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Design, Configure, and Create Clever Circuits

The Pragmatic Bookshelf

Raleigh, North Carolina

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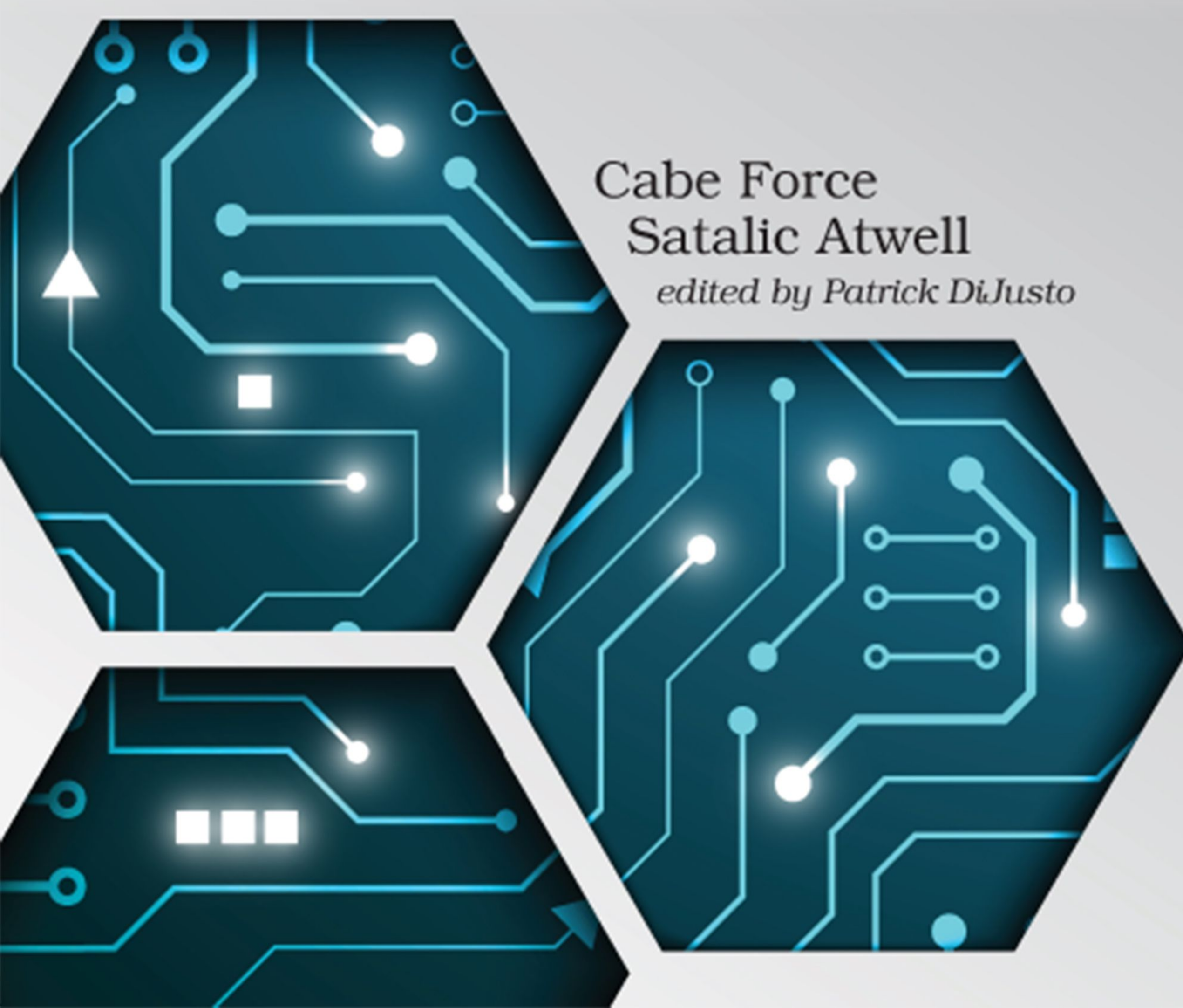

