

# Digital Electronic Decimal Counter

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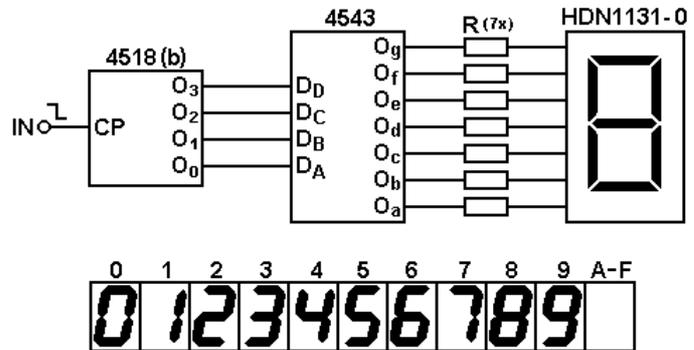
## Introduction

With two IC's and a 7-segments LED-display one can build a decimal counter that counts pulses from 0 to 9. A possible application of this is counting the number of products that pass a certain point of a production line. The counter can be cascaded to count any large decimal number.

## Diagram

The total diagram consists of a BCD-counter, a 7-segments-decoder and a 7-segments LED-display.

The counter is in a C-MOS IC of the type 4518. It contains two 10-counters, a and b. Each counts binary from 0000 to 1001 and then returns to 0000. We only use one of them; b. For more information, print the data sheets of this IC.



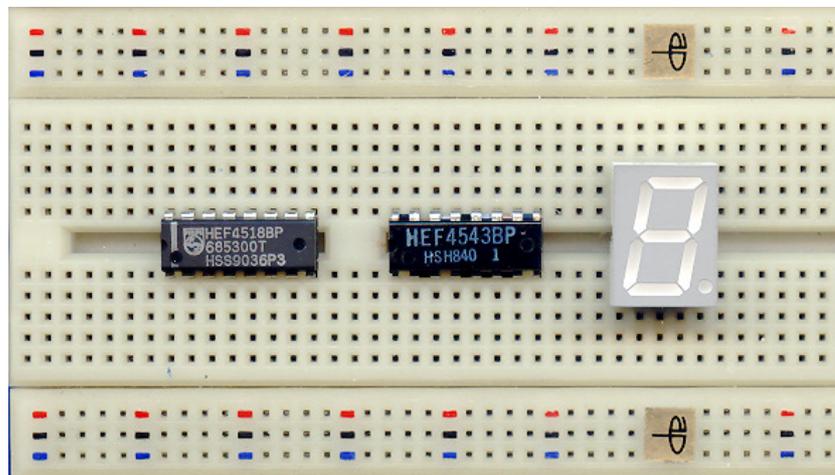
The 7-segments decoder is in the CMOS IC 4543. This IC turns a binary number of 0000 to 1001 into seven binary digits, in such a way that on the display they show the number shown on the picture. Print the data sheets of this IC as well.

The LED-display HDN1131 (print the data sheets) needs resistors R to restrict the current in each diode. For this type, that should be about 2 mA.

## Building on a breadboard

It is wise to start building your circuit on a breadboard; you can easily test your circuit there. The only drawback is that you will be restricted in the lay-out, which can make it badly organized. Once the circuit works on the breadboard, you can transfer it to a circuit board to make it manageable.

Underneath a grid with a pitch of 0,1 inch (which is the distance between the pins of an IC) are little grips to put wires and pins of components in. The connections between the grips are rather logical. With some wires and your ohmmeter you can **find out how the holes are connected**. Do this before you start; it is better to find it out for yourself than to be told and just hold it as being true.



Use small stretches of insulated wire (called Telephone wire) that have been stripped at both ends.

They might already be available at the practical. With these pieces of wire, you should make the connections between the pins of the IC. Resistors, diodes and transistors can be put into the board directly.

Don't forget to connect the ground and the supply voltage of the IC's (pins 8 and 16 respectively). It is advisable to keep track of what you already did in a schedule to keep a good overview of the situation.

