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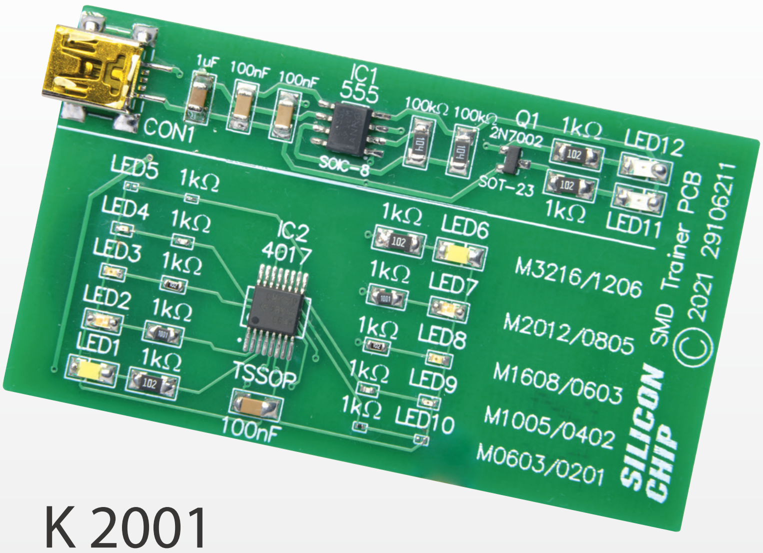
SMD Trainer



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Are you interested in learning to solder small surface-mount devices but don't want to ruin an expensive board or chip gaining those skills? Perhaps you have no choice but to learn since so many parts made these days only come in SMD packages. This simple Trainer project is a great way to practice soldering a variety of surface-mount devices. If done correctly, you'll be rewarded with a series of LEDs flashing in sequence.

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Surface-mount devices (SMDs) are the preferred type of parts used in most commercial equipment to their compactness, good reliability, low cost and widespread availability. While some manufacturers are still producing new through-hole parts, your choices become a lot more limited if you can't handle SMDs.

We know it seems daunting initially (it did to us, too), but you will be surprised how easily you can do it with a bit of practice. And that's precisely what this board is designed for. It's a working circuit designed using a wide variety of different SMD parts, allowing you to try out soldering them. This way, you can master the techniques and become familiar with the common sizes and packages.

It's designed so you can start with the larger parts and, as you gain confidence, move onto the smaller ones. And you can test it along the way, so you'll find out pretty quickly if you've made a mistake and have an opportunity to correct it.

This article includes the basic instructions for building and testing the Trainer board, along with a description of how it works.

Circuit details

The circuit of the SMD trainer board is shown in Fig.1. We'll explain how it works before going any further. It's important to know what it should do, especially so that you can figure out what's wrong if it doesn't work initially.

There are two main parts to the circuit, the second of which depends on the first. The first part of the circuit is also easier to build, so you can try out your skills on that before dialling up the difficulty.

Common to both parts is the power supply. Coin cell holder BAT1 is paralleled with a USB socket, CON1. Only one of these should be fitted. We recommend the coin cell holder, as a coin cell is less likely to deliver damaging current in case you make a mistake building it.

Because of the presence of a coin cell, take care that the SMD Trainer is kept out of reach of children. It has flashing lights, so it will appeal to curious eyes, but there is no reason for it to come into a child's hands as it is not a toy.

First half

IC1 is a timer IC (a 7555). We've chosen this CMOS variant rather than the bipolar transistor based 555 to allow the circuit to work at low voltages and be powered by a coin cell. The supply passes to IC1's pin 8 (positive) and 1 (negative). Pin 4 (RESET) is held high to allow the timer to run.

IC1 has its supply bypassed by a 100nF capacitor and a second 100nF capacitor stabilises the internal voltage on the CV pin, pin 5. IC1 is configured with the 100kΩ resistors and 1µF capacitor in the well-known astable oscillator configuration.

