

II. Safety Precautions

A. Personal protective equipment (PPE)

1. Safety glasses
2. Anti-static wrist straps
3. Pants

B. Workspace safety

1. Proper ventilation
2. Organization of tools and materials (workflow methodology)

III. Tools and Materials

A. Essential tools

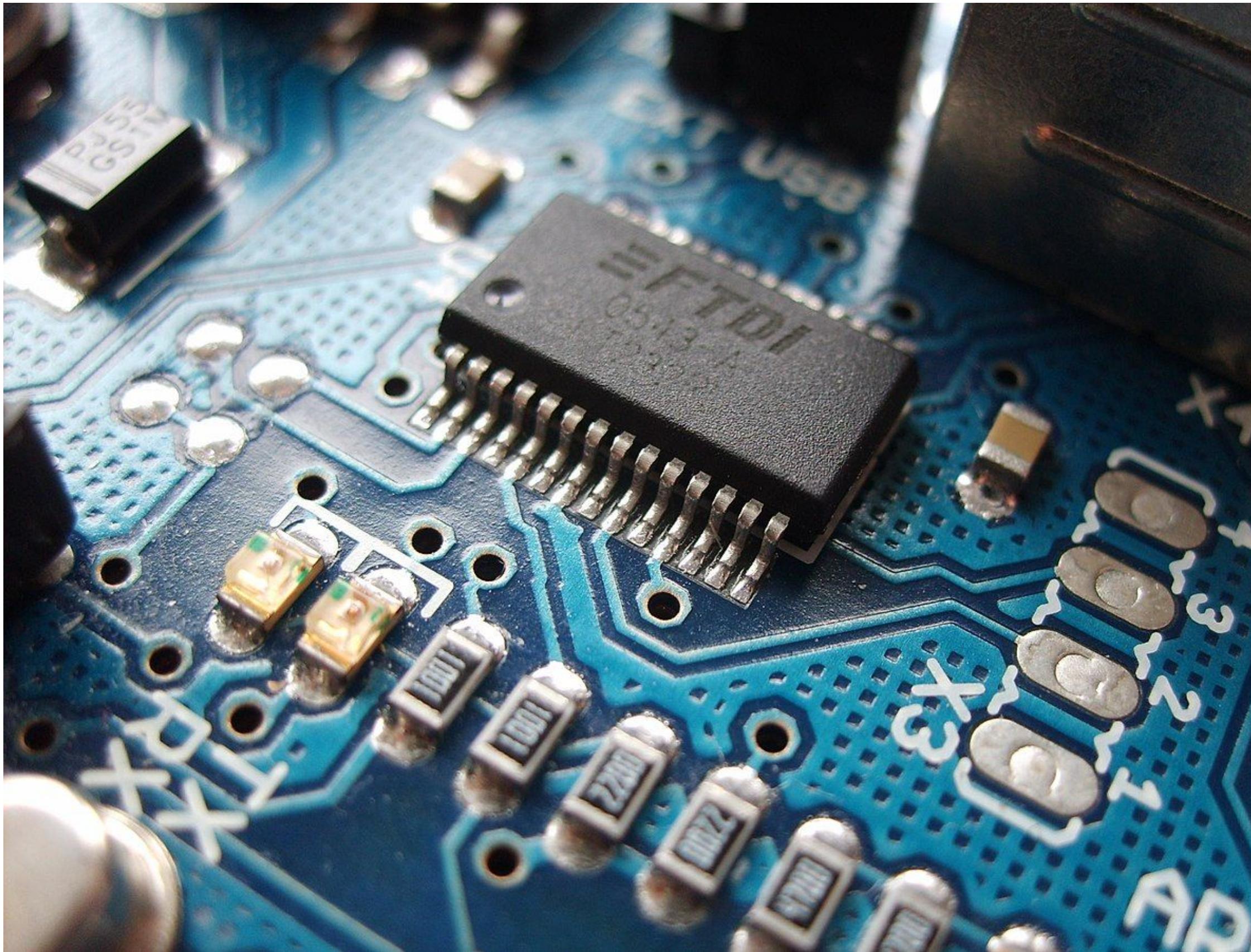
1. Soldering iron with appropriate tip
2. Solder (lead-free vs. leaded)
3. Flux (liquid, gel, and paste). No Clean/ Clean. (Plumbing [acid] Flux= Bad)
4. Cleaning solvents: IPA, Flux remover, Ultrasonic bath
5. Tweezers and pick-up tools (suction)
6. Soldering mat or station
7. Loupe, Microscope (USB or eyepiece-less stereo microscopes)
8. Kapton [polyimide] tape
9. Stick-vice or blue tape
10. Flush cutter, wire strippers,

IV. Preparing for SMD Soldering

A. PCB preparation

1. Surface Cleaning

Surface Mount Technology (SMT)



Hi!

Your Instructor: Ryan Bates

Edu: BSEE

Exp: 10yr + Electrical and
Hardware Engineering

Ask questions any time!

