THINK TANK

By John J. Yacono

Multiplexing With Counters

A new month is here and with it a batch of creative ideas from you readers. You've been most generous with your correspondence this time out, thank you. As always, the people submitting to this month's column will receive a copy of *Think Tank II*. If you've already received that fun and useful book, we'll find something else to send you.

I would also like to hear from those of you that have some ideas about what you would like to see in this column. As you know, I like tinkering with circuits myself, so if you have a question regarding a circuit that you've come across, or perhaps you need general information on a topic just ask it. I'm here to both help budding "circuiteers" and present their circuits.

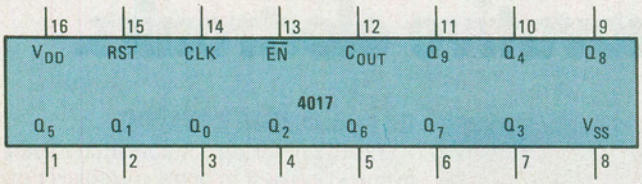

Fig. 1. The lowly looking 4017 decade counter can do much more than you may think. It can divide by 1–10, count, and even run a multiplexed display.

THE HUMBLE 4017

With that in mind, I'd like to discuss a very inexpensive chip and show you a number of interesting uses for it (including one that's not in the data books). It's the 4017 decade counter (shown in Fig. 1). At first glance, the application notes won't lead you to believe that it's a powerful contender for breadboard space. But after a short introduction, we'll see what it can do when you take the notes a step further.

Most of you readers are probably familiar with integrated-circuit counters of one sort or other. The vast majority of them count in either binary or binary-coded decimal. What that means is their outputs represent a number in binary or binary-coded decimal; each time such a chip receives a pulse, it increments the value available from the outputs. That more or less restricts their use to simple counting—not exactly a vista of toe-curling applications.

On the other hand, the 4017 counts by ten. It has ten outputs assigned values 0 through 9. When first turned on, the 0 output (denoted Q_0) is high and the other nine outputs are low. When a clock pulse is received (via the CLK pin), the Q_0 output goes low and the Q_1 output goes high. On the next pulse, Q_1 goes low again and Q_2 goes high. Each time a pulse is received, a high will appear at the next highest output. It's as though the high gets pushed from one output to the next with each clock pulse.

When the high is at Q_9 (the last or highest output), the next pulse causes the high to jump back to Q_0 and the process starts again.

The most obvious use for such a chip, besides just counting from 0 to 9, is as a light-chaser controller. If LED's or lamps were turned on (or off) in sequence by a 4017, it would give a marquee appearance to the lights. However, the chip itself cannot supply enough current to power LED's or light bulbs (although it can sink enough current if you want nine LED's on and one off). You should use transistors or relays under the control of the 4017 to supply power to your display.

But there are three other pins on the chip that make it much more useful and applicable to more interesting circuits: First, there's a clock-enable pin (denoted $\overline{EN}$ in Fig. 1). If that pin is held high, the counter ignores the clock pulses and refuses to advance. There's also a reset pin (the one labeled RST) and, as its name implies, if it is pulsed high, it puts the counter back to zero.

The last pin of interest is a carry output (C_{OUT}), which is high while the chip is counting from 0 to 4, and stays low as the count proceeds from 5 to 9. That output is useful for cascading 4017 chips (and little else as far as I can see). If you connect that output to the clock input of another 4017, the first 4017 will count in "ones" (0 through 9), and the additional chip will count in tens (10, 20, 30, etc.). Each chip you add on in that way will give the circuit the ability to count to the next power of ten.

But enough of counting, what else can one do? To help me answer that, take a look at the circuit in Fig. 2. That circuit will count from 0 to 4 and stop. To start the cycle again you have to depress S1. If you connect the clock-enable pin to a different output, the circuit will count until it sets that output high and then halt.