In this arrangement, the 1µF capacitor charges from the supply via the two 100kΩ resistors; its top is connected to input pins 2 and 6. When pin 2 rises above 66% of the supply voltage (about 2V), an internal flip-flop toggles and pin 7 is connected to ground (through a transistor inside IC1). At the same time, pin 3 goes low.

This causes the 1µF capacitor to discharge through the lower 100kΩ resistor into pin 7, until the voltage on the capacitor reaches 33% of the supply (about 1V). The flip-flop resets, pin 3 goes high, pin 7 stops sinking current, the capacitor begins charging again, and the cycle repeats.

With the provided component values, the oscillator frequency is around 4.8Hz with a 66% duty cycle at pin 3 (ie, pin 3 is high about 2/3 of the time).

When pin 3 is low, current is sunk from the supply via LED12 and its 1kΩ series current-limiting resistor, causing it to light. When pin 3 is high, Mosfet Q1 is switched on by the positive voltage at its gate, and current flows through LED11 and its series resistor instead. Thus these two LEDs flash

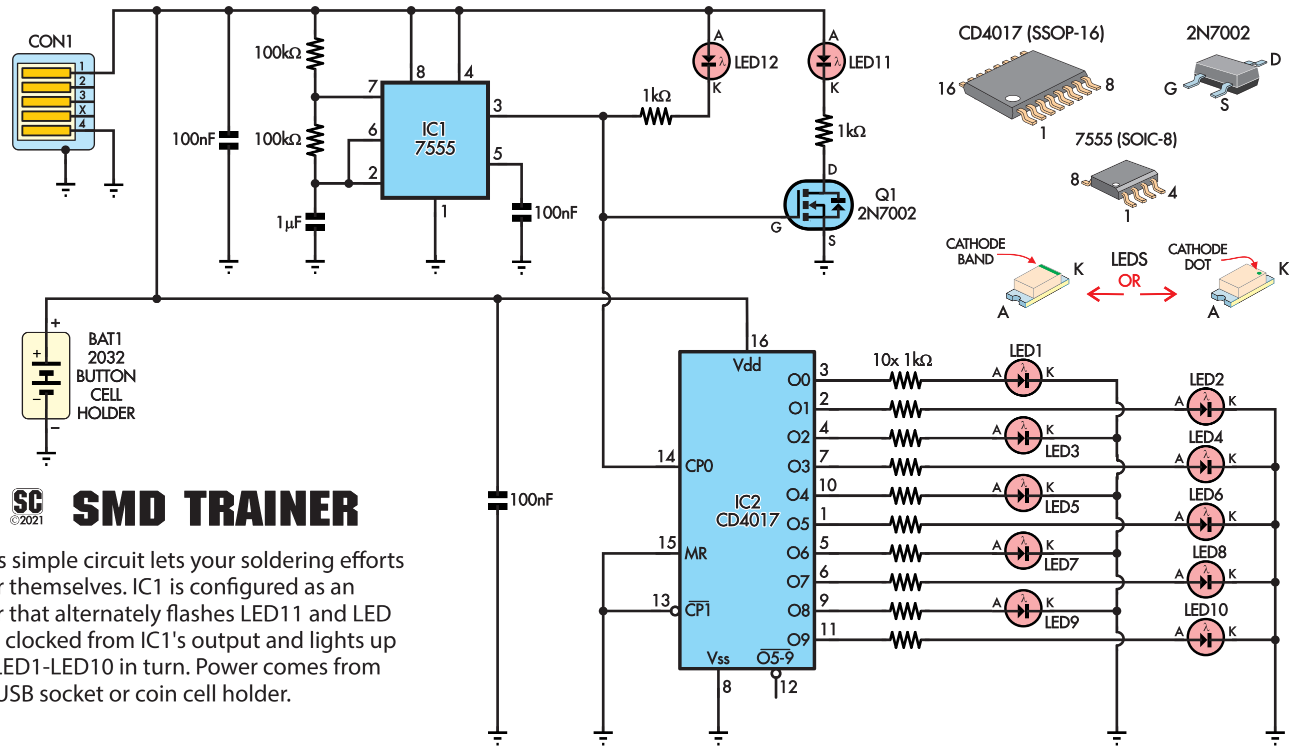


Fig.1: this simple circuit lets your soldering efforts speak for themselves. IC1 is configured as an oscillator that alternately flashes LED11 and LED 12. IC2 is clocked from IC1's output and lights up each of LED1-LED10 in turn. Power comes from either a USB socket or coin cell holder.

alternately.

