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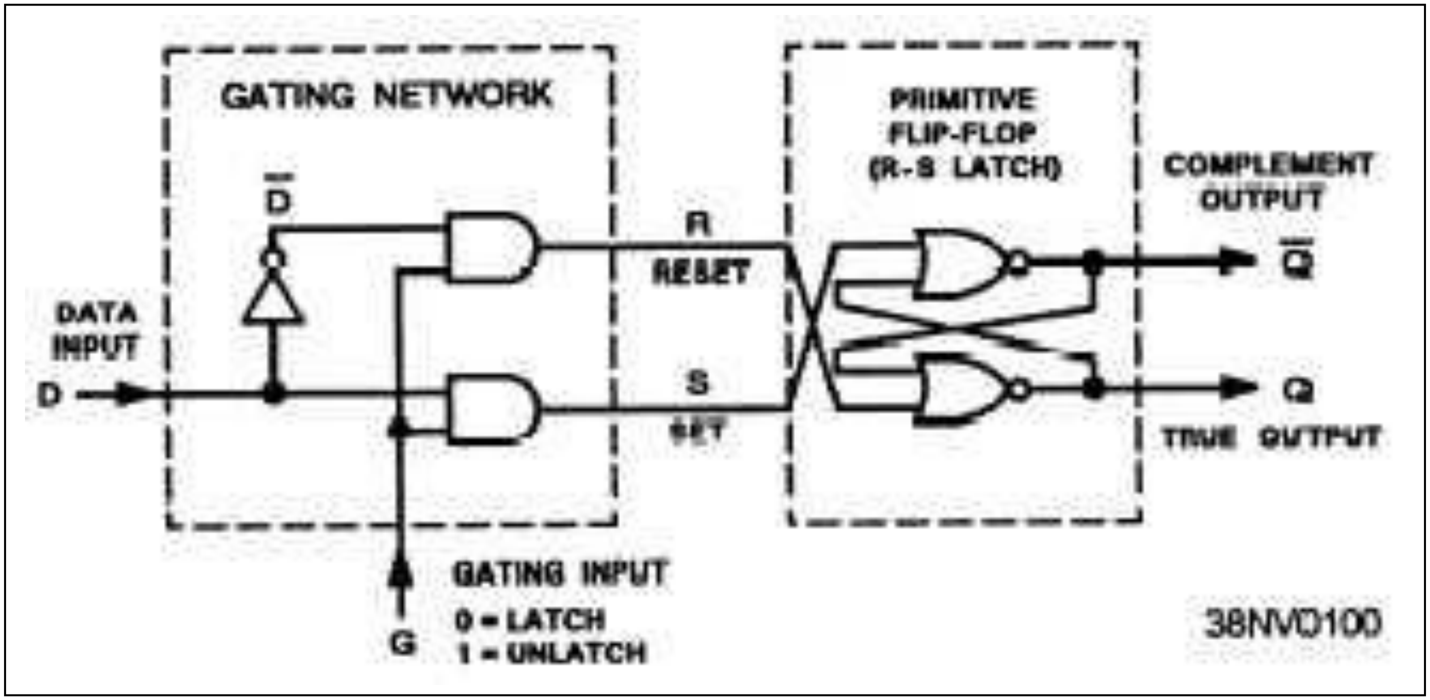
Lesson 12

Advanced Digital Integrated Circuits
Flip-Flops, Counters, Decoders, Displays

Flip-Flops: True name -- Bistable Multivibrator. A flip-flop ("ff") is a digital circuit that can remember what state the input was at any given time. It must be given a "look-see" pulse to tell it to fetch data and store it. Look at the circuit on the left. Don't try to figure out how it works; that's for CIE-20 students.