That kind of circuit is useful for turning on some number of devices one at a time. For example, let's say there's a long hall in your home or perhaps an office building that leads to an exit door and you don't

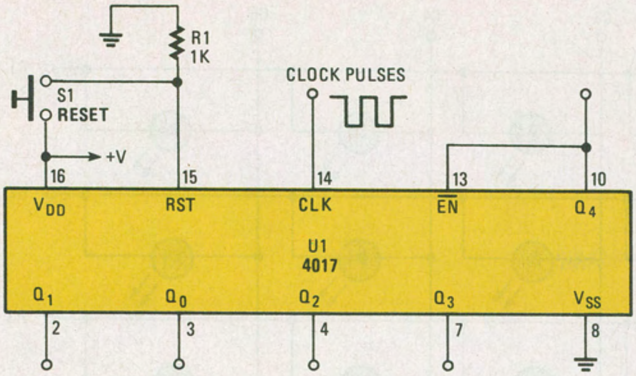

Fig. 2. By connecting pin 13 to the appropriate output, you can make a 4017 count to a one-digit number and halt.

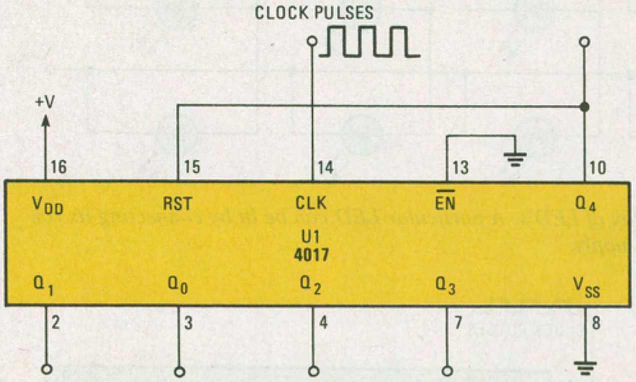

Fig. 3. By connecting pin 15 to the appropriate output, you can make a 4017 divide a series of clock pulses by a value from 1 to 10.

want to leave more than one light on at a time. You can use the circuit in Fig. 2 to sequence the hall lights on and off one at a time. To do that, you'll need a slow clock circuit to sequence the 4017's outputs at the desired rate. You'll also need some optoisolator/couplers to control the lights.

If you control the light at the exit with output Q_4, the next light down the hall with Q_3, and so on, and place S1 at the far end of the hall (away from the exit), someone heading for the exit just has to press S1. The light nearest him will come on, then the next light, and so on until the light nearest the exit is lit, and then the sequence will stop leaving the light at the exit on. Every time a light comes on, the one prior to it goes out.

Another useful circuit is shown in Fig. 3. That circuit repeats a sequence over and over. The output you connect to the reset pin determines the number of steps in the sequence. The circuit shown has 4 steps. The first three steps last for the length of one clock cycle. The last step only lasts until the chip resets itself. That is a great circuit for performing digital frequency division.

Let's say you need to measure the clock frequency of a really fast computer circuit, but you've only got an old oscilloscope with too narrow a bandwidth. Send the computer pulses to the 4017 and connect the scope to Q_0 and the positive supply. Set the scope's input to AC coupling. Now connect the reset input to Q_1. That divides the computer pulse frequency in half and the AC-coupling

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circuit in the scope should be able to integrate the wave form into something more visible (although it may not be a square wave).

If that doesn't work try connecting the reset pin to one of the other outputs (it's best to try them in order). If the duration of the negative pulse produced by the 4017 is too brief that's easy to fix: you need to tie more of the 4017's outputs to the scope. Just make sure the subscripts of the outputs connected to the scope are all less than half of the subscript of the output you connect to the reset pin. To determine the frequency, just multiply the frequency of the wave on your scope by 1 plus the subscript of the output connected to the reset pin.