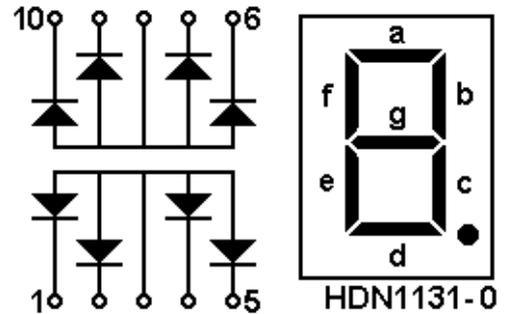
A lot of effort has been put into securing the connections of the grips. However, be aware that the connections are the least reliable points of electric circuits. Circuits on a breadboard therefore shouldn't be used for permanent applications.

## The LED-display

Build your circuit step by step and check after each step if everything still works as expected. In this case reverse building is most suitable, because you will have the display as a means of checking things. So start with the LED-display.

First sort out the connections of the HDN1131. You could do this only on paper, but it is better to do it "in real life". A multimeter can help you with this.

In the diagram on the right the numbering of the pins is given, seen from above. Pin 3 and 8 are the so-called common anodes. With the multimeter on  $\Omega \times 100$  (the current with the pins against each other is then 1,5 mA), you can light up the different LEDs. Beware; the black pin is the positive! On the blue scale LV you can see the voltage over the diode.



Make an overview of the pins and which segments are connected to them. Use the internationally common indications a to g like in the diagram. Also determine if the two CA-pins are connected. If not, later on you have to connect them both.

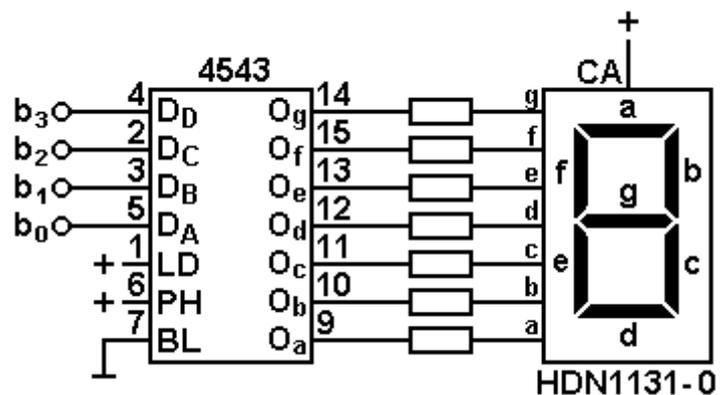
Now you can also calculate the optimal value of resistors R. Try for instance a supply voltage of 5 volt and take into account the voltage over the diode at a current of 2 mA. Take the closest standard value and test it with the loose wires and 5 volt from a power source. Convince yourself by measuring the current if necessary.

## The 7-segments decoder

The C-MOS IC 4543 contains a 7-segments decoder. A binary number can be put into the input ports  $b_3 \dots b_0$ . On outputs  $O_g \dots O_a$  a bit pattern will appear and the corresponding number will be shown.

One of the input ports is BL (blanking), which will turn off the display when its input is 1.

Input port PH (phase) determines if outputs  $O_g \dots O_a$  should give a lit segment on the display with 0 or 1. In this case, for a Common Anode display, the outputs should be 0. This is the case if you connect input PH to 1, so on the supply voltage. This input is important for controlling LCD's. Read more about this in the data sheets.



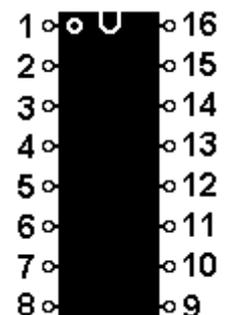
Furthermore there is a 4-bits register (latch) in the IC. If input port LD (load) becomes 0, the state of  $D_D \dots D_A$  freezes as it is. This allows the user to read the display without it changing. If LD changes to 1, the display will follow the state of  $b_3 \dots b_0$  again. First put the input port LD on 1, as depicted in the diagram.

## Connecting

Pay attention to the numbers of the pins of the IC. Seen from above the numbering is counterclockwise, like with the display.

Sometimes pin 1 is denoted by a dot on the IC, but there always is a U-shaped notch between pin 1 and the last pin. If the IC has less (14, 8 or 6), or more (20, 24, 28, 32 or 40) pins, the numbering will be similar. So from the bottom, where you will solder the wires if you build it on a circuit board, it will be the other way around. Don't let this confuse you!