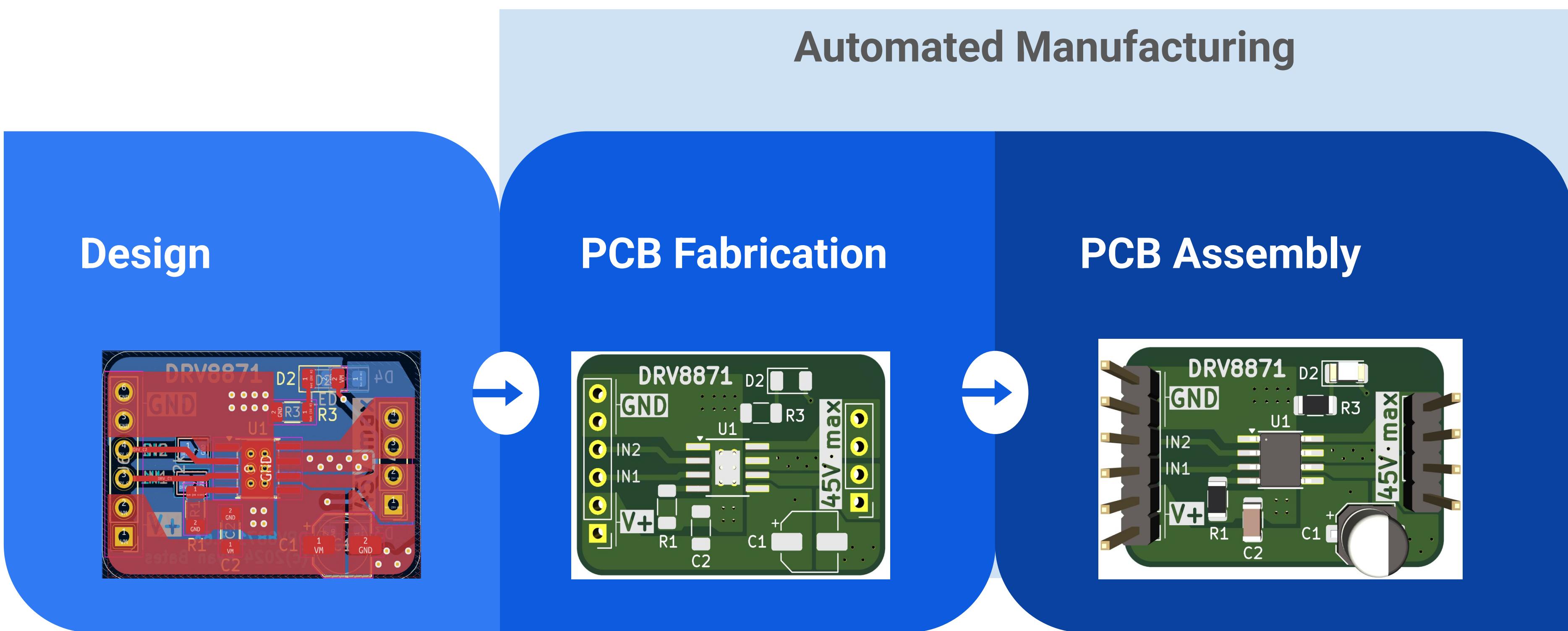


Education vs Experience

Skills take time to learn.
Invest in yourself.