This first part of the circuit is built from larger SMD parts, like those we usually include in our projects when through-hole parts are unsuitable. It can operate independently of the remainder of the circuit, and can be built and tested as the first part of a two-part challenge.

Second half

A horizontal line on the PCB divides it neatly into two distinct parts; part two is below this line.

IC2, a 4017-type decade counter, is the heart of the second part of the circuit. It is powered from the same supply as IC1, connected to its pin 16 (positive supply) and pin 8 (negative supply). Its supply is also bypassed by a 100nF capacitor for stability.

IC2 has ten outputs at pins 3, 2, 4, 7, 10, 1, 5, 6, 9 and 11. These are driven high, one at a time, in response to a clock signal applied to pin 14. This signal comes from pin 3 of IC1 mentioned above. Pins 13 and 15 are pulled low to allow normal counting operation. Pin 12 is a carry output, which can be cascaded to other chips, but is left disconnected in this case.

Each of the ten outputs noted above has a 1kΩ series resistor and LED connected to its output. Thus, a clock signal at pin 14 causes the LEDs to light up in order, one at a time.

The components around IC2 have a variety of sizes to present a more interesting challenge; IC2 is also in a smaller SMD package than IC1. See Table 1 for more details.

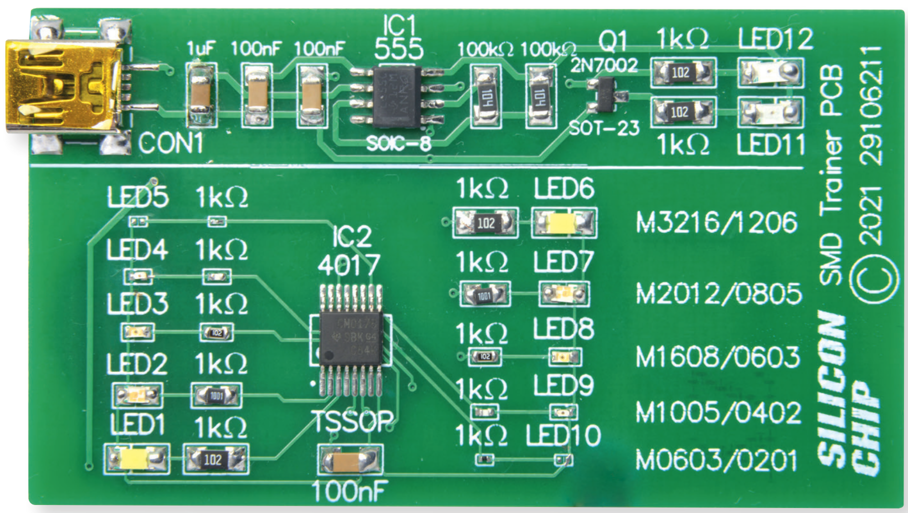
Placement and order

Our recommended assembly order for most through-hole designs is for a few reasons. Working by component type, for example, starting with resistors, then diodes, capacitors and then ICs, makes it easier to keep track of what step you are up to.