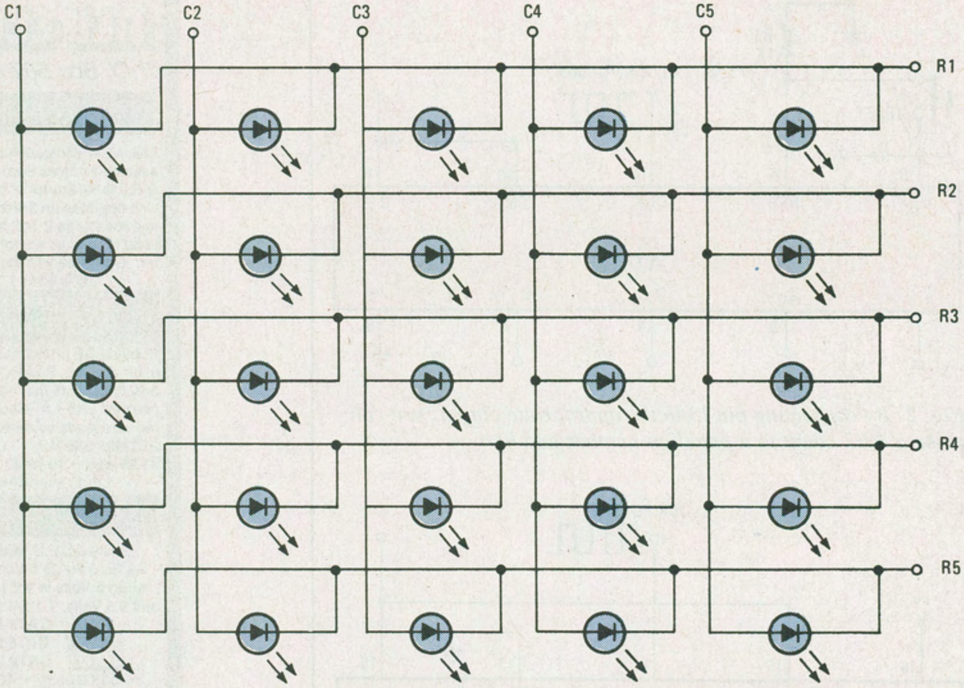

Fig. 4. This is a multiplexed display of LED's. A particular LED can be lit by connecting its row and column terminals to a power supply.

And now for a real neat application: sequencing up to 100 "multiplexed" devices with only two chips. If you haven't heard the term multiplexing don't worry: it's just a big word for a simple concept. Multiplexing is a way of wiring a number of devices together, but allows

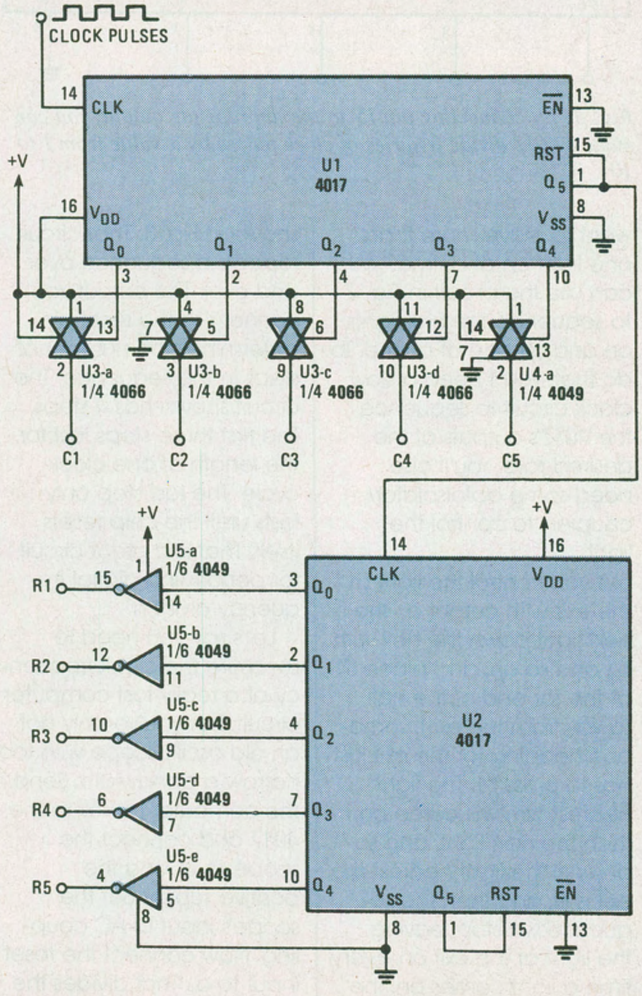

Fig. 5. Two dividing 4017's can be configured to count up to 100. The circuit shown here can count to 25.

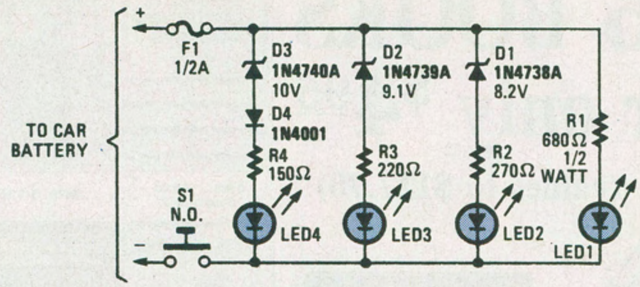

Fig. 6. This simple car-battery voltage checker can be built small enough to be installed in your car's dashboard.

them to work independently. It reduces the number of wires and components you need in a circuit, as you'll see. Take a look at the multiplexed LED's in Fig. 4. If we connect one of the column terminals (marked C_1–C_5) to a voltage supply, and one of the row terminals (marked R_1–R_5) to ground, then the LED in that row and column will light.