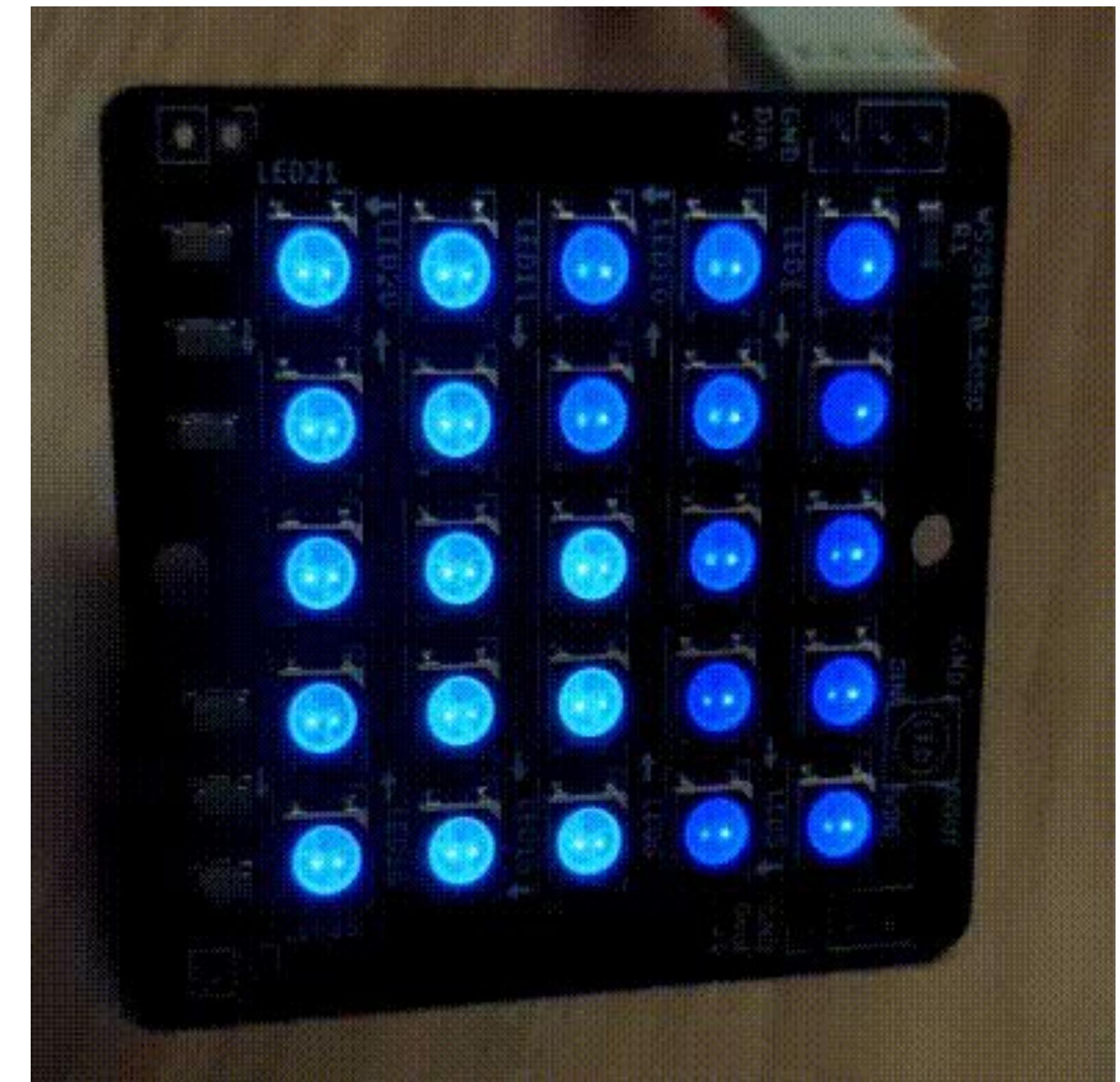
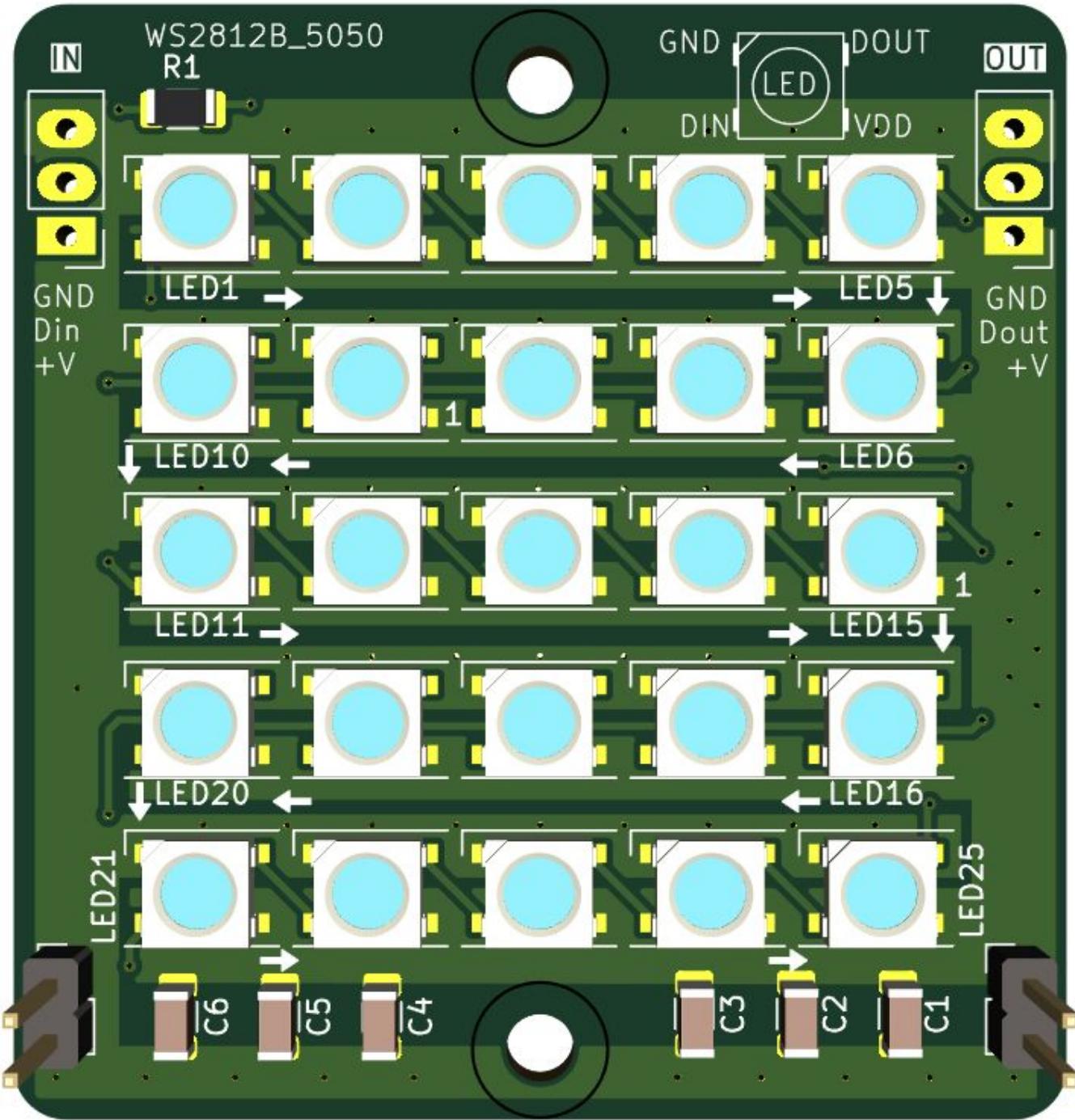
(ryan tells story about his first engineering job)

