PUT YOUR

Digital capacitance meters do a lot more today than just measure capacitor values!

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CAPACITANCE METERS HAVE BEEN around for decades. Surprised? The hullabaloo in the last year or so over the new wave of digital capacitance meters makes them seem like the newest instrumentation available, but capacitance has needed measuring for lots of reasons for a long, long time.

Believe it or not, measuring the value of capacitors *isn't* the most useful function a capacitance meter can be put to.

History

In the past, many schemes have been used to measure capacitance. Capacitance has been determined by calculations of the surface area (A), of metal plates, the dielectric constant (K) of an insulator, the distance (d) between plates, and the number (n) of plates. The formula, $C = \frac{KA}{d}(n-1)(0.224)$, is used to determine capacitance in picofarads for area in square inches and distance in inches.

Time and frequency measurements have been used to determine capacitance when the capacitor is placed into an oscillator or delay circuit. Another, simply implemented scheme involves passing a signal of known frequency and amplitude through the capacitor under test. Signal losses are determined through the formula for capacitive reactance, $X_c = \frac{1}{2\pi fC}$ and knowledge of the design of the attenuator path. And, of course, precision bridges are an excellent way to measure a wide range of capacitance values with high accuracy.

Today's digital capacitance meters use analog-to-digital conversion techniques. The basic task is to measure the time that it takes to charge a capacitor to a known voltage through a known resistance.

Why measure capacitance?

For most applications, the exact value of a capacitor doesn't matter. You've heard that valid piece of advice many times by now, no doubt. So why not just take what the capacitor is labelled with to be its actual value and forget it?

Many times you can, but not always. For AC coupling, for DC blocking and bypass applications, for power supply filters, for deglitchers—no problem. But for notch filters, bandpass filters, band-reject filters, phase-shift oscillators, single-sideband quadrature filters, oscillators, neutralizing, tuning, and many other applications, precision becomes more of a necessity than a virtue.

In many applications, while the precise capacitance value doesn't make a great deal of difference, it's important to *match* capacitances.

How tolerant should you be?

Capacitor tolerance, usually expressed as a *percentage* value, is usually specified either by design rules-of-thumb or the specific criteria of a given application.

A .001 µF ceramic, for example, might well be offered by a manufacturer with a −20%/+80% tolerance—meaning that its actual value could be anywhere between .0008 and .0018 µF and still meet its specifications.

The circuit you need it for, on the other hand, may require .001 µF ± 1%. Buying a 1% cap can be both expensive and frustrating. It's much easier to survey the capacitors you have on hand. First, set yourself some limits:

$$\text{Limits} = (\text{Target value}) \times \left(1 \pm \frac{\text{percentage}}{100}\right)$$

Similarly, you can determine within what tolerance of its nominal value any given capacitor is by calculating:

$$\%\ \text{Tolerance} = \frac{(\text{Measured} - \text{Nominal value}) \times 100}{\text{Nominal value}}$$

Measuring temperature

Of course! Capacitors are available with stated temperature coefficients, stated as parts-per-million-per-degree-Centigrade. Normally, not even the newest digital capacitance meters could take care of measuring the small capacitance change produced by small changes in temperature; there is, however, a range of temperature coefficients between 500 and 1000 that permit some of today's more accurate instruments to measure temperature changes of just a few degrees accurately and repeatedly.

Note that to work effectively, the capacitor would have to be used as a transducer in conjunction with a cable no more than a few feet in length, calibrated at a known temperature (or a few), and the instrument itself (which may or may not be temperature-tolerant in terms of its own accuracy) thermally

CAP METER TO USE

isolated or separated from the capacitor/transducer.

The cable length, of course, contributes some capacitance to the measured total.

Capacitances that are not capacitors

We are very used to thinking of capacitance solely in terms of its manifestation in capacitors. But capacitance is an electrical characteristic arising out of physical laws, while a capacitor is simply a component.

