DECAGON DEVICES

Capacitance and TDR Probe: Differences?

Capacitance and TDR techniques are often grouped together because they both measure the dielectric permittivity of the surrounding medium. In fact, it is not uncommon for individuals to confuse the two, suggesting that a given probe measures water content based on TDR when it is actually uses capacitance. With that in mind, we will try to clarify the difference between the two techniques.

The capacitance technique determines the dielectric permittivity of a medium by measuring the charge time of a capacitor which uses that medium as a dielectric.

We first define a relationship between the time, t, it takes to charge a capacitor from a starting voltage, Vi, to a voltage V, with an applied voltage, Vf

$$\frac{V - V_f}{V_i - V_f} = e^{-\frac{t}{RC}}$$

where R is the series resistance and C the is capacitance (Fig. 1).

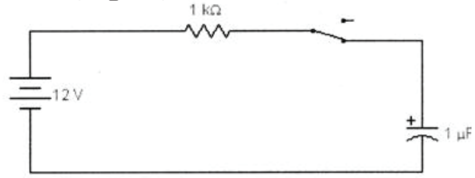

Fig. 1. Simple capacitor circuit.

The change in voltage across the capacitor over time, is illustrated in Fig. 2. If the resistance and voltage ratio are held constant, then the charge time of the capacitor, t, is related to the capacitance according to

$$t = -RC\ln\left(\frac{V - V_f}{V_i - V_f}\right).$$

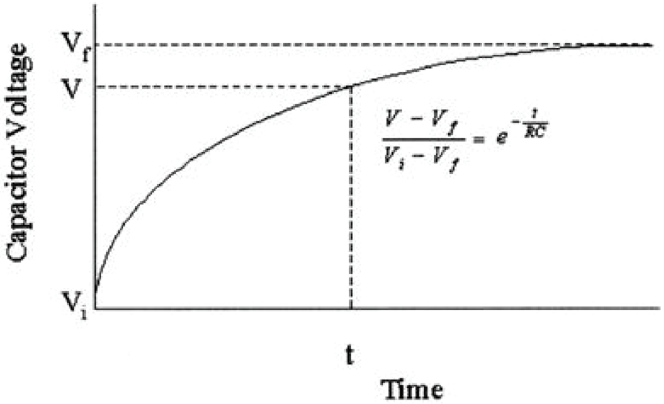

Fig. 2. Charging of capacitor when switch in Fig. 1 closes.

For a parallel plate capacitor, the capacitance is a function of the dielectric permittivity (k) of the medium between the capacitor plates and can be calculated from

$$C = \frac{\kappa A}{S}$$

where A is the area of the plates and S is the separation between the plates. Because A and S are also fixed values, the charge time on the capacitor is a simple linear function (ideally) of the dielectric permittivity of the surrounding medium

$$\kappa = \frac{t}{\frac{RA}{S}\ln\left(\frac{V - V_f}{V_i - V_f}\right)}.$$

Soil probes are not parallel plate capacitors, but the linear relationship shown in Eq. [4] still holds.

Time domain reflectometry (TDR) determines the dielectric permittivity of a medium by measuring the time it takes for an electromagnetic wave to propagate along a transmission line that is surrounded by the medium. The transit time (t) for an electromagnetic pulse to travel the length of a transmission line and return is related to the dielectric permittivity of the medium, k, by the following equation

$$t = \frac{2L\sqrt{\kappa}}{c}$$

where L is the length of the transmission line and c is the speed of light in free space (3 x 108 ms-1). Thus, the dielectric permittivity is calculated

$$\kappa = \left(\frac{tc}{2L}\right)^2.$$

The dielectric constant is therefore proportional to the square of the transit time.

Printed in USA

05-26-15