KEURIG SMART CUP

ASSEMBLY AND TESTING GUIDE

GETTING STARTED

This is a handy guide to assembling and testing the **Keurig Smart Cup** circuit board. After reading this, you should be able to assemble and test the board successfully!

So, first things first, there's some terminology you should look over, which I will be using throughout this guide:

Through-Hole - A part with lead wires or pins, which are fed through holes in the board and soldered to the opposite side.

SMD - Surface Mount Device. Parts designed to be soldered directly to the surface of the board, without drilled holes.

Pad - A rectangular area of exposed metal on the circuit board, designed to accept solder, connecting a part to the rest of the circuit board.

Footprint - The collection of pads associated with a single part.

Solder Mask - The green areas of the board. Prevents solder from sticking to the board in coated areas

Silkscreen - The white printed part markings on the top of the board

Test Point - A circular pad with a label, used for testing various voltage levels

Castellated - Semi-circular metal-coated indentations in the side of a part, which serve as pins.

Tape - The paper or plastic strip which contains parts under plastic film

Leader - The plastic removable film covering the parts in the tape

MEET THE PARTS!

Almost all of the parts you'll be working with are called **SMD** parts, or **Surface Mount Devices**. These are much smaller than the parts you typically work with on a breadboard. In fact, most have no pins at all, and are soldered directly onto the surface of the circuit board. Take some time to familiarize yourself with the shapes and sizes of the parts shown below.

RESISTOR
Much smaller than a through-hole resistor, this little thing is black on one side, with a number printed on top. You'll need a magnifying glass to read the number though. The black side always faces up.

RESISTOR ARRAY
This is four resistors in the size of two! Like the single resistor, it has a dark top side with a number printed on it. The ones we're using have "331" printed on top. These have castellated pins.

DIODE
Like its bigger brothers, this one has a white stripe on one side. It's an uncommon diode package, but it looks quite nice on the board.
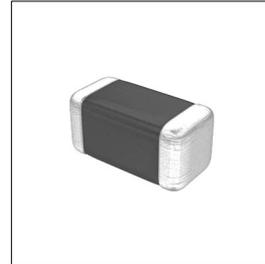
INDUCTOR
This one's pretty sneaky. It looks just like the ceramic capacitors, only it's black instead of tan. It's marked by the letter "L" on the board.

L stands for "inductor", clearly.
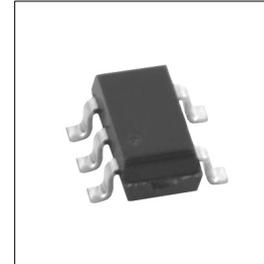
IC – SOT23
This one's called SOT23, which means Small Outline Transistor.

Sadly, the presence of the number 23 is a mystery that has been lost to time.
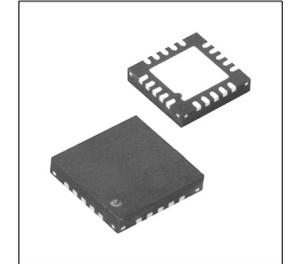
IC - QFN
This is a QFN package: Quad Flat No-Leads. They come in various sizes and pin counts, but they have no pins on the outside to solder to. This is one of the reasons we're using solder paste, since it makes soldering these guys a snap.

CERAMIC CAPACITOR
This little guy is the same size as the resistors. Like the resistor, it has a metal cap on each end. It comes in various shades of tan, and it has no markings.

It's pretty small, so don't eat it!

TANTALUM CAPACITOR
A nice yellowish brick, these are bigger than the ceramic caps, with a dark orange line on one side.

Sometimes I like to pretend these are little orange trucks driving around.

LED
These little LEDs are pretty annoying! They're as small as the resistors and capacitors, and they have a polarity marking on the bottom, but no markings on the top.

They might not look it, but they're green!

RESONATOR
This guy's my favorite. With a white base, gold contacts, and a black ceramic lid, he's the belle of the ball. This one has "737KM" printed on the top, indicating that it oscillates at 7.37MHz. This also has castellated pins.
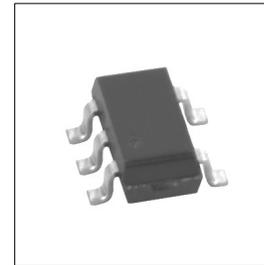
IC – SC70
This might look like a SOT23, but it's actually about half the size.