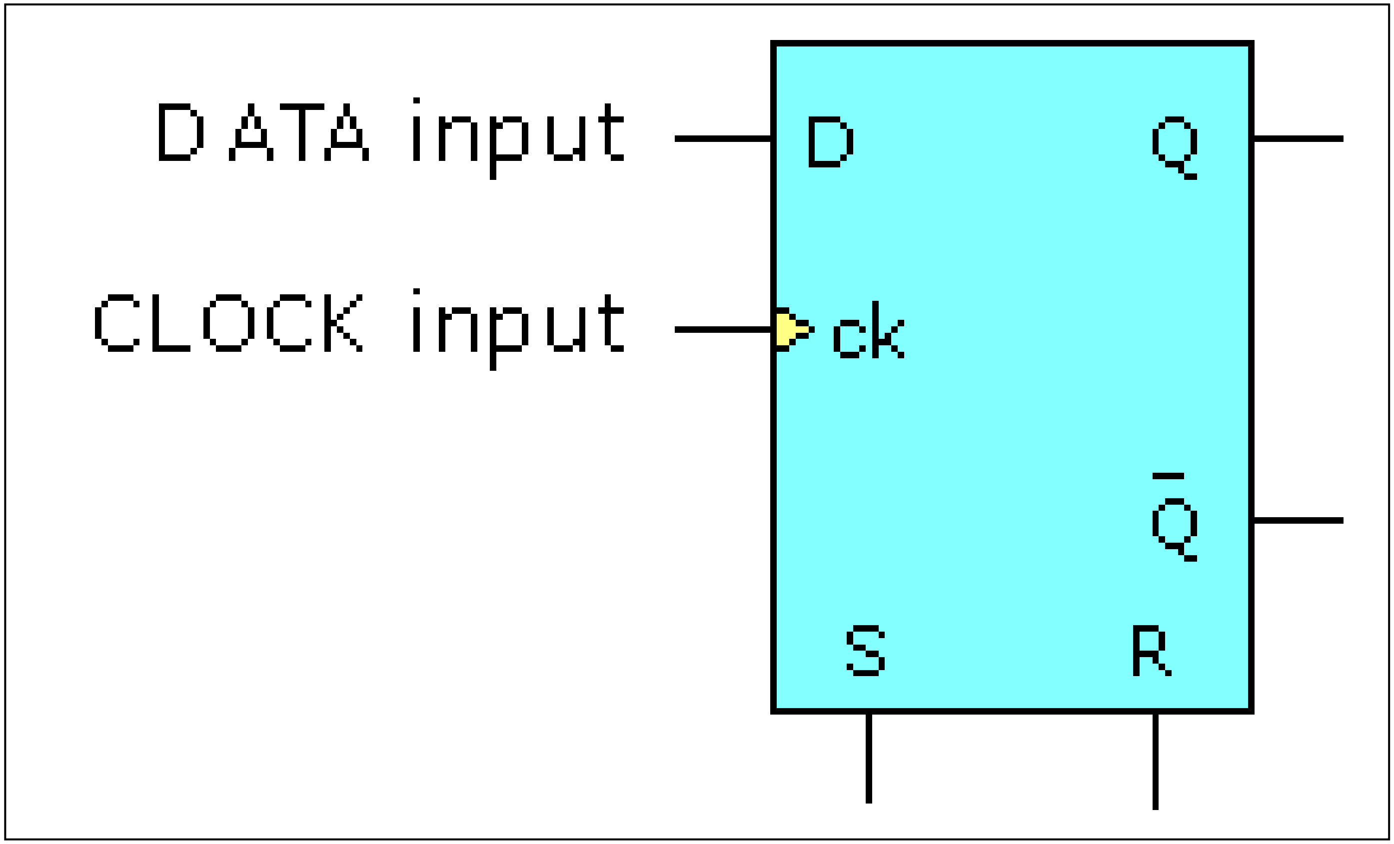


What we should be seeing is what the various inputs and outputs do, not what goes on inside.

There are two inputs and two outputs. Let's look at the two inputs first. One is what is called a "data" input and the other is the "gate" input. Just for illustration, let's say that there is a logic high at the data input and that there is a high at the gate. A logic high at the data input forces the Q output high (and the /Q -not Q- output low). Now switch the gate to "latch" by means of a logic low signal. The output is latched and nothing you do at the data input makes a bit of difference.

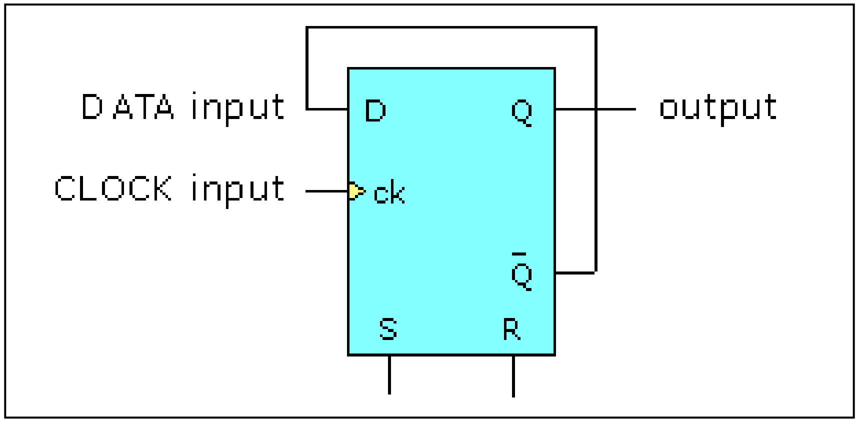
Now give me a low at the data input and bring the gate high for the briefest of instants and then back low. What did we do? We "clocked" that data low onto the Q output and then instantly latched it. Again, nothing we do at the data input now makes a bit of difference -- Q will stay low until the end of time unless we put an "open the gate" pulse onto the gate input. If Q is low, by the way, what state is /Q ?