Surface Mount Technology (SMT)



Surface Mount Technology (SMT)

We will build this!



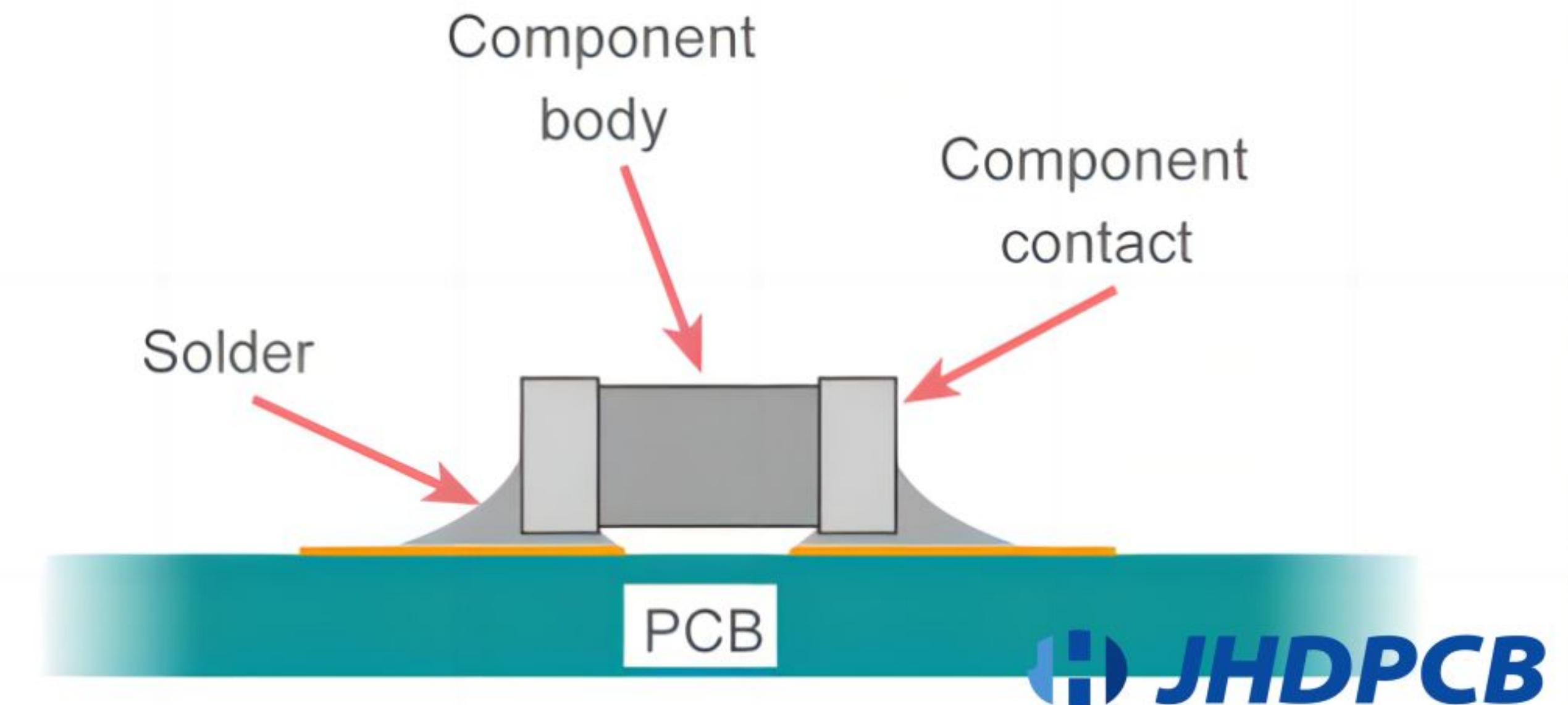
Surface Mount Technology (SMT)