Really, please don't eat this one. It doesn't even look very delicious.
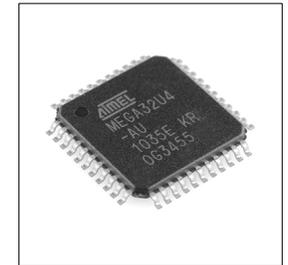
IC - QFP
The biggest chip I'm using, this is the QFP, or Quad Flat Package. A symphony in black, it has "gull wing" pins and a circular indentation in the top. This lines up with a dot on the circuit board.

POLARITY

Polarity is the presence of positive (+) and negative (-) connections on a part. An LED is a polarity-sensitive part, for example. Inserting it in the wrong way in a circuit will cause it to not work — or worse — **blow up**. It's very important to get this correct, so let's go over all the places on the board where polarity is important!
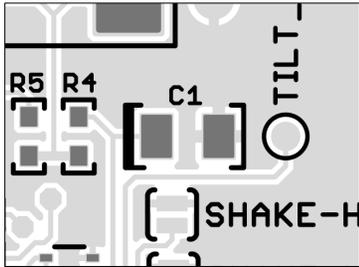
C1 (and **C4** off to the left) are polarized **tantalum capacitors**. As you saw above, they have a dark orange band on one side. There is a matching thicker line mark on the circuit board. The band on the capacitor **faces the thicker band** on the circuit board.
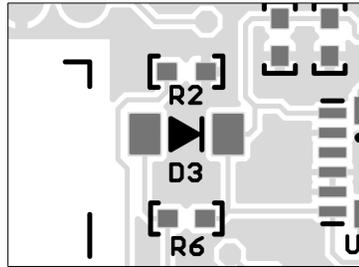
D3 is a **diode,** and all diodes are polarized. As you saw above, this one has a white band on one end. This white band should be on the **same side as the vertical line** in the transistor symbol.
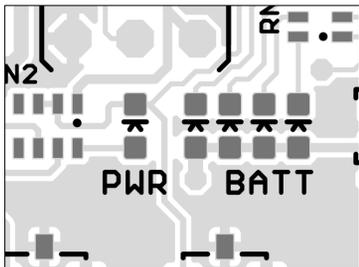
PWR and **BATT** (along with **STATUS** and **CONN.**) are **LEDs**. As you saw above, our LEDs have a large green arrow mark on their underside. This green arrow mark should point **towards the horizontal line** in the LED symbol.

ORIENTATION

Orientation applies to chips, and it refers to the rotation of the chip in relation to the circuit board. Chips almost always have a "1" pin, which is marked on the body of the chip with a **printed dot or circular indentation**. The chip should be oriented so that the first pin matches the first pin mark on the circuit board.
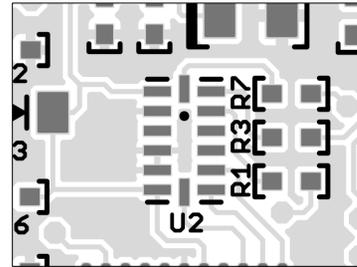
U2 is a **QFN** package chip**.** The markings on the top of the chip are difficult to see, so look at it under a light. The dot will be in the **upper left corner** of the chip, and it should match with the dot in the middle of the chip pads on the circuit board.
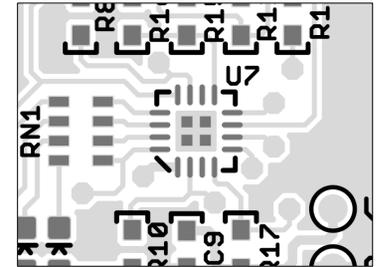
U7 is also a **QFN** package chip. Like chip U2, the markings on the top of the chip are difficult to see, so look at it under a light. The first-pin marker on the board is the **angled lower-left corner line**.
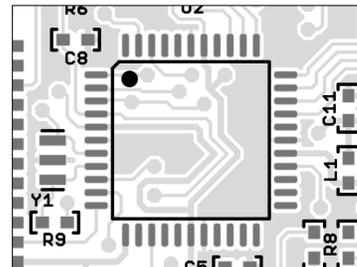
This is the main chip, a **QFP**. This chip will have a non-printed **circular indentation** in the corner of the chip, which should line up with the **dot and notched corner in the upper-left** of the chip's footprint.