This is the most elemental of memory cells. Remember last week when we were trying to remember what an "a" was? 01100001, as I binarially recall. To store that one letter, you would have to have 8 of these circuits with the first Q a zero, the second and third Qs one, then the next 4 Qs zero, and finally the eighth Q a 1. Fortunately for us, we can manufacture these "memory cells" by the billions on the head of a silicon pin.



We can go one step further with a little magic and witchcraft. Here is a diagram of a popular CMOS ff called a 4013. Note that it has a DATA input and what we called a "latch" input on the ff above, we now call a CLOCK input for a very good reason. We normally use these ffs with a digital square wave called a "clock". Internally we have arranged a series of and, nand, or, and nor gates to make it so that the DATA logic is transferred to the Q output when the clock square wave transitions from LOW to HIGH. Whatever logic level is on the data input when the clock transitions from low to high is immediately transferred to the Q output (and what does the /Q output do under these circumstances?). This is called a D(ata) type ff.

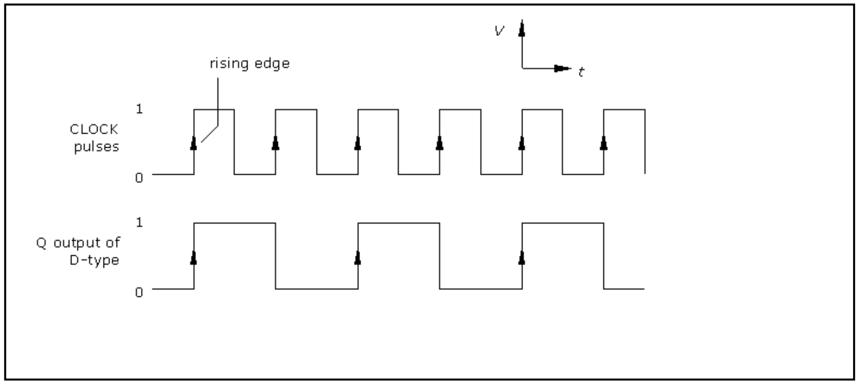
There are two other inputs called S(et) and R(eset) but for right now, let's not worry about them. They are used in some applications to override the data and clock operations.



A very popular configuration of this "D" type ff is to connect the /Q output to the data input. Let's see what this configuration (called a "T" type ff). You may assume that the /Q is high or low to start off with; it really makes no difference. Let's assume a high, just for example.

A high on /Q means a high on D. When the clock transitions low to high, that transfers the data high to the Q output and forces the /Q output low. When the next transition occurs, the low on the /Q output transfers to the Q output, and round and around we go. On an oscilloscope, this is what you would see:

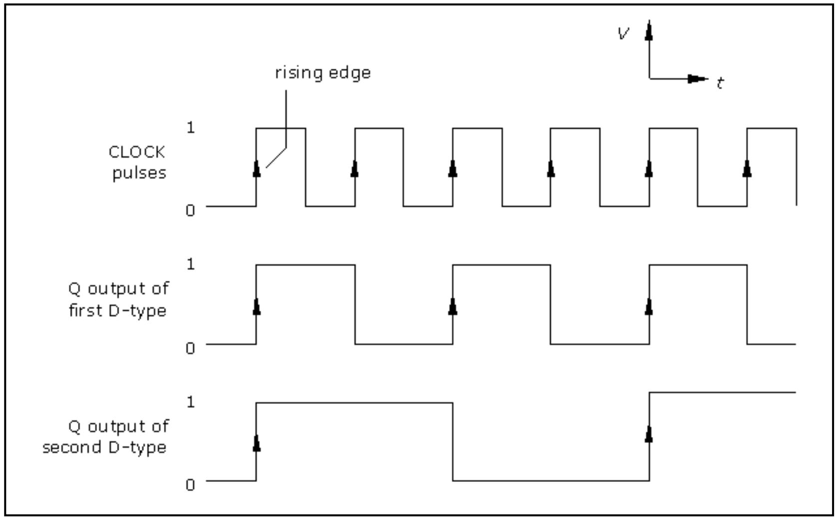
We call this a T(oggle) type of configuration because for each two clock pulses we get exactly one Q transition. In effect, we have DIVIDED the clock frequency by two. Hmmm…