This kind of IC's always has its 'ground' ( $V_{ss}$ ) at the bottom left, in this case on pin 8 and the supply voltage ( $V_{DD}$ ) in the upper right, in this case on pin 16.



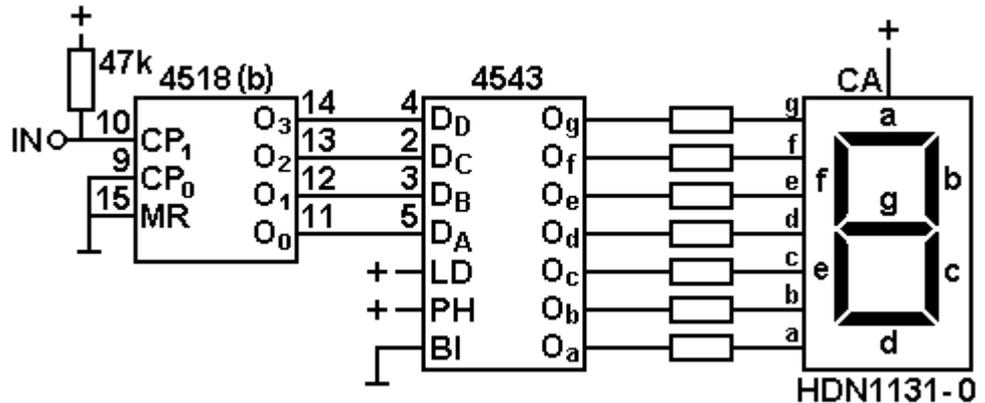
Start by connecting the ground and the supply voltage, otherwise you might forget them later on. Also put a capacitor of 0.1  $\mu\text{F}$  from the supply voltage to the ground. This decouples the supply rail.

First connect data-inputs  $b_3\dots b_0$  to 0 (earth). If you connect the supply voltage, a 0 should appear on the display. Then try other combinations of zeros and ones as input.

Be careful! The input ports are very high-ohmic; the insulated gate of a field transistor. A pin that is not connected can take any value between 0 and 1. Unexpected things will happen.

### The counter

In the C-MOS IC4518 are two counters that count to ten. The first counter (a) is connected to pins 1...7, the second (b) to pins 9...15. We only use counter (b) to begin with.



Each counter has an input port MR (master reset) that with input 1 will put the counter on 0000 and will keep it 0000 until MR turns 0 again.

Each counter has two input ports CP (clock pulse).

- As long as  $CP_0$  is high (1) or  $CP_1$  is low (0) the other input port is blocked
  - If  $CP_1$  is high, the counter will count on an up-going edge on  $CP_0$  (from 0 to 1)
  - If  $CP_0$  is low, the counter will count on a down-going edge on  $CP_1$  (from 1 to 0)
- This is how we are going to use it.

### Connecting

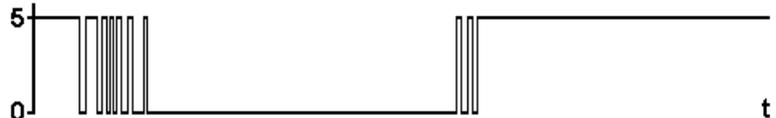
Extend the circuit you made with the counter. Again connect the ground and the supply voltage first. Clock pulse input port  $CP_1$  is connected with a 47 k resistor to the +. If we connect it with a loose wire to the 'ground', a counting pulse is provided.

Counter (a) can stay unconnected, but do connect the MR of this counter (pin 7) to the + (this is a 1). The counter will be continuously reset and won't do anything funny.

### Counting

If you switch on the supply voltage a figure should appear on the display. Shortly switching the input to 0 will change the figure. Try tapping the wire connected to 'ground' against the proper side of the 47k resistor. Notice that the display will jump to a seemingly arbitrary figure...

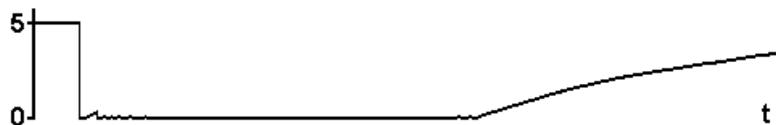
The counter-IC is so fast that interruptions of 0,1  $\mu\text{sec}$  (a ten millionth of a second), can already be counted. Try rubbing the ground wire against the wire of the resistor. The figure will change so fast and frequently you won't be able to see it properly.