Note: a few other components have dot markers printed on the board, but either their orientation is not important, or one side of the chip has a different number of pins than another side, making it unlikely to orient incorrectly. Please don't prove me wrong by orienting the side of the chip with three pins on the side of the board with only two pins.

SAFETY

Everybody loves to be safe! Being safe helps to make sure no mistakes are made during assembly, and more importantly, it gives you less of a reason to sue me when you eventually succumb to whatever sort of cancer you get from solder fumes!

Remove all loose jewelry, rings, beads, gewgaws, and dangly bits. This will prevent accidentally dragging something through the solder pasted board.

Roll up your sleeves! You don't want solder paste to get on them; I'm pretty sure even your mom couldn't get that stain out.

If you get any solder paste on your skin, remove it with rubbing alcohol. Always wash your hands when you are done, too!

Concentrate! Many of the parts you'll be handling are unlabeled. If you get distracted between picking a part out of the tape and placing it down, you will forget what the part is or where it goes. If this happens and you cannot re-identify the part, DISCARD IT and pick from the tape again.

Don't eat the paste! It's grey; you don't eat grey stuff, right? It's like 45% lead, and lead poisoning sucks. Don't get it on your fingers and put your fingers in your mouth or rub your eyes or whatever, either.

Be aware of your arms! Make sure you don't accidentally bump the board or touch the paste with your arms when moving around to pick and place parts. You could accidentally brush parts off the board and have to start over!

WORKSPACE TIPS

A clean and organized workspace is key to quality production. Remember these tips before you start working:

- Your work surface should be clean and free of solder paste, flux grossness, melty plastic, dirt, and tiny SMD components.

- Make sure the circuit board is in the middle of your work area, and your parts boards are near by.

- If you are left-handed, place the parts board to the left of the circuit board. You should never have to reach ACROSS the board to get a part. Similarly, if you are right-handed, place the parts board to the right.

- If you are out of a part on a parts board, notify me and I will restock it.

- Periodically trim the plastic tape leaders to ensure they don't get in the way.

- After you are done with the paste for a while, put the syringe back in the fridge.

- Most parts can be handled with tweezers, but the larger chips may handle better with needle-nose pliers. When using the pliers, always grab large chips by the corners, to avoid squishing any of the pins.

- Rotating the board can help position the board for easier part placement, but always be aware of how this affects part polarity and orientation!

- I'm not super into the paste stencil holding method of using tape and a bunch of extra boards. It takes a while to set up and the tape is hard to remove while trying to get a clean release from the pasted board. I can't immediately think of a better way of doing this though, at least not a cheap solution. If you have a better idea, I'm definitely open to it, so let me know!

- If you have any other ideas for process improvement, I'm all ears.

ASSEMBLY

OK, let's make a cup thing! If you remember everything you've learned so far, you're ready to whip out those tweezers and maybe even slightly degrade your vision while staring at these tiny parts!

1. **INSPECT**
   Inspect the paste, making sure all pads are covered and there isn't a lot of excess paste residue. If there are any issues, notify whoever put the paste on the board. Or if it was you, go fix it!

2. **CHECK**
   Make sure there are enough components left in each tape on the boards. Roll your shirtsleeves up and remove any jewelry from your hands and arms. Also grab a new process checklist and place it somewhere you can see it.

3. **PLACE**
   Using the Component Reference page, place components in the following order: **Resistors, Ceramic Capacitors, Tantalum Capacitors, Diodes, Misc, Integrated Circuits, Buttons, Battery Connector.**
   - As you complete each category of parts, check it off on the **process checklist**.
   - Remember to watch out for **polarity** and **orientation**!

4. **INSPECT**
   Make sure all the parts are in place, oriented correctly, and in roughly the middle of their footprints. Check off the appropriate boxes on the checklist.