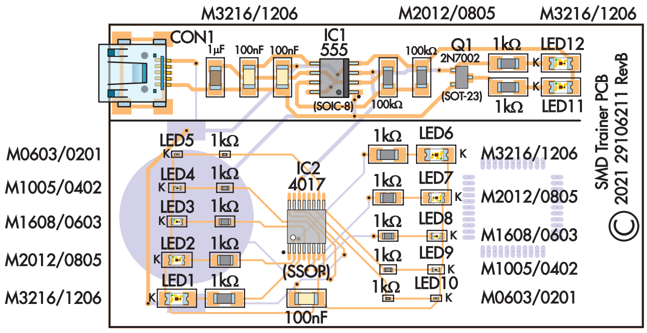
For the most part, this order is dictated by the component heights. Components that are close to the PCB are placed first as they don't restrict the placement of taller parts. Also, this means that the PCB can be turned upside down without the through-hole components falling out; they are held on the PCB by the work surface.

Working with SMD parts has similar motivations, but there is much less need to invert the PCB, so no real chance of parts falling out. Also, most SMD parts have a low profile.

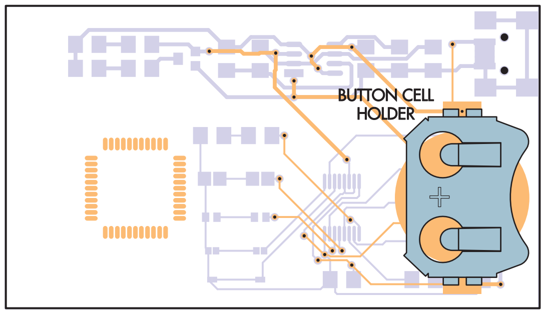
So the primary consideration will be to place the more difficult-to-access or difficult-to-solder parts first, so that they aren't impeded by parts fitted later.



This is the SMD Trainer board that we put together (shown at approximately 166% actual size). If you're having trouble making out the M0603/0201 LEDs, it might be because they're not fitted! We couldn't solder these by hand, and won't pretend that it's easy to do so.



TOP OF PCB



BOTTOM OF PCB

Figs.2 & 3: start by fitting the components in the top half of the PCB, which forms the alternate flasher, lighting LED11 & LED12. These components are larger SMDs that are generally not too hard to solder. Once you have those working, you can move onto the more challenging parts below, which form an LED chaser. With IC2 and its bypass capacitor in place, fit LED1, LED6 and their series resistors, then move onto the smaller parts, testing it at each step to ensure your soldering is good.

With this in mind, the best way to construct hybrid circuits (that have both through-hole and SMD parts) is to fit the SMD parts first. Whether they are on the same side or not, the taller through-hole parts will be a greater impediment to construction if they are fitted before the smaller SMD parts.

This also means that the process of placing ICs last is no longer appropriate. Nowadays, ICs tend to be more rugged and less prone to damage from static, which was usually the motivation to fit them as late as possible.

In SMD designs (or at least those intended to be hand-soldered), the ICs typically have finer leads and are harder to work with. So it makes sense to do them first and then work on their surrounding passive components, which are often larger.

Assembling the SMD Trainer

Refer now to the PCB overlay diagrams, Figs.2 & 3, which show which components go where. The SMD Trainer PCB is double-sided, measures 70.5 x 40mm and is coded 29106211.

We recommend starting with the USB socket if you will be fitting it. The leads are not too small, but they are not very accessible. Fortunately, this part has locking pins on the underside that go into holes in the PCB. So positioning the part correctly is easy.

Place flux on all the pads for the USB socket and press the part down. For this application, only the two outer pads of the five are needed to supply power; hence they are the only ones that are extended. You can add more flux to the top of the pads too.

Clean the iron's tip, apply a small amount of solder and press the iron against the PCB pad. If the solder doesn't run onto the lead, bring it closer, until it is touching if necessary. Repeat for the other outer pad.

With this connector, make sure you don't touch the iron against the USB socket shell when making these power connections. The tight angle here is what makes this tricky. If you form a bridge, apply heat to all the pins to remove the part and tidy both the socket and PCB with solder braid.