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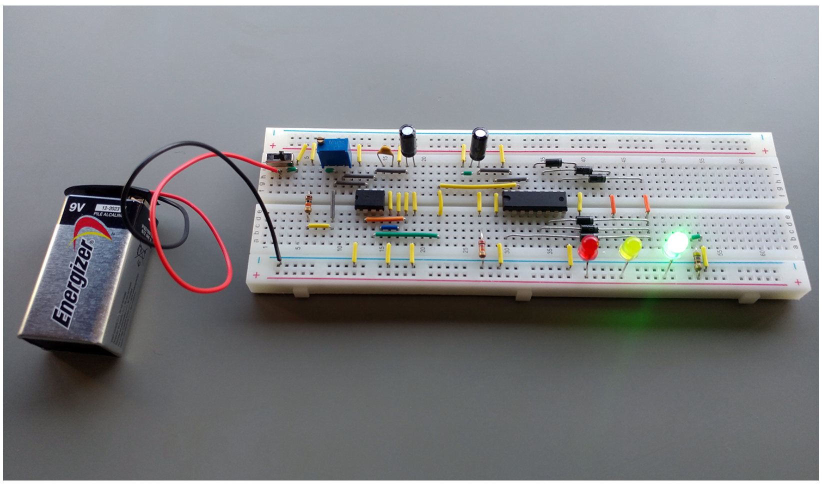
CHAPTER 4

Traffic Light Controller



Traffic light circuit giving the OK-to-drive signal

Traffic lights—known as traffic control signals—are everywhere. There are over 300,000 in the United States and millions around the planet.

> The decision to use red, amber, and green for automobile signals was an easy one—the same colors, with the same meanings, had been in use for railroad signals since the middle of the 19th century.

They tell drivers which lanes of traffic have the right of way, indicating when cars should go, slow down, and stop by lighting up indicators of universally agreed upon colors (red, amber, and green). Though they seem like complex systems, a 555 timer is a perfect device to use as the basis of a simple traffic light.

Notice we said that the 555 is "the basis" of a traffic light. A 555 is a versatile component, but sometimes you want to build a gadget to perform actions that are outside the scope of a timer, such as counting from 0 to 9. Fortunately, other integrated circuits can do just that, and they can be triggered, or controlled, by 555 timers. For this project, we're going to use the 555 timer to control another circuit. While you probably could make a traffic light system from a hodgepodge of old electromechanical circuits, this is a good point to introduce an important new integrated circuit that adds functionality to the 555 timer.

Meet the 4017 IC, also known as the CD4017, IC 4017, Counter, and Divider. It's a 16-pin CMOS Decade Counter Integrated Circuit that will make this and the next project much simpler to build. Like all ICs (including the 555 itself), the 4017 is nothing but a large collection of discrete electrical components arranged in different circuits, placed into a small silicon chip.

> If you're curious what the CD stands for in CD4017, it's sort of simple. It represents the first two words in the description of the IC, *CMOS*-Decade counter/divider. CMOS stands for *complementary-symmetry metal-oxide-semiconductor*, which is a way to make low-power transistors.

Inside the 4017 IC is a series of inverse feedback ring counter circuits, referred to as *Johnson Counters*. The ring counters are a collection of two opposing transistors and some resistors, which together act almost like a single bit computer memory. Without any electricity, the counter is set to 0. When an electrical pulse comes in, the counter is set to 1. When another electrical pulse comes in, the counter pulses the *next* counter in the circuit, setting it to 1, and sets itself back to 0. There are ten of these ring counter circuits, and they cascade from one to the other. When the tenth counter is triggered, it triggers the first counter in the series and the cycle starts all over again.

The counter circuit has two stable states, 0 and 1, and with each electrical pulse it flip-flops between the two states. In the poetic voice of the electrical engineer, such a circuit is called a *flip-flop*. Zooming in to the electrical components inside the 4017 is a great way to show how dense the IC is, which is why we use it instead of using full-sized transistors and resistors to make the circuit.