5. **HEAT**
   Consult the Dave Jones video for proper technique. Make sure the airflow is set to around **4.5**. For temperatures, set the heater to **200° C**, and head the entire board for around **60** seconds or so. Raise it to **250° C**, and spot-heat a group of components until the paste reflows, then repeat until all components are reflowed.

6. **INSPECT**
   After waiting for the board to cool, inspect the solder joints under a magnifying glass. Refer to the NASA Workmanship Guidelines packet for details. Ensure that the solder coverage is even and every pin has reflowed. Remove any solder bridges with **solder wick**, and re-solder any suspicious-looking pads.

7. **SOLDER**
   Manually solder the 3x2 header pin in the middle, and the 1x2 header pin in the holes labeled **USART0**, next to the Bluetooth module.

8. **CLEAN**
   Remove any flux or paste residue with **rubbing alcohol**.

9. **TEST PREP**
   Make sure everything is checked off on the Assembly portion of the checklist. Then, write the last 4 digits of the Bluetooth module's **MAC address** in the designated area on the checklist. Fold the checklist and secure it to the board with a rubber band, and it is now ready for testing!

WAIT! SOMETHING WENT WRONG! WHAT SHOULD I DO?

Whoa there Bubs, don't panic! If anything goes wrong during the assembly process, assess the situation and see if it can be resolved safely, and without damage to the circuit board or any components.

First, return the heat gun to its stand if it's not already there. Determine if you're capable of resolving the issue, and if you are, go for it! If not, bring it to my attention and we'll work it out together.

If I'm not available, write a description of the problem on the back of the process checklist, and rubber band it to the board and place it on my desk.

TEST & PROGRAMMING

Almost there! Let's see if all that hard assembly work has paid off with a working circuit board. The last step is to test the board and program the microcontroller. You'll need some special equipment, so make sure you have a multimeter and oscilloscope near by.

Note: If at any point any of these tests fail or something unexpected happens, disconnect the power immediately and follow the instructions in the "Wait! Something Went Wrong!" box on the next page.

After each step, check the corresponding box on the process checklist if it has been completed successfully.

1. **INSPECT**
   Remove the rubber band and checklist from the board, and make sure all the items in the Assembly section have been checked. Make sure all the components are on the board and that the soldering looks reasonable. If you see any issues, alert whoever assembled the board, or if it was you, go fix it!

2. **TEST LIGHTS**
   Connect the power connector to the board, and press the **STATUS button**. If the **PWR** led does not light up, the test has failed. If it does light up, check that all 4 battery lights are lit, and the **STATUS** light is blinking in some way.

3. **TEST POWER**
   Using the multimeter, touch the red probe to the **VCC** test point, and the black probe to the **GND** test point. The multimeter should read somewhere around **3.3 volts**. If not, this test has failed.

4. **CONFIGURE PROGRAMMER**
   Plug the AVR programmer into the **2x3 header pin** connector on the board. Make sure the ribbon cable side **faces** the two buttons on the board. A **green** light should turn on inside the programmer box.

   In **AVR Studio**, open the Device Programming window using the **Ctrl+Shift+P** shortcut. Click the Apply button, and a side menu should appear in the window, along with a slider labeled "**ISP Clock**". Drag this slider to the left until the text box reads **125 kHz**, then click the **Set** button. A success notification should appear in the lower portion of the window.

5. **TEST MICROCONTROLLER**
   Click the Device Signature **Read** button near the top of the window. A hex number should appear in the window next to the button. It should read **0x1E9508**. The Target Voltage box should read **3.3 V**.

6. **SET FUSES**
   Click the **Fuses** menu item in the bar on the left. The programmer will attempt to read the fuse values. In the middle of the window will be 3 text boxes for setting the Fuse Registers: **EXTENDED**, **HIGH**, and **LOW**. Change the values as follows:

   EXTENDED: **0xFF**
   HIGH: **0xD9**
   LOW: **0xBD**

   Triple-check that you entered these numbers correctly. An incorrect fuse setting could permanently disable the chip entirely. When you have made sure they are correct, click the **Program** button. Make sure that the output text area says this was successful. Close the window when it is complete.