PRECISION Starts
From Every Step

Surface Mount Technology (SMT)

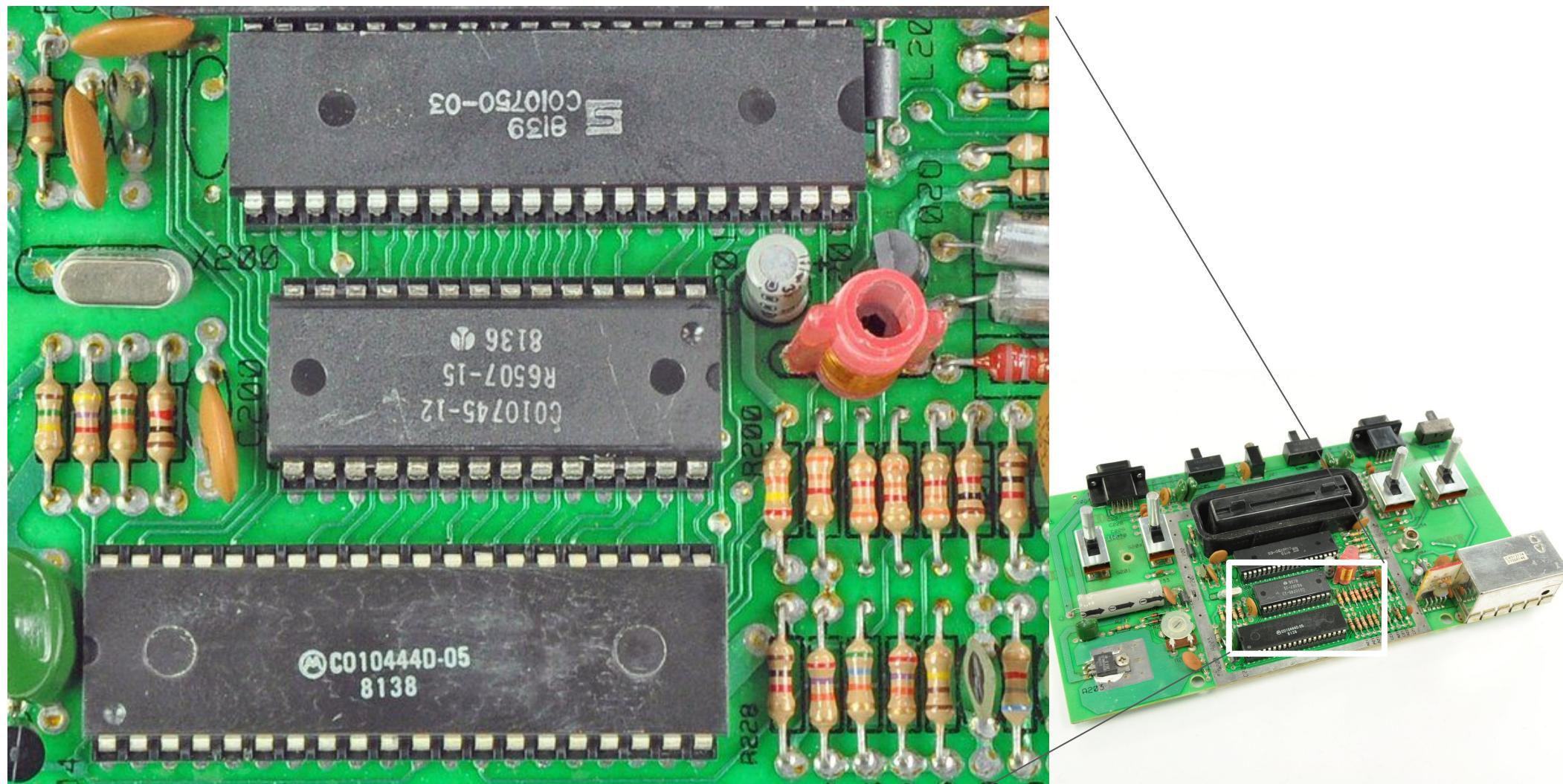
Electronics Manufacturing.