And yes, switches also do this, some worse than others; even the switches that say 'click'. There even is a word for this phenomenon: "contact-bounce". No, we can't count properly like this.

### Input filter

Connect a capacitor of 0,1  $\mu\text{F}$  between the counter input port and ground. The capacitor is charged to 5 volt via the 47k resistor. With the short circuit wire it is discharged very quickly, but charging takes a relatively long time. Calculate the RC-time for this! Now you can count properly.



## Experimenting

Try to experiment with the blanking-input, the load-input and the phase-input. Especially the latter will give unexpected results that need some good thinking to work out.

## Cascading

Two or more of these counters can be put in cascade, for instance with the counters of your neighbours in the practical. Connect the other counter (without the input-C, but you can keep the 47 k resistor in place) to  $O_3$  (pin 14). Don't forget to connect the grounds, otherwise it will not work.

When the first counter goes from 9 to 0, the second counter will go up by one. You can now count from 0 to 99.

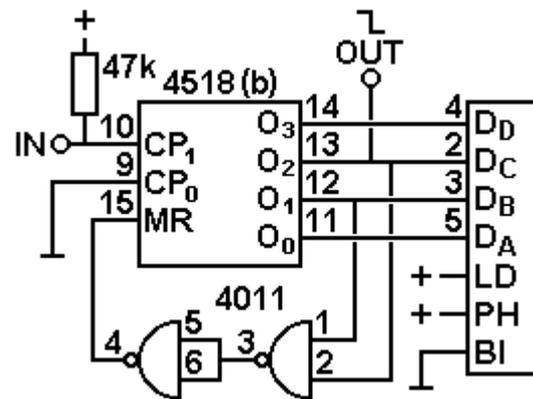
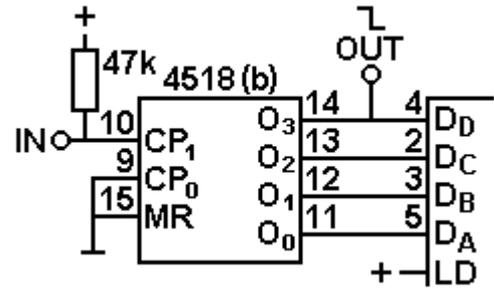
In this way you can cascade more counters. If giving the pulses begins to take too much time, you can ask for a pulse generator at the practical. They are made for this cause and can do it very quickly.

## Other dividends

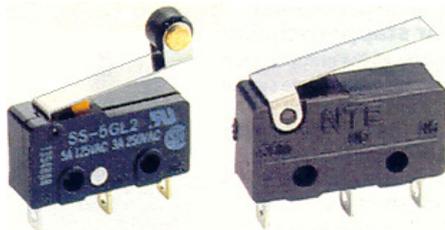
With a few figures you are already on your way to making a digital clock. Take pulses of 1 sec for a second counter. However seconds do not add up to 99, but to 59. The last figure is right, but how can we force the first figure to return to 0 after 5?

We have a quick and simple, but also somewhat dirty solution for this. We will permit the divider count to 6, and if a 0110 is detected (6 is 0110, two ones in the middle) we will reset the counter to zero by MR. This happens so fast that you will not see it happening.

Two NAND's from a 4011 will 'AND' the two bits in the middle and the result will go to the MR.  $O_3$  will never turn to 1, an output should now be connected to  $O_2$ .



## Pulse generators



Tapping wires against each other seems alright for now, but eventually we will need something better. The micro switch (see picture) is not called a micro switch for its dimensions but for the very small movement that the pin needs ( $\frac{1}{2}$  mm) for switching. Usually they are equipped with a lever, with a little roll or otherwise, to be less sensitive to mechanical inaccuracy.

In these switches there is a contact that is closed in its normal state (NC; Normal Closed) and a contact that is open in its normal state (NO; Normal Open). The switches will give a clear 'click' when

they're turned, but they will bounce any way.

Another useful kind of switch is the reed switch. Two small iron contacts are cast into a small glass tube filled with an inert gas, in such a way that they almost touch each other. If a magnet is held next to it, the contacts will become magnetic and will attract each other. The switch closes. The sensor of the speed meter on your bicycle works the same. And yes, a reed switch also experiences contact bouncing.



