)$ . Thus for a given frequency  $f$  (and  $R = 50$ ) we can calculate the required minimum capacitance needed to assure at most a 10% degradation of signal. This relation is shown in the chart in Figure 3 which is plotted with logarithmic scales on both axes.

The frequency range for  $f$  runs three decades from 10 MHz to 10 GHz. Capacitance varies over four decades from 10 to 10,000 picofarads. The 10 MHz value is in the range of clock frequencies used by Boundary-Scan ATE equipment. When Boundary-Scan is executing, we

<sup>1</sup> We are considering *test* waveforms transmitted on a high frequency path, that are square waves with frequency  $f$ . Data waveforms may contain a limited number of contiguous 0s or 1s that are rectangular. Data may be transmitted at GHz rates while testing may be conducted more slowly. The widest part of a data rectangle may have a period similar to a test waveform. While  $f$  may be lower than the data rate, degradation considerations could be similar.

could expect to see TCK-based square waves in the 10 MHz range for capable ATE. This would require 10,000 pF coupling capacitors. As we scale mission frequencies higher, we can use smaller capacitors, which could be integrated into IC packages or even onto silicon. However, test frequencies will need to scale to support this. For example, a 500 pF capacitance would support a 200 MHz test frequency.

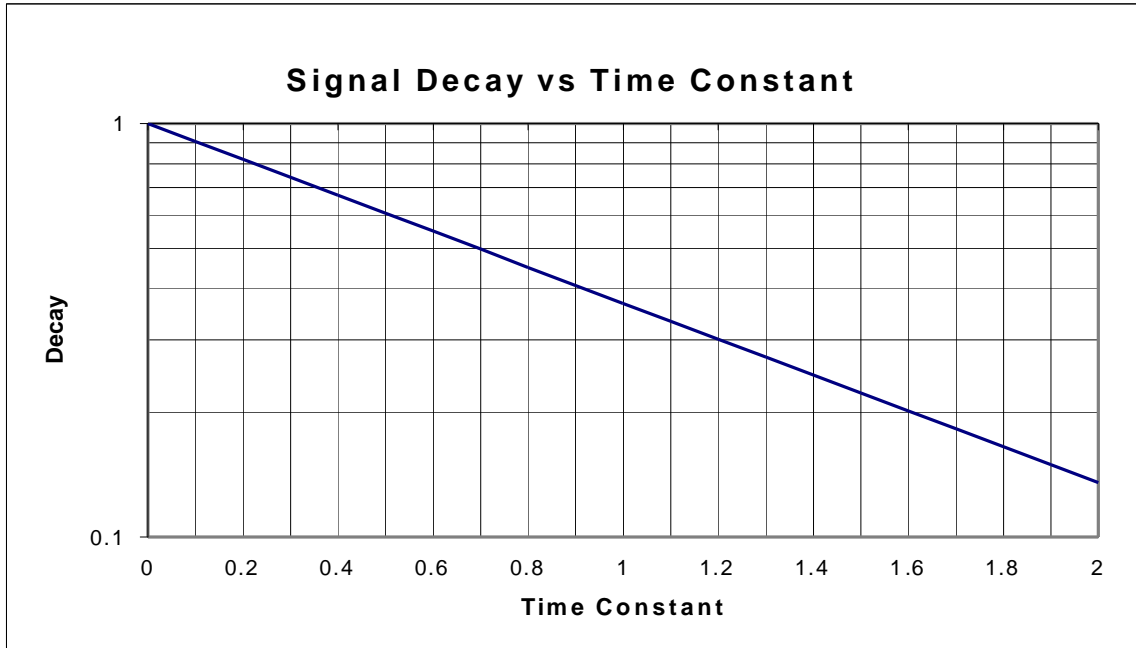


Figure 2: Decay of capacitor charged by a step function, versus time measured in time constants.

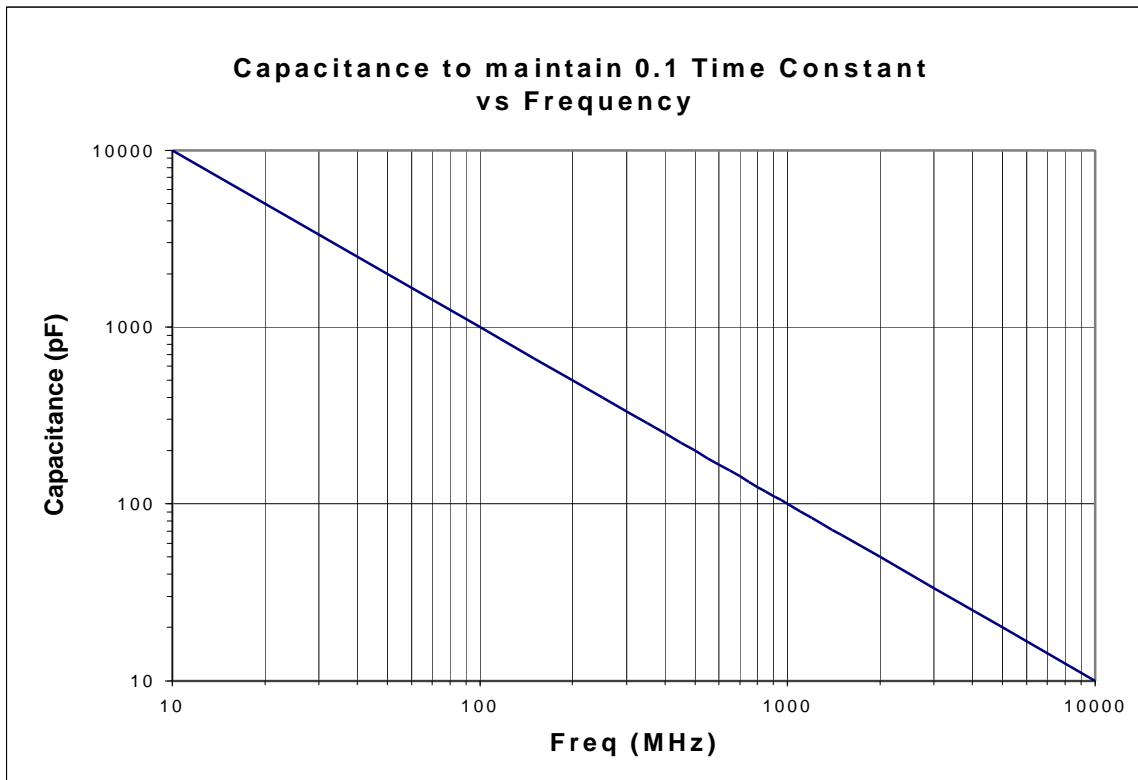


Figure 3: Minimum capacitance needed to assure =10% decay versus frequency.