Theoretically, all conductive surfaces not electrically connected to each other exhibit capacitance between each other. In practical terms, many things have capacitance:

Cables; adjacent printed-circuit traces, on either side of the printed circuit board; switches; relays, including reed relays; microphones; quartz crystals; semiconductor junctions; neon lamps; antenna-ground systems; adjacent windings of a coil (even though electrically connected at DC, there is a substantial potential difference between windings at RF); connectors; liquid crystal displays, and more.

While capacitance is not the primary, most sought-after, characteristic of these components, the fact that they have capacitance which we have a newfound capability to measure is of substantial value to us.

Measuring cable capacitance

The fact that an open pair of conductors in a cable exhibits capacitance leads to an invaluable collection of cable-troubleshooting techniques.

First, the capacitance for a number of standard cables, such as coax, twin-lead, and ribbon cable, is an integral part of their specifications. That value is expressed in various ways, such as in terms of capacitance-per-meter, capacitance-per-foot, capacitance-per-mile or some other convenient capacitance-per-unit-length expression.

But even without access to the published data, that information can easily be determined for any cable, using your capacitance meter, with this relationship:

$$\text{Capacitance per-unit-length} = \frac{\text{Measured capacitance}}{\text{Number of units of length}}$$

As you will see in a moment, determining that value for each cable you commonly use can be a tremendous aid.

Determining cable length

Imagine having a huge spool of wire—

TABLE 1

DIGITAL CAPACITANCE METERS—A REPRESENTATIVE SAMPLING

Manufacturer	Model	Range	Best Accuracy	Price
B&K-Precision Dynascan Corp. 6460 W. Cortland St. Chicago, ILL 60635	820 830	0.1 pF-1 farad 0.1 pF-199,900 μF	0.5% 0.2%	$140 $199
CIRCLE 92 ON FREE INFORMATION CARD				
Continental Specialties Corp. 70 Fulton Terrace New Haven, CT 06509	3001	1.0 pF-199,900 μF	0.1%	$250
CIRCLE 93 ON FREE INFORMATION CARD				
Data Precision Corp. Electronics Ave. Danvers, MA 01923	938	0.1 pF-1,999 μF	0.1%	$149
CIRCLE 94 ON FREE INFORMATION CARD				
Optoelectronics, Inc. 5821 N.E. 14th Avenue Fort Lauderdale, FL 33334	CM1000A	0.1 pF-10,000 μF	1%	$200 (Assm.) $150 (Kit)
CIRCLE 95 ON FREE INFORMATION CARD				
Sencore 3200 Sencore Drive Sioux Falls, SD 57107	CA55	1.0 pF-200,000 μF	1.0%	$495
CIRCLE 96 ON FREE INFORMATION CARD				
IET Labs, Inc. 761 Old Country Rd. Westbury, NY 11590	CM-500	1.0 pF-200,000 μF	0.1%	$299
CIRCLE 97 ON FREE INFORMATION CARD				

say telephone cable, on a spool big enough to be a college dormitory's prize coffee-table—and not knowing how much is there.

Imagine stringing intercom cable through a building and not knowing which of two cable ends goes all the way across the building, and which to the next room.

Ah, but you do know, given the capacitance-per-unit-length of the cable and your trusty capacitance meter.

Once again, the calculation is easy enough for the simplest of four-banger calculators:

$$\text{Cable length} = \frac{\text{Measured capacitance}}{\text{Capacitance-per-unit-length}}$$

Since the capacitance per-unit-length for most cables is relatively small, and the range of capacitance measurable with most capacitance meters extends quite high, the problem of very long cable lengths may be solved accurately by using that method.

Inspecting for cable flaws

The third arrangement of our basic relationship is especially useful.

A cable of known length and capacitance-per-unit-length can be inspected for open, shorted, or physically distorted conductors with a capacitance meter. Simply, the actual measured value of capacitance is compared to the value determined by:

$$\text{Capacitance} = (\text{Cable length}) \times (\text{Capacitance per-unit-length})$$

Here's how to interpret the results. A capacitance reading lower than the calculated value indicates either an open (or broken) conductor or severe stretching. Generally, a reading only a *little* lower than the calculated value shows stretching; a reading a few percent or more lower usually indicates a break.