7. **TEST RESONATOR**
   Turn on the **oscilloscope**, then take the oscilloscope probe and connect the **black** alligator clip to the black wire on the **power supply** board. Touch the probe tip to the **4th pin from the left** on the **top edge** of the large microcontroller chip. You should see a **wiggly signal** on screen. The **Freq(1)** measurement box should read around **7.37 MHz**.

   Remove the probe from the pin and disconnect the black alligator clip, then set the probe aside.

8. **BURN PROGRAM**
   In AVR Studio, compile and burn the program using the **F5** shortcut key. The output window in the lower area of the screen should stream a bunch of stuff out, ending with "**Build succeeded**."

   Disconnect the power and programmer wires from the board.

TEST & PROGRAMMING

Continued…

9. TEST SERIAL COMMS

Rotate the board so that the two **USART0 pins** are closest to you. Take **red** wire from the **FTDI** board and connect it to the **left pin**, and the **black** wire to the **right pin**. In AVR Studio, in the 2nd column, is the **Terminal Window**. Ensure the port is set to **COM4**, and the Baud setting is **115200**.

Plug the power connector in to the board, and verify that "**Connected to PC**" has been printed to the **Receive** box in the Terminal Window. If it has not, disconnect the power and try swapping the red and black wires on the USART0 pins, then plugging the power back in again.

10. TEST BLUETOOTH COMMS

In the Terminal Window, there is a text box labeled **Send**. Ensure that the **LF** and **CR** boxes to the right are inactive, and type **$$$,** then click the **Send** button. It should print "**CMD**" in the Receive window. If not, try sending **$$$** a few more times.

The Bluetooth module is now in **Command Mode**. Click both the **LF** and **CR** buttons, then type **D** in the send field and click **Send**. It should respond with a list of settings. Again, if it doesn't respond, try sending **D** a few more times.

11. BLUETOOTH CONFIGURATION

After entering each of these commands, it should give a response of **AOK**. If it responds with **ERR** or **?**, re-enter the command and send it again a few times.

Enter the following commands, clicking **Send** after each one. There are no spaces in these commands. Ensure that you get the **AOK** response after each one before going on to the next.

S-,Keurig
SQ,128
SX,1

Enter the **D** command again and verify that **BTName** starts with **Keurig**, and **Bonded = 1**. Exit command mode by entering the command "**---**" (without quotes).

12. TEST ACCELEROMETER

Uncheck the **LF** and **CR** buttons in the Terminal Window panel, then enter "**A**" (without quotes) into the send box, and click **Send**. The device should now send accelerometer numbers out for about 5 seconds. **Shake** the board around a little, the numbers should change with your movements. Wait for the word "**DONE**" to appear in the Receive panel before continuing.

13. TEST TILT SENSOR

If the cup does not have a tilt sensor installed, you may skip this step.

Shake the board up and down or left and right, depending on which tilt sensor is installed. After several shakes, "**SHAKE**" should appear in the Receive text box.

14. WRAP UP

Disconnect the **USART0** wires, then disconnect the power connector. Ensure that your process checklist is complete and fold it back up, using the rubber band to secure it to the board, then place it in the **DONE** bin.

WAIT! SOMETHING WENT WRONG! WHAT SHOULD I DO?

If the board is being powered, turn the power off immediately!

With the board safely disconnected from power, note the last **4 digits of the MAC address** as listed on the process checklist, then start to file a **Mantis** bug report. Format the bug summary as follows – "[4 digit MAC address] – Failure at [Step you were on when you encountered the failure]". For example: "**4A5F – Failure at Bluetooth Configuration**". In the bug description, write a brief description of what you were doing, and which part of the test failed.

File the bug, and write the bug's **ID number** on the process checklist in the labeled area. Fold the checklist back up and secure it to the board with the rubber band. Then place the board in **BAD** bin.

PROCESS CHECKLIST

Date: _____

MAC Address: _____

PASTE APPLICATION

Name: _____

ASSEMBLY

Name: _____

☐ Resistors   ☐ Misc.