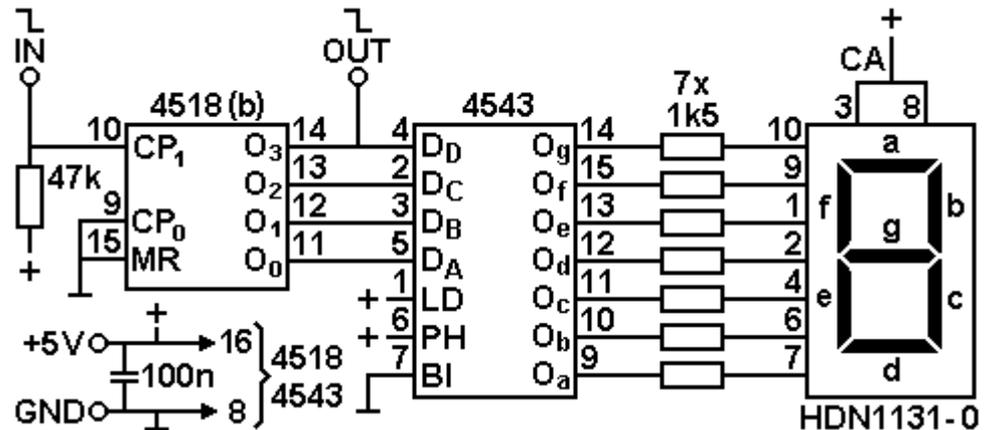
Still another way of counting is by interrupting a beam of light. A component that is of good use for this is the LDR (Light Dependent Resistor). The resistance of an LDR becomes lower when it catches light. With an Ohm meter you can measure the value at the light intensity that you

want to use as the switch point between 0 and 1 (let's say  $\frac{1}{2}$ ). The resistance of 47k at the input port should be replaced by a resistor of that measured  $\frac{1}{2}$  value.

## Building on a circuit board

A circuit on a breadboard is good to experiment with, but the connections are too unreliable for long term use. Building the circuit on a circuit board is a better idea. If you do this neatly, it is reliable for years of untroubled use.

### Lay-out



Anticipate how the components should be positioned on the board. This is not really important for a prototype, but if you don't do it conveniently it will result in much and long wiring. You might lose the general picture, which becomes a problem if the circuit fails to work.

Before you start, draw on a sheet of squared paper how the IC's could be positioned next to each other and how the wiring will be. After a few attempts you will have a decent component arrangement. This short preparation will save you a lot of time when building the circuit.

### Wiring

Start with the wiring you can make with bare non-insulated wires. This is for instance the ground wire (GND or  $V_{ss}$ ) and the supply voltage (+5V or  $V_{DD}$ ). Some connections can also be made with bare wire if you positioned the components smartly. Provide a capacitor between the +5 and ground to decouple the supply voltage.

A smart positioning of the components will also allow you to bend the connection wires of resistors and capacitors underneath the board and, after cutting them at the right length, soldering them directly to the pins of the IC. Work as neatly as possible to get a result that looks very presentable. The pieces of wire you cut from the components can even be used for connections that happen to be close to each other.

For 'wild' wiring you can use so-called Wire Wrap wire. This is a very thin copper wire with Teflon (PTFE) insulation. The advantage is that PTFE will not melt if you happen to touch it with the soldering iron. A disadvantage is that the material is hard and stiff; the insulation is hard to remove. However with the trick in the box to the right you can use it quite well.

Put the stripped end of the wire in the hole with the IC-pin and solder them together. The solder that flows into the hole forms a very reliable connection. Lead the wire to the point you need it, cut it 2 mm 'too long' and treat the end in the same way. Well done.

### Order

Again reverse building is advisable and check as often as you can if everything is still working. For connections to the outside, use solder eyelete. This allows you to dis- and reconnect the wiring a few times later on.

#### Stripping Teflon insulated wire

Proceed like this:

- flatten the last two mm with a flat pair of tongs,
- the insulation will split and forms two little tabs,
- cut the tabs off with a small pair of wire-cutters,
- or a nail clipper is very suitable in this case.

