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# Capacitance-Box Applications

NOW THAT YOU HAVE BUILT THE CAPACITANCE SUBSTITUTION BOX (C-BOX), YOU ARE READY TO START USING IT TO TEST ACTIVE AND PASSIVE CIRCUITS. TO GET YOU GOING, THIS MONTH I AM GOING TO PRESENT SOME EXAMPLES OF HOW you can put the box to work.

If you do any amount of circuit designing, you will find surely find the C-Box to be a handy test-bench accessory. That's because while any designer who knows what he is doing can use standard formulas to calculate any needed values, there is nothing like a real in-circuit trial to prove the theory.

Of course, using mathematics is certainly the right way to start the design process. But once the values have been calculated, it is important to build a working prototype of the new circuit. I have been fooled in the past, when something that I calculated did not work as planned. Test and measure is always a very good idea and good advice.

To illustrate what I consider to be the proper design procedure, let's consider the circuit shown in Fig. 1. The design equations we will be using are also shown in that figure.

The first thing we will be looking at is the effect changing a capacitor will have on the audio signal. Capacitor C1 is used to set the low-frequency point in the circuit. Take a look at Equation 1. It is the design formula used to determine frequency when the resistance and capacitance are known, and it is no doubt familiar to almost anyone who has studied even a little electronics math. The problem is that the equation is not in the most convenient form for our exercise as the unknown we are looking for is the capacitance. Fortunately, that is easy enough to fix; a little algebra allows us to rearrange the terms and gives us the formula shown in Equation 2. Since the lowest frequency of interest is 20 Hz and the impedance (resistance) is 100k, we can plug in those values to find that the capacitance needed to establish our -3-dB point is 79.57 nF.

Now let's see how this calculation works in the real world. Insert the C-Box in place of C1 and wire the rest of the circuit in the usual way. Set the C-Box to 79.57 nF. To do that, start with all of the buttons in the up position. Then depress the 4 button in the 10-nF column and then the 3 button in the same column. The next step would be to depress the 4, 3, and 2 buttons in the 1-nF column. Now push in the 4 and 1 buttons in the 100-pF column. For the final digit depress the 4 and 3 buttons in the 10-pF column. That should set the capacitance to 79.57 nF ± 1%.

Now, place a 20-Hz tone between C1 (the C-Box) and ground and measure the signal at the output of the first op-amp. If all is well, the output will be down 3 dB (the signal voltage will be reduced in half).

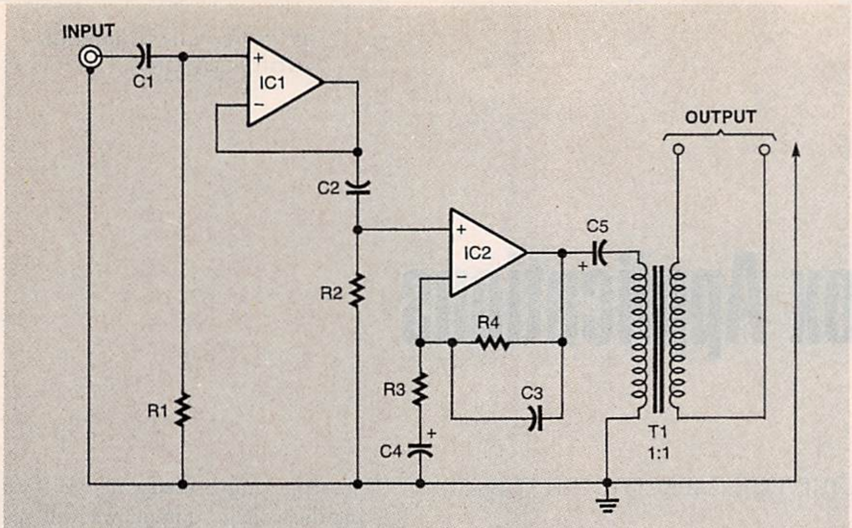
Now that we have confirmed that the real result matches the calculated one, let's try something different. Let's assume that we decide that the output should be flat at 20 Hz. That means that the -3-dB point must be moved to a lower frequency. The problem here is that we do not know what that frequency should be. But we can use the C-Box to easily solve this problem.

The same setup is used as above. If we look at the voltage output, we will see that it decreases as the value of capacitance increases. You can push the switches on the C-Box in and out and watch what happens at the meter. How close you get to a 0-dB loss is entirely up to you, the designer. I have found that replacing the 2 in the formula with a ¼ is a good way to start, though that is just my rule of thumb. If you do the calculation, to get a 0-dB loss you will come up with a value of 636.61 nF for C1. Of course, we cannot replace the C-Box with a capacitor of that exact value at a reasonable cost. The tolerance of the capacitor we do use will determine the exact value. For example, a 1-mF-electrolytic capacitor with a 20% tolerance will work well. Be sure to observe the proper polarity when installing the capacitor.