In that way, we can turn on any one LED from a group of 25 by just using 10 wires (5 row wires and 5 column wires). You could use that technique to control 100 LED's (or other devices) by using only 20 wires, etc. For the sake of brevity, the multiplex-control circuit (see Fig. 5) is shown set up to control only 25 devices. The two decade dividers in the circuit are both set up for divide-by-five operation using the same technique as the circuit in Fig. 3. However, U2 gets its clock pulses from the Q_5 output of U1, so U1 sequences Q_4 through Q_4 and then U2 gets its clock pulse.

Note that the outputs of U1 are used to control several bilateral switches. The switches act just like relays, although they have a little internal resistance. When an output goes high, its bilateral switch closes, connecting one of the column outputs to the power supply. For example, if Q_0 goes high, U3-a closes, connecting C_1 to V+.

The outputs of U2 are connected to inverters. When a divider output goes high, the inverter connected to it grounds the corresponding row output. For example, if Q_0 goes high, the output of U5-a goes low grounding R_1.

If you connect that circuit to the display circuit in Fig. 4 and supply it with clock pulses, it will turn on one LED at a time. First the LED connected to C_1 and R_1 is active. Integrated circuit U1 then activates C_2–C_5 in turn, while U2 leaves R_1 active. Then U2 receives a clock pulse from U1 so R_2 becomes active and U1 gets reset, so the LED in column 1, row 2 is now lit. Integrated circuit U1 will light each LED in that row, then the next row, and so on until all the LED's have been lit and the process starts over again. You can use more of the outputs on the two decade counters to control up to 100 LED's provided that you connect the reset pin to the proper output.

And now for the mail!

BATTERY-VOLTAGE INDICATOR

My circuit is a car-battery voltage indicator (see Fig. 6) that allows you to quickly check the relative health of a battery. The LED readout simplifies testing and the circuit lets you monitor the battery even under cranking conditions.

When placed across a battery's terminals and the normally open momentary

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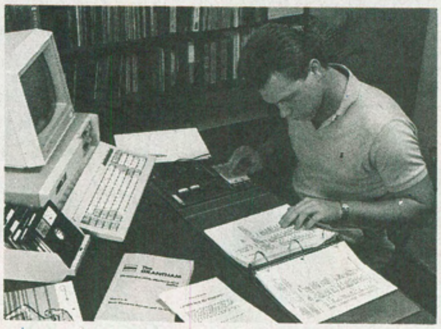

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switch (S1) is pressed, current flows through each branch of the circuit. Any voltage over two volts will light LED1. The next LED (LED2) will light if the voltage is 9 volts or greater, LED3 will come on if the voltage is over 10.5 volts, and LED4 will come on if the voltage is greater than 12.25 volts. Note that D4 prevents the branch it's in from being blown out by incorrect polarity.

Depending on the LED's that you use, you might need to place a 5k potentiometer in series with the circuit to fine-tune it.

—Mike Giamportone, Yale, MI

Nice circuit. Those of you that might want to expand the circuit can do so easily. Just use more branches and select Zener diodes rated at about 2-volts less than the voltage the branch must measure.

ANSWERING-MACHINE BEEPER

Here is another application for the much-used 555 oscillator/timer. Since my telephone-answering machine is "beeperless," I missed a few calls because I forgot to check its blinking LED. I worked out this circuit (see Fig. 7) to buzz on cue from the LED.

Photoresistor R1 is mounted directly over the answering machine's LED and surrounded by a tube made of thick black paper to keep out room light. Resistors R3 and R4 divide the supply voltage to keep pin 2 of the 555 just above the switch-over point. That assumes that R1 is getting a steady amount of light from the machine's LED. With the LED on, R1's resistance is low. If the LED goes out, R1's resistance will rise, causing a drop in voltage across R2. The drop will be fed to R5 through C2, activating the 555 monostable.

The monostable activates the buzzer for about 0.2 second. Each time the LED flashes, the buzzer sounds. Note that capacitor C1 was added to the circuit to help it avoid false activation from power-supply transients.