Now, think of how a traffic light works. Picture what it might be like if the green and red lights of a traffic signal were connected to the output pins of a 4017. Suppose the green light is connected to pins 0, 2, 4, 6, and 8 and the red light is connected to pins 1, 3, 5, 7, and 9. When the 4017 receives its first pulse, the green light comes on. When the second pulse comes in, the green light shuts off and the red light comes on. When the third pulse comes in, the green

> In the computing world, a counting sequence usually starts with zero.

light comes on, the red light shuts off, and so on, and so on. A traffic light is, ultimately, nothing more than a timed sequence of lights.

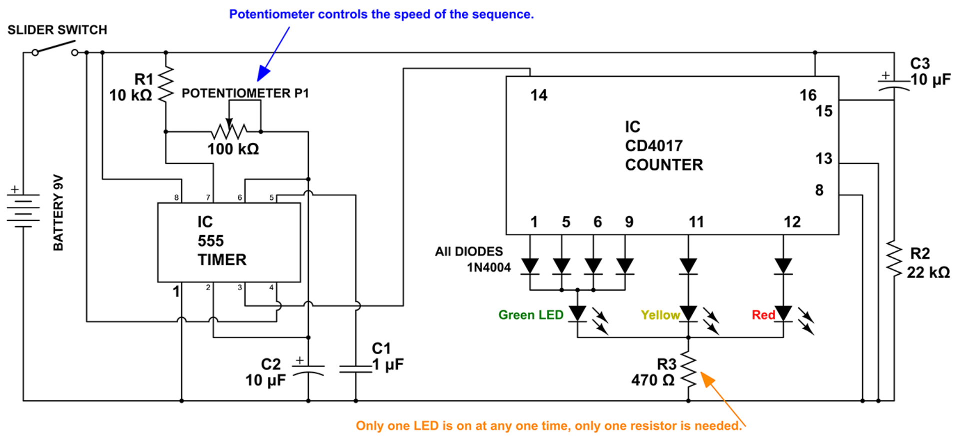
Just as the 555 timer can't exactly perform what the 4017 can, the 4017 cannot operate without an input signal. In this project, the 555 timer will provide that signal. The 555 will be placed into astable mode, producing a square wave with an exact frequency of pulses. Those pulses will control the 4017's LEDs, producing the traffic light sequence.

Parts

1x Counter ICs, CD4017	Newark part number 60K5099	
555 Timer IC	Newark part number 58K8943	
6x Schottky Diode, 1N4004	Newark part number 12T2303	
2x Red LED	Newark part number 52K5254	
2x Yellow LED	Newark part number 97K4048	
2x Green LED	Newark part number 97K4041	
330 ohm Resistor	Newark part number 28X2253	
470 ohm Resistor	Jameco part number 690785	Newark part number 58K5055
1 kOhm Resistors	Jameco part number 690865	Newark part number 38K0327
10 kOhm Resistor	Jameco part number 691104	Newark part number 58K3886
20 kOhm Resistor	Newark part number 58K5026	
100 kOhm Potentiometer	Newark part number 62J1426	
1 µF Ceramic Capacitor	Newark part number 97M4165	
2x 10 µF Electrolytic Capacitor	Newark part number 63K2677	

9 V Battery Holder/Strap	Newark part number 31C0662 or 59K0356
9 V Battery	Newark part number 81F157
2x Slider Switch SPDT	Newark part number 10X9279
1x Full-sized Breadboard	Newark part number 99W1760

The Official Schematic



The schematic shows the new IC, the 4017. Keep in mind the pins of the 4017 are not labeled in order like the 555 timer. They're labeled for convenience and to show the LEDs in a line.

A traffic light project showcases the functionality of a 4017 perfectly. It's a clever use of a straightforward signal progression through the output pins. One output after another of the 4017 is set high, lighting up green, amber, and red LEDs, and then the whole process starts over.