☐ Ceramic Capacitors   ☐ Integrated Circuits

☐ Tantalum Capacitors   ☐ Buttons

☐ Diodes   ☐ Battery Connector

☐ Polarity Check   ☐ Orientation Check

☐ Solder Check   ☐ Header Pins

## TEST & PROGRAMMING

Name: _____

☐ Lights Test   ☐ Serial Comms Test

☐ Power Test   ☐ Bluetooth Comms Test

☐ Programmer Config   ☐ Bluetooth Config

☐ Microcontroller Signature   ☐ Accelerometer Test

☐ Fuses Set   ☐ Tilt Sensor Test

☐ Resonator Test

Mantis Bug ID: _____

BOARD LAYOUT
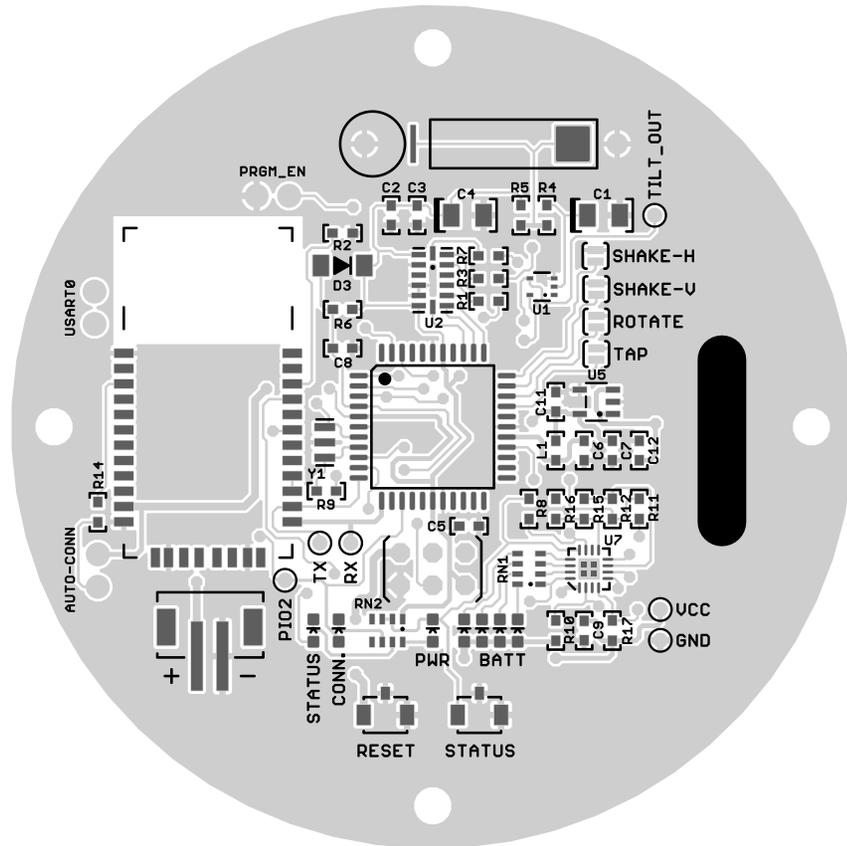
COMPONENT REFERENCE

RESISTORS	
R1, 3, 7, 14	1k Ω
R11, 12, 15, 17	2k Ω
R8	3k Ω
R4	5k6 Ω
R2, 6	10k Ω
R10	28k Ω
R16	33k Ω
R5	82k Ω
R9	1M Ω
RN1, 2	330 Ω Array

CERAMIC CAPACITORS	
C3, 5, 6, 7	0.1 µF
C2, 9, 11, 12	1 µF
C8	22 pF

TANTALUM CAPACITORS	
C1	1 µF
C4	10 µF

DIODES	
D3	S01575
All LEDS	APT1608SGC

MISC.	
Y1	7.37 MHz Resonator
L1	10 µH Inductor

INTEGRATED CIRCUITS		
U1	Schmitt-Trigger Buffer	SN74LVC1G17
U2	Accelerometer	ADXL345
U3	Microcontroller	ATMEGA324P
U5	3.3v LDO Regulator	TPS78233
U7	Quad Comparator	LM239
N/A	Bluetooth Module	RN-42-HID