—Jim Drake, Albuquerque, NM

If I'm not mistaken, there was a request for such a circuit that appeared in our letters column. Circuits like this one are useful for the blind, as they turn light from indicators into sound.

I liked your use of the LM317 adjustable voltage regulator. Everyone should take note of how it is used in the power supply. If the transformer is chosen wisely, a variable power supply built with that chip would be capable of providing from 1.3 to over 30-volts.

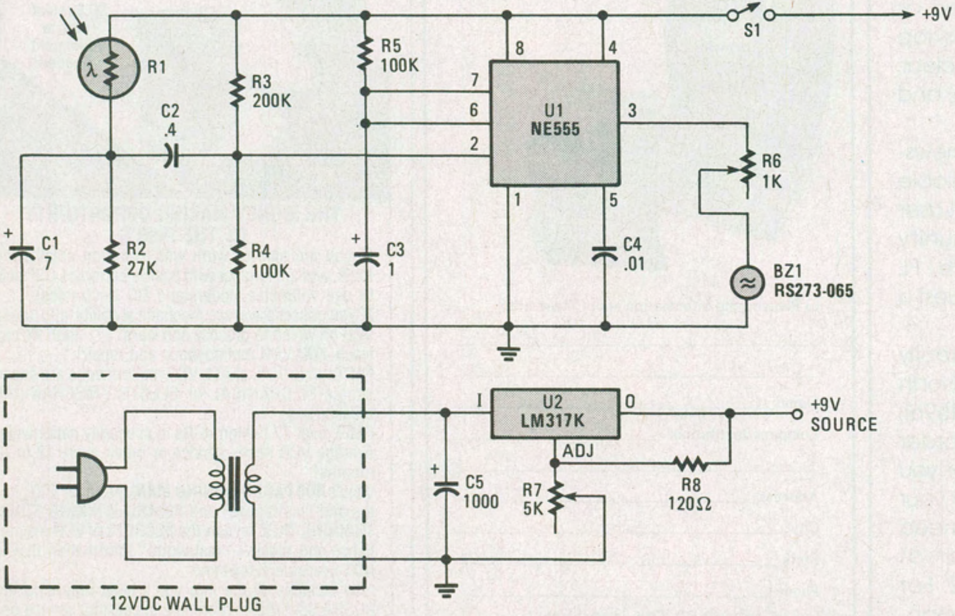

Fig. 7. This simple circuit can turn light into sound. The 555 IC is shown connected as a monostable timer that turns on a buzzer when light strikes R1.

A TIME-DELAY CIRCUIT

When I was building an alarm, I had to design some kind of exit delay. So I came up with this simple circuit (Fig. 8) to do the job. Only two parts are required: a relay and a capacitor.

When voltage is applied to the capacitor, it charges. While it's charging, the relay remains latched. When the charging current falls below the level needed to hold the relay down, the relay unlatches. The higher the the value of the capacitor, the longer the relay will remain latched.

—Ricky Furtado, Toronto, Canada

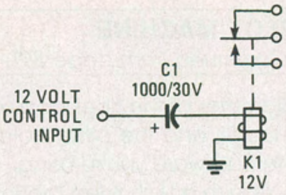

Fig. 8. This simple circuit is technically called a delay-off relay timer. The relay remains active as long as the charging current through C1 is high enough to engage the coil.

This is one I wish I had thought of. If anyone needs to figure out the time constant of the circuit, it is a little less than the capacitor's value times the resistance of the coil. If you don't know the coil's resistance, you can either measure it with an ohmmeter or divide its specified coil voltage by its coil current.

Well, it's time to close out another month. As always, you should send your contributions to *Think Tank*, **Popular Electronics**, 500-B Bi-County Blvd., Farmingdale, NY 11735. ■

CIRCUIT CIRCUS

(Continued from page 77)

AC supply—that's handy to have on the workbench. All you need is a variable 117-volt AC transformer, a power cord, fuse, switch, and an output receptacle. Wire the components together as shown in Fig. 5.

A variable AC-power source is a valuable tool to have when checking electronics gear that's been idle for years or when smoke testing a new project. It's usually a good idea to slowly bring up the AC line voltage to such equipment before attempting to use it. Try the surplus stores, flea markets, and hamfests first when trying to locate a variable transformer—a good used unit is cheaper than a new one. ■