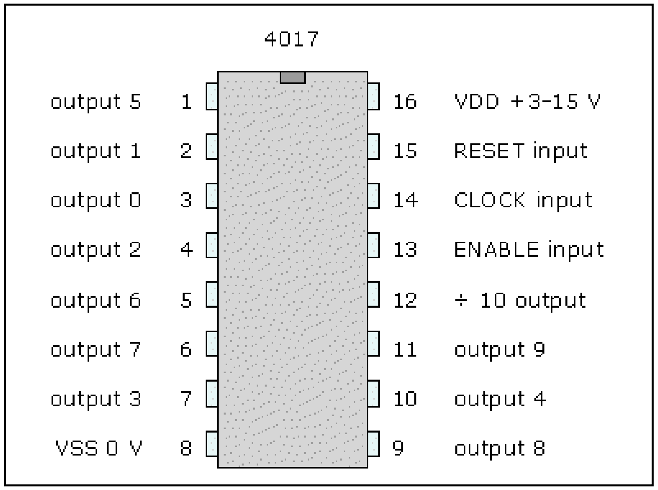
What would happen if we connected two of these T ffs in series, with the Q output of the first one becoming the clock input of the second? Again, we divide by two giving a total division of the clock by 4.

Oh, boy. I'll bet a third T ff would give us a divide by eight, and now we are off to the races.

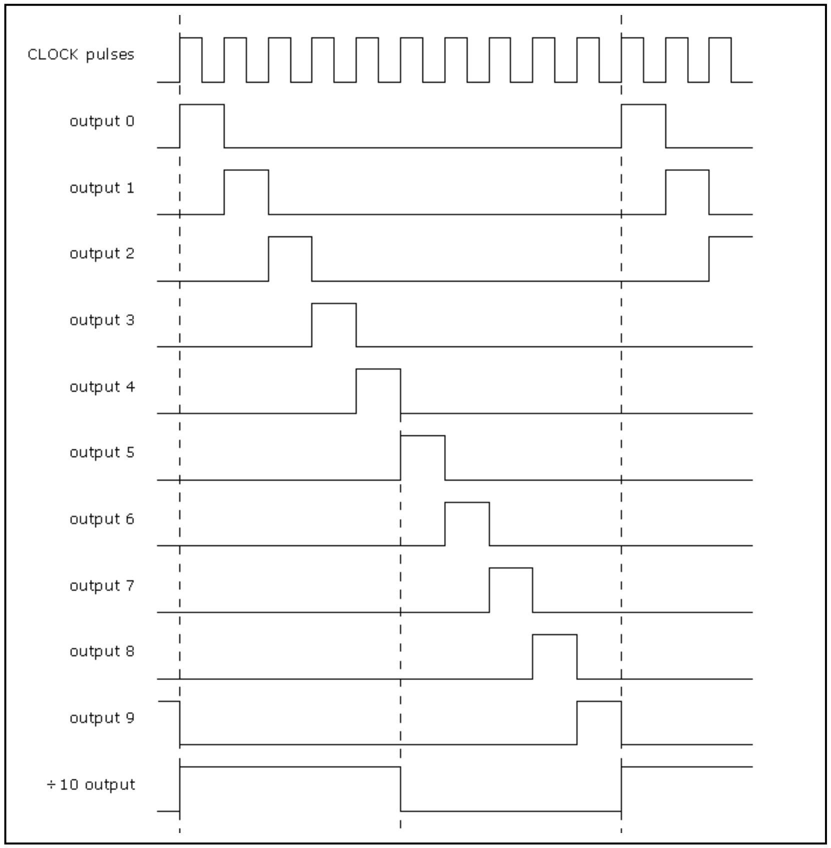
By a clever use of AND gates, I can "decode" the Q outputs and the clock to make a digital DIVIDER of any integer multiple I want. I'll call the clock 1, the first Q 2, the second Q 4, and the third Q 8. If I AND the first Q with the clock, I divide by 2+1 or 3. If I AND the first Q with the second Q I divide by 2+4 or 6. By a clever arrangement of AND and OR gates, I can divide by any integer I want so long as I have enough flipflops in series.