The distance to a cable break can also be determined by calculating for cable length.

A capacitance measurement reading higher than the calculated value indicates a short—even a short of significantly high impedance—or insulation failure somewhere within the cable, or severe crimping. Unauthorized taps into a cable would also result in a higher-than-calculated reading.

DETERMINING VALUES of ordinary capacitors is only one of the many uses of these versatile meters, such as the model *830* shown above from B&K—Precision, Dynascan Corp.

Printed circuits

Under the banner of "good technique," we've been told how to design our printed-circuit board layouts to reduce a number of problems, most of which boils down to unintentional capacitive coupling: They include ringing, spurious oscillation, propagation delays, phase shifting, frequency shifting, unwanted pick-up of signals, cross-talk, noise, loading factors, and more.

Obviously, if the design-frequency criteria are known, a circuit's tolerance for additional, incidental, or stray capacitance can be calculated. And an actual PC board can be inspected with a capacitance meter even before parts are mounted to see whether or not the specs are met.

Other components

We have mentioned a number of "other" components that have capacitance. Capacitance measurements can be performed on those components for either of two broadly defined reasons.

First, capacitance measurements are a jim-dandy way of determining a component's suitability for application at a given frequency, using capacitive reactance as the key. For example, while you might use a reed relay at DC, would you use it at HF? VHF? UHF? Sure, it depends on how you're using it and what the circuit and the signal are; but you can save yourself a lot of trial and error—and error and error—with a little preliminary measurement and calculation up front.

DIGITAL CAPACITANCE METERS come in a variety of sizes. This one, the Data Precision *938*, fits in your pocket.

Second, since capacitance varies with geometry, as we've seen at the beginning of this discussion, capacitance measurements can be used, either directly or indirectly, to determine whether or not a given component falls inside or outside of tolerance for given specifications, such as arcing point voltage (determined by spacing between electrodes), capacitive loading (encountered in TTL, CMOS and other IC technology) and more. Membrane switches and liquid-crystal displays are two excellent examples of components that can be "inspected" with a good capacitance meter.

Checking insulators

Remember our basic capacitance formula? For a simple capacitor of two plates, it reduces to $C = 0.224 \frac{KA}{d}$

Want to determine the dielectric constant of a given insulator? Build it into your own capacitor. The dielectric constant of air is either 1 or close enough to be considered 1. So two plates of known geometry (or, as we'll see in a moment, undetermined geometry) and separation will have different capacitance values with materials other than air between them. As a result, the ratio of those values to the value with air between yields the dielectric constants for these materials.

Want to try for yourself? Start with a piece of window glass and two pieces of coated PC stock. You should get a K for window glass of about 8.

By the way, in applying the formula with unequally sized plates, it's best to use the smaller area in your calculations; also, where the plates are not precisely opposite each other, use the overlapping area.

Capacitive transducers

General Motors recently announced developments in tranducer technology for monitoring critical carburetor adjustments, and for determining the fuel level within a tank.

The transducers in both of those cases were capacitors.

Obviously, since capacitors don't require (in fact, forbid) contact between their terminals, they are a natural choice in selecting transducers that will provide consistently accurate performance over extended use and they'll exhibit little or no wear.

You can make your own capacitive transducers, and check their performance characteristics and actual capacitance values with your meter.

For rotational (or angular displacement) measurements, try coupling to the shaft of an old tuning or trimming variable capacitor.

For linear motion, parallel plates or concentric tubes do quite well. For example, you could use a piece of PC board (say 12 × 12 inches) glued to the underside of a drawer as one plate of a capacitive transducer, and a second piece of PC board, foil side down, at the bottom of the drawer's cavity as the other. An RF signal coupled between them could hold in a relay (through a transistor). Sliding the drawer open would reduce the coupling, thus allowing the relay to drop out and sounding an alarm.

In fact, a cheap capacitor microphone will demonstrate changes in capacitance with air pressure, providing an easy and quick-responding barometric transducer.

The more you play the game, the more you'll learn. **R-E**