For the larger pads that secure the USB socket mechanically, simply apply the iron, add some solder until a tidy fillet forms, then remove the iron. A generous amount of solder here will result in a secure connection.

Using a similar procedure, place IC1 and Q1, ensuring that they are rotated correctly. Then solder the resistors and capacitors in place. Note that there are two different values of each; you can refer to our photos too.

The LEDs are polarised too, and must be fitted with their cathodes to the left towards the resistors.

If you wish to fit the cell holder instead of the USB socket, do so now. It's usually easier to fit parts on one side of the board at a time, but this will allow you to test out the first part of the circuit that you have just assembled.

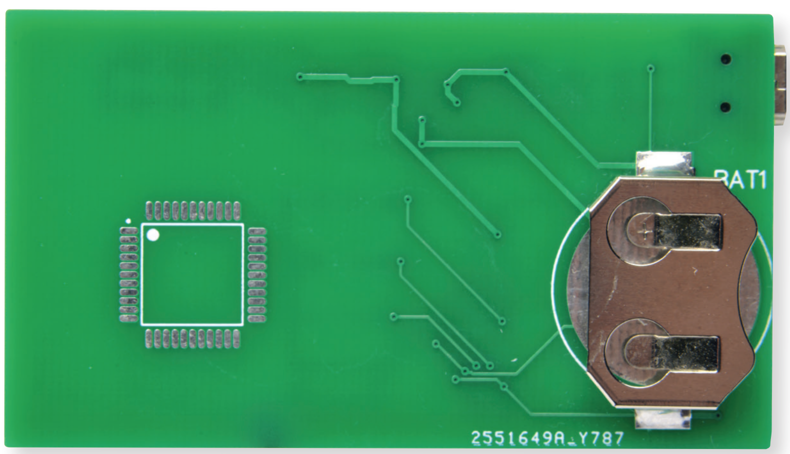
Flip the PCB over and put some flux on the two smaller outer pads. Leave the large inner pad clear, as the PCB pad itself becomes the negative terminal and doesn't need soldering.

Also ensure that the holder opening is towards the edge of the PCB, so that you can easily insert the cell. Position the holder roughly in place and add some flux to the top of the leads too.

Note that, unlike the USB socket, there is nothing to lock this part in place.

You will probably need to turn up the temperature on the iron slightly (if it's adjustable) and load some solder onto the tip; a bit more than for the smaller parts. Use tweezers to keep the cell holder in place and touch the iron to the pad.

Give it some time to heat up; remembering that it is all one piece of metal, so it is unlikely to be damaged by too much heat. You should see the flux smoke and



There's a set of TQFP pads located on the underside of the PCB. This is for you to practice soldering, and does not have any electrical connection to the circuit.

the solder flow. Remove the iron and give the part (and solder) a few seconds to cool before releasing the tweezers.

The first joint doesn't need to be perfect; the main thing is that the part is accurately placed and held firmly.

The second pad can be approached like the larger pads on the USB socket. Apply the iron, feed in the solder until a good fillet is formed, then remove the iron. Give it a few seconds to solidify before returning to the first pad to make it tidy. You can touch it up by applying the iron and solder in the same fashion.

Initial testing

The first part of the circuit should now be functional. You can test it by fitting the button cell or applying power from a USB source. If using the button cell, make sure the polarity is correct. You should see LED11 and LED12 flicker alternately.

If one LED is stuck on, then IC1 is not oscillating, and you should check it and the components around it. If only one LED is flashing, the other might not be soldered correctly; this could include either of the 1kΩ resistors or Q1.

You might also see what appears to be the two LEDs on at the same time. In that case, they are probably flashing faster than the eye can see. One possible reason for this is that the 1µF timing capacitor has been mixed up with one of the 100nF capacitors.