Introduction to SMT

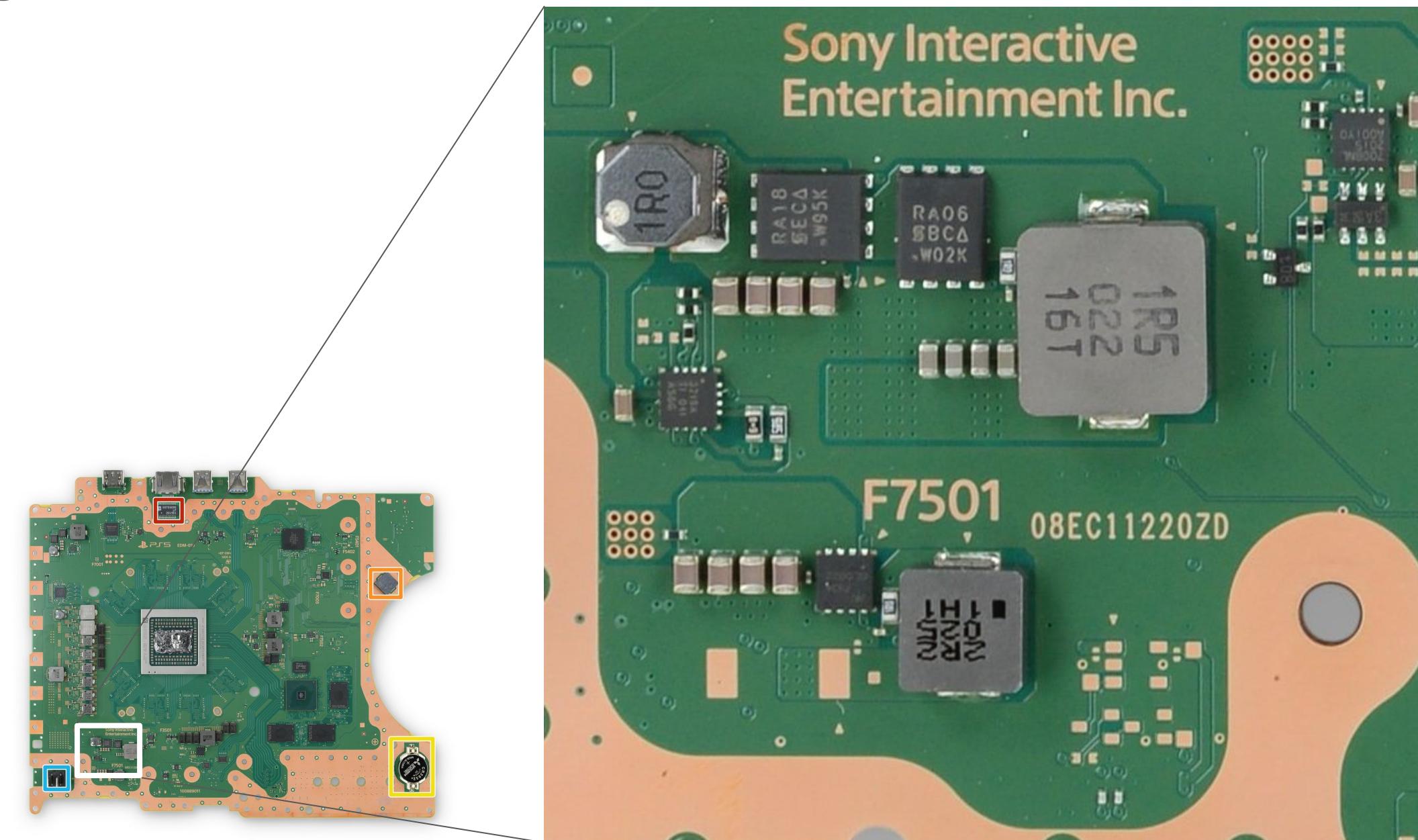
SMT = Surface Mount Technology.

Printed Circuit Board (PCB) assembly by mounting components (Surface Mount Devices) directly onto the surface.



Atari 2600 PCB (1977)