All ten output pins of the 4017 are labeled, from the first output Q0 to the final output Q9. Unfortunately, the pin numbers that correspond to the outputs are not arranged in a line:

Q0 = Pin 3

Q1 = Pin 2

Q3 = Pin 7

Q4 = Pin 10

Q5 = Pin 1

Q6 = Pin 5

Q7 = Pin 6

Q8 = Pin 9

Q9 = Pin 11

The mixup of numbers is due to the internal logic of the 4017 IC. When the IC was designed, it was just more convenient to lay the pins out this way, or perhaps it was just too cramped inside the 4017 to do it any other way. Whatever the reason, this *pin-out*, as it's called, is standard for this particular IC.

Note that the first 5 pins of the sequence Q0 to Q4 are not being used in the schematic or breadboard view. There's a reason, and it has to do with our strive for a simpler circuit. In the 4017, pin 12 actually outputs a logic high signal for the first five counts the chip receives. So, we can light up an LED for five counts with a single pin.

The sequence is as follows:

The first five outputs, Q0 to Q4, will energize pin 12, lighting up the red LED.

Q5, on pin 1, is the green LED.

Q6, pin 5, is also green.

Q7, pin 6, is green.

Q8, pin 9, is green.

Q9, on pin 11, is connected to the yellow LED.

So this particular traffic light is red for 5 counts, green for 4 counts and yellow for one count.

By using pin 12, we're saving components and in general simplifying the circuit. We don't *have* to do it this way to make a traffic light, but it is pretty handy. In the circuit as built, the first five pulses sent by the 555 timer to the 4017 will light up the red LED on pin 12. By wiring the project this way, we're severely reducing complexity.

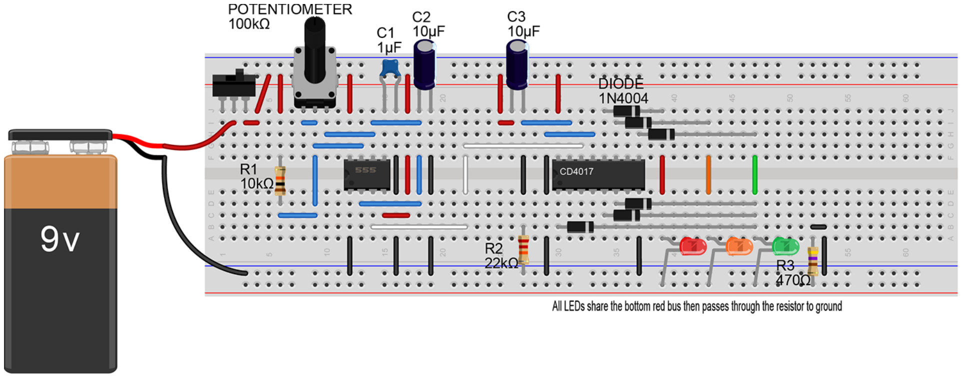
Notice also that each LED is connected to the 4017 via a diode. The diode blocks electrical signals from being fed back into the 4017 IC from other pins or sources. Feedback could damage the IC, or at least mess with the IC's operation.

Breadboard

In the schematic view, the pin connections are simplified for an easier to follow graphic. However, in the breadboard view shown in the top image on page 11, we see exactly how the components are connected to each other.

Since only one LED should be lit during the traffic light's operation, all LEDs share a single resistor. This, again, is to reduce the component count in the build. Reducing the component count will also be helpful in organizing the breadboard for the project. In this case, all the negative sides of the LEDs are connected together at the bottom power rail, which is a single shared electrical point. Since we have to connect the LEDs at one point, this will help. Then, from there, it goes back up to the 470 ohm resistor and ultimately to ground.

Take a look at that breadboard and imagine what it would look like if we were using pins Q0 through Q4 directly. Try to picture four additional diodes crammed somewhere around that 4017 IC. It's a good thing we're using the pin 12 trick!



The breadboard view shows just how confusing a circuit can get in reality.