Counters -- We can take some of those ffs, combine them on a single chip with some decoding gates and come up with a counter. Case in point is the venerable CMOS 4017 decade counter. Here is what an oscilloscope would see connected to the various inputs and outputs on a 4017 counter



Note that for each rising edge of the clock, the counter advances one "decimal" place. One, two, three, and so on.



This is not the only kind of counter we could have. You may want to visit

http://www.electronicsclub.info/cmos.htm

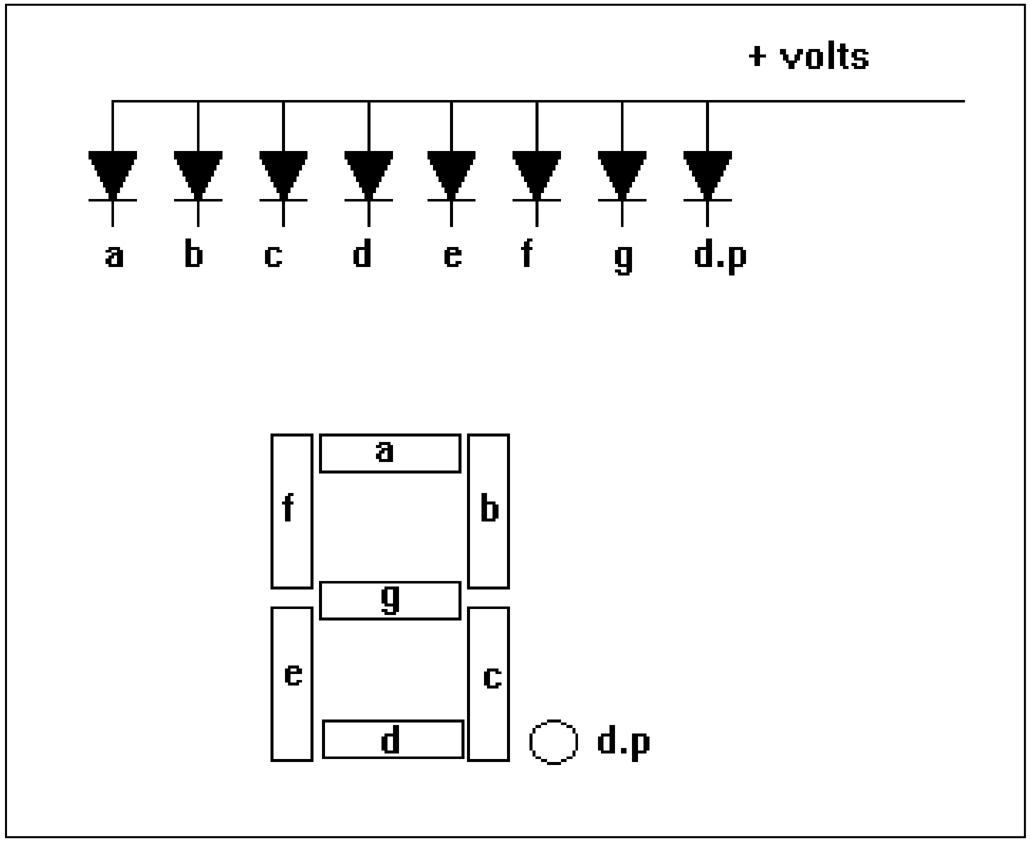
To see just a sampling of the counters that are available.

Decoders And Digital Displays -- A DECODER is meant to take a digital byte and output some other code that is usable for another purpose. For example, the CMOS 4028 shown at

http://www.electronicsclub.info/cmos.htm

takes a 4-bit binary digital word representing the decimal digits 0-9 (binary 0000 through 1001) and output the decimal value. This digital word is called BCD for Binary Coded Decimal.

Before we start to talk about the CMOS 4511, it of us to talk about digital displays. If all we want the decimal numbers 0-9, we can do it with what segment display. If, for example, I have 7 can arrange them in a way to display all ten numbers. would be smart to display are is called a 7- matchsticks, I decimal



Similarly, I can arrange 7 LEDs in a mirrored the same task. Each one of the diodes shown laid into a v-shaped trough that is mirrored to from the diode across the whole "bar" trough. For want to display the numeral 9, I would turn on and g. (Plus, for some applications, a decimal "trough" to do above (a-g) are diffuse the light example, if I diodes a, b, c, f, point.)