At this point, it's best to verify that this part of the circuit works correctly. Otherwise, if the second part doesn't work, it will be harder to determine the problem.

Remainder of the circuit

You'll note that the components in the lower half of the PCB are fairly well spread out. This is a luxury that won't be present in all SMD designs.

With the amount of space present on the SMD Trainer, it's certainly possible to install these components in just about any order. But we recommend starting with IC2 and its capacitor, followed by the LEDs in order of size from largest to smallest. This will allow you to power up the circuit at any time after you have any of the larger LEDs fitted, and check that it is working.

Start with IC2. Apply flux and position the part. We've been quite generous with the length of the pads here, for two reasons.

Firstly, we have seen SOP variants of this part being available with various body widths. So this pad configuration offers the flexibility to accept a range of compatible parts. Secondly, it makes it easier to solder.

Clean the tip of the iron and add a tiny amount of fresh solder to it. Hold IC2 with the tweezers and apply the iron to the PCB pad only. You should see the solder flow onto the lead and form a joint strong enough to hold the part in place.

Check that the leads are aligned and solder the remaining pins in this fashion. These tiny parts do not need much solder, so you might find that you only need to occasionally add solder to your iron.

Check for bridges and rectify as needed. Follow with the remaining 100nF capacitor. LED1 and LED6 are M3216/1206 sized parts, so you should be comfortable fitting them and their respective 1kΩ resistors. Note that all cathodes are on the side away from IC2.

And test again

Our design is incrementally functional, so you can power and test the partially completed design at just about any time. You should see LED11 and LED12 continue to alternate as before; if they do not, then you might have a short circuit that is shunting power away from IC1 and its components.

LED1 through to LED10 should flicker on and off in turn when fitted. If you get nothing at all, check that IC2 is fitted correctly, with the correct orientation and no bridges. Individual LEDs not flashing are probably a sign that a single LED or its resistor are not fully soldered.

Completion

Take your time and work through the differently-sized LEDs and resistors in turn. Don't be disappointed if you can't solder the M1005/0402 or M0603/0201 parts by hand. We have not used anything smaller than M1608/0603 in any of our designs, and even we find anything smaller than M1005 challenging.

Anything that tiny is not intended to be soldered by hand. The smaller LEDs often have exposed pads only on the underside, making it very difficult to transfer heat where it is needed.

There are some tricks you can use, such as applying a small amount of solder to the pads and trying to conduct heat through the PCB trace radiating out from the lead. Or try your hand at reflowing solder using hot air or infrared.

Cleaning

Once you are satisfied with your progress, clean up any residual flux and allow the board to dry fully. Although the board doesn't do anything incredibly useful, it is still a handy reference tool and will remind you of the tricks and techniques you learned in its construction.

Parts List – SMD Trainer

1 double-sided PCB
29106211, 71 x 40mm
1 mini-USB socket (CON1) OR
1 SMD coin cell holder (BAT1)

Semiconductors
1 7555 CMOS timer IC, SOIC-8 (IC1)
1 4017B decade counter IC, SSOP-16 (IC2)
1 2N7002 N-channel Mosfet, SOT-23 (Q1)
4 M3216/1206 size LEDs, any colour (LED1, LED6, LED11, LED12)
2 M2012/0805 size LEDs, any colour (LED2, LED7)
2 M1608/0603 size LEDs, any colour (LED3, LED8)
2 M1005/0402 size LEDs, any colour (LED4, LED9)
2 M0603/0201 size LEDs, any colour (LED5, LED10)

Capacitors (all SMD X7R 10V+ ceramic)
1 1µF M3216/1206 size
2 100nF M3216/1206 size

Resistors (all SMD 1% or 5%)
2 100kΩ M3216/1206 size
4 1kΩ M3216/1206 size
2 1kΩ M2012/0805 size
2 1kΩ M1608/0603 size
2 1kΩ M1005/0402 size
2 1kΩ M0603/0201 size