## The High-Frequency End

The next capacitor to look at would be C3. It limits the high frequency of the op-amp system. The op-amp may be able to pass frequencies above 20 kHz, but there is little practical need for information above that frequency. As such, a good -3-dB point could be 30 kHz. Again use Equation 2 to solve for the needed value. Assuming a frequency of 30 kHz and a resistance for R4 of 100k, the answer is $53.05 \times 10^{12}$, or 53.05 pF. You cannot get that exact value with the C-Box. The closest value that you can get is 50 pF. Set up the C-Box for that value and test the circuit at the point where C5 connects to output of the IC2.

Next, set the audio oscillator to 30 kHz and put the level at +4 dBm. You should read a voltage of 1 dBm. Now look at the output when the frequency is set at 20 kHz. The voltage should be +4 dBm. If this is satisfactory, then you have




EQUATION 1: $f = \frac{1}{2\pi RC}$

EQUATION 2: $C = \frac{1}{2\pi f R}$

EQUATION 3: $g = 1 + \frac{R3}{R4}$

EQUATION 4: $20\log(dB) = 1 + \frac{R3}{R4}$

**FIG. 1**—HERE'S THE CIRCUIT WE'LL BE USING to demonstrate one of the best uses of the C-Box, which is to verify the capacitor values that are obtained using the standard design equations.

made a good choice. If not, you must use a lower value of capacitance. You might try designing for 40 kHz. Then the capacitance value will be 39.78 pF (use 40 pF). Continue to take readings and experiment with values until you are satisfied.

### Setting The Low Frequency

The next capacitor in Fig. 1 that we need to look at is C4. It sets the low frequency of IC2. We will use Equation 2 again to calculate the value of the capacitor. But first we must calculate the value for resistor R3, which sets the gain of that op-amp. To do this we need to use Equation 3, or, if we already know the gain (specified in dBs), Equation 4. For this example, I selected a gain of 14 dB, and once again assumed a value of 100k for R4. That yields a resistance of 24,937 ohms for R3. For the sake of reality, use 24k. Plug that value into Equation 2, along with the frequency of 20 Hz, and your solution should be 331.5 nF.

Try that value in a real circuit and see how it works. Again, that is the -3-dB point. As resistance increases, the -3-dB point moves to a lower frequency. The exact value that you chose will depend on the use of the circuit. Use the C-Box to try different values and see what happens.

The final component that we will be dealing with in this circuit is C5, the output capacitor. That capacitor limits the low-frequency value. The only other factor that you do not know from Fig. 1 is the load impedance into which this circuit will work. Let us make two assumptions. First let's assume that the load impedance will be 600 ohms. Then let's look at a second load impedance at 10k. Again assuming a -3-dB point of 20 Hz, for the 600-ohm impedance the answer is 13.26 mF. As that value is out of the range of the C-Box, let's try 40 Hz instead of 20 Hz. That yields 6.63 mF, which can be set in the C-Box without any problems.

Now let's investigate an output impedance of 10k. Again use Equation 2 to solve for C. The answer is 795.7 nF. That value is easy for the C-Box. You might have noticed that the higher the impedance the lower the capacitor value. Knowing the load impedance with this capacitor is quite important. With this circuit you can investigate the effects of the capacitor on the frequency response. It will be a great learning experience for those of you that have not done this kind of work before. Practice makes perfect; experiment often and you will eventually be able to do this by instinct. EN

## NEW PRODUCTS

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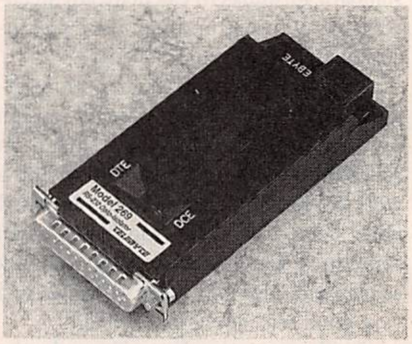
## Optoisolation Unit

The continual appearance of new government regulations worldwide causes havoc with equipment suppliers. IEC 601-1 invokes higher limits of isolation for electronic equipment used in medical environments. That requirement led to Telebyte's development of the Model 269, IEC-compliant, Optoisolator.

Designed for medical electrical equipment, the Model 269 is a compact RS-232 to RS-232 optoisolation module that withstands 4000 volts AC for one minute and provides that level of isolation for the TD (Transmit Data), RD (Receive Data), and ground RS-232 signals.



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The primary RS-232 port is a DB-25 male connector, which may be configured via switch selection as a DTE or DCE device. The secondary port is configured in an RJ-12 six-position modular jack with pins 3, 4, and 5 being Transmit Data, Receive Data, and Isolated Ground, respectively.

Packaged in a plastic case that measures 2 by 4.1 by 0.75 inches, the Model 269 retails for $120.

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