Please don't restrict me to LEDs. Look at your See how the time digits are made up from little arranged in the same configuration? Those are crystals" and are much more efficient in power LEDs. wristwatch. black bars called "liquid usage than

The neat high intensity displays on some upper gear? Vacuum fluorescent or gas discharge. Any make light, you can make digits by an appropriate lights you turn on. priced stereo way you can choice of which

So how do we turn these digits on? With a BCD to seven segment display DECODER. Back to the decoder page if you please. See the 4511? This common CMOS decoder will take a BCD word and directly drive those seven segments in an LED display and will drive other types of displays by adding a few more parts to the circuit. Look at the next page to see the various ways of driving different types of displays.

FAIRCHILD
SEMICONDUCTOR™

October 1987
Revised January 1999

CD4511BC
BCD-to-7 Segment Latch/Decoder/Driver

General Description

The CD4511BC BCD-to-seven segment latch/decoder/driver is constructed with complementary MOS (CMOS) enhancement mode devices and NPN bipolar output drivers in a single monolithic structure. The circuit provides the functions of a 4-bit storage latch, an 8421 BCD-to-seven segment decoder, and an output drive capability. Lamp test (LT), blanking (BI), and latch enable (LE) inputs are used to test the display, to turn-off or pulse modulate the brightness of the display, and to store a BCD code, respectively. It can be used with seven-segment light emitting diodes (LED), incandescent, fluorescent, gas discharge, or liquid crystal readouts either directly or indirectly.

Applications include instrument (e.g., counter, DVM, etc.) display driver, computer/calculator display driver, cockpit display driver, and various clock, watch, and timer uses.

Features

- Low logic circuit power dissipation
- High current sourcing outputs (up to 25 mA)
- Latch storage of code
- Blanking input
- Lamp test provision
- Readout blanking on all illegal input combinations
- Lamp intensity modulation capability
- Time share (multiplexing) facility
- Equivalent to Motorola MC14511

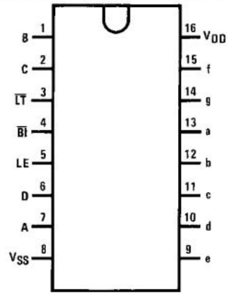
Ordering Code:

Order Number	Package Number	Package Description
CD4511BCWM	M16B	16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-013, 0.300" Wide
CD4511BCN	N16E	16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide

Devices also available in Tape and Reel. Specify by appending suffix letter "X" to the ordering code.

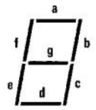
Connection Diagrams

Pin Assignments for SOIC and DIP



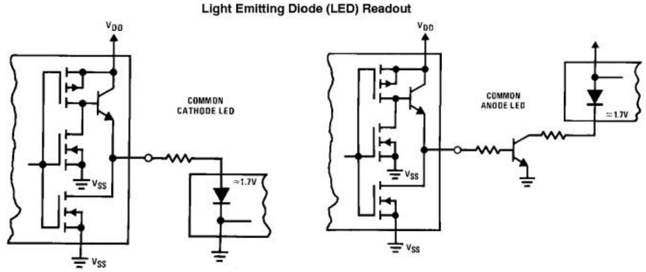
Top View

Segment Identification

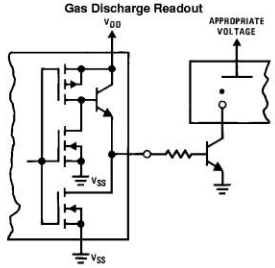


Typical Applications

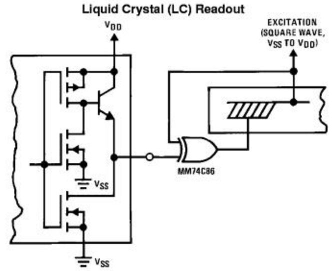
Light Emitting Diode (LED) Readout



Gas Discharge Readout

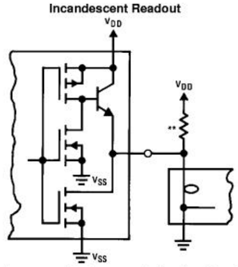


Liquid Crystal (LC) Readout



Direct DC drive of LC's not recommended for life of LC readouts.

Incandescent Readout



**A filament pre-warm resistor is recommended to reduce filament thermal shock and increase the effective cold resistance of the filament.

Fluorescent Readout