© ifixit <https://guide-images.cdn.ifixit.com/igi/WV5iq3vUCpG5fpOI.huge>



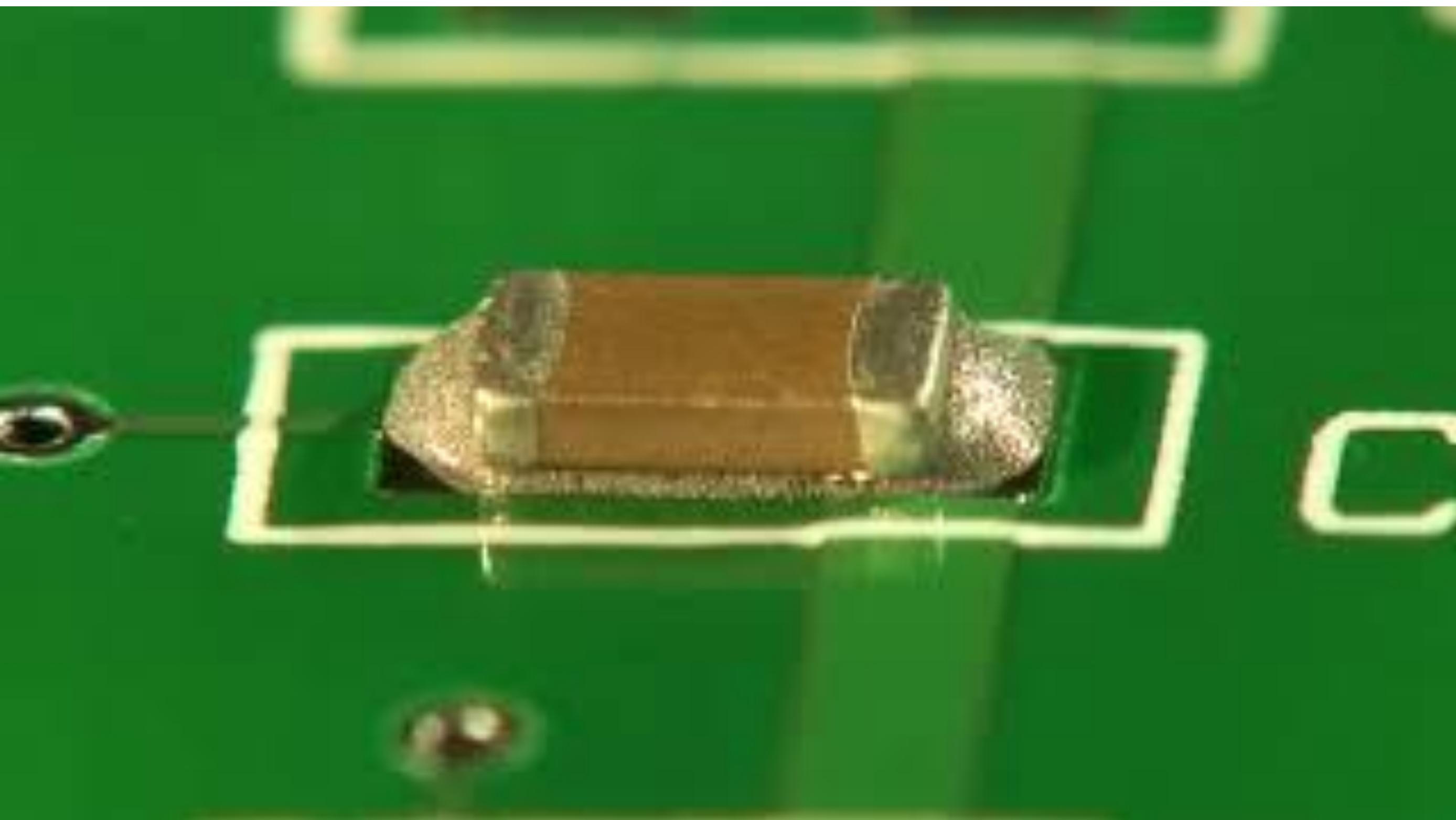
PlayStation 5 motherboard (2020)

© ifixit <https://guide-images.cdn.ifixit.com/igi/FUGnem5h2EmFLwlA.huge>

Benefits of SMT

- Smaller component size + Predictable shape/ footprint
- Higher component density
- Automated assembly
- Low Cost & High Output

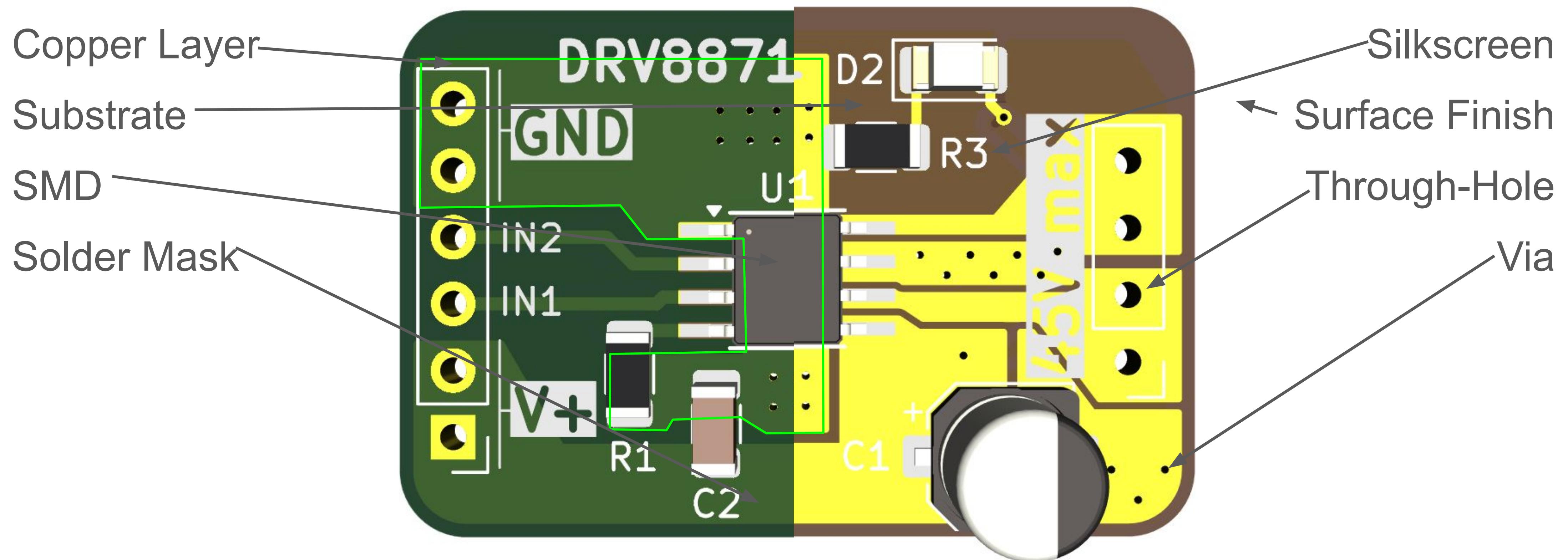
SMD video:



Applications of SMT

- **Consumer Electronics:** Smartphones, tablets, laptops,
- **Automotive Industry:** ECU, battery management
- **Industrial Electronics:** automation systems, robotics, plant monitoring
- **Medical Devices:** production, diagnose, monitoring equipment.
- **Economies of Scale:** SMT allows for high volume production at lower costs.

PCB Basic Vocabulary



PCB Basic Vocabulary

(Surface Finish)

Two common examples:

HASL (Hot Air Surface Level)

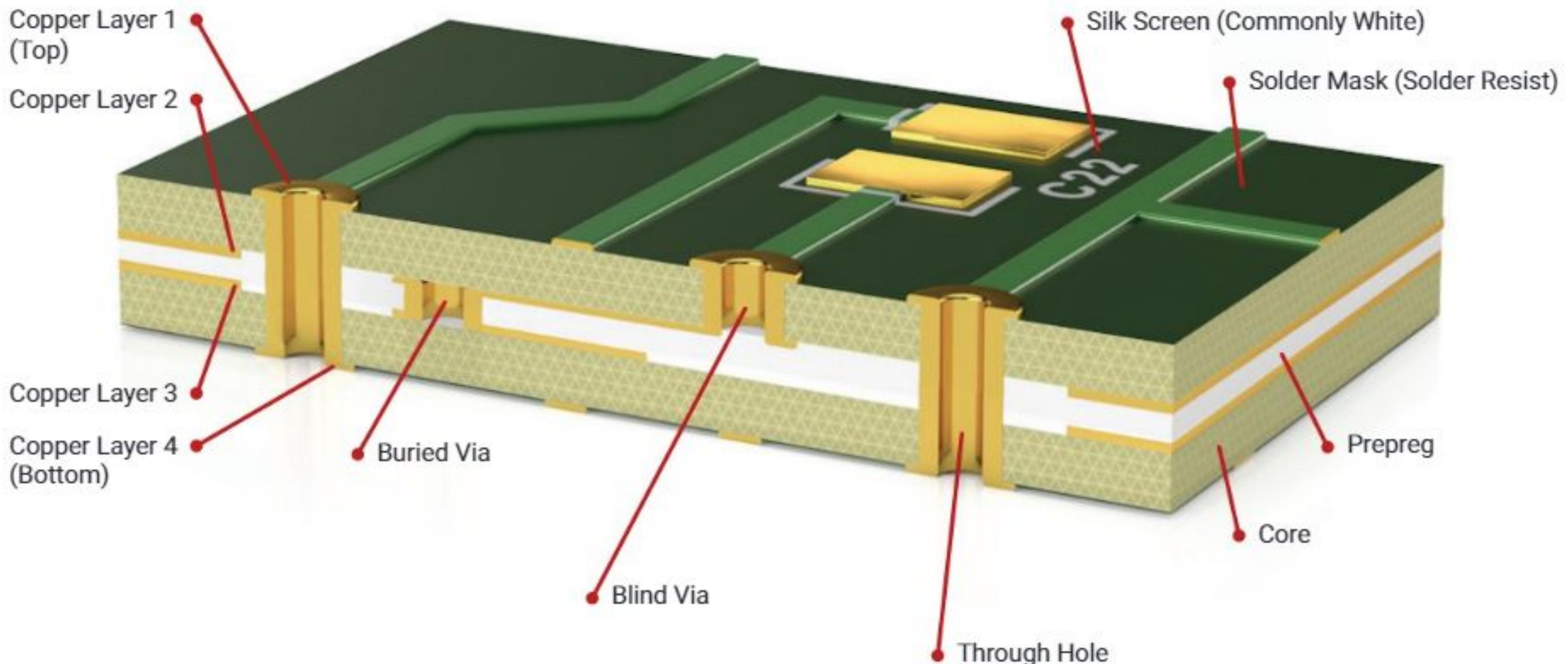
ENIG (Electroless Nickel Immersion Gold)

Conformal Coating

...a dozen more



PCB Layers



Regulatory and Compliance

Safety Standards: PCBs (and electronics) often need to meet safety standards. USA's main regulatory body is UL (Underwriters Laboratories).

Examples: UL 60079-0 and UL 923.

Can you spot something UL listed/ registered.

[Public Search](#)

On file with UL?

What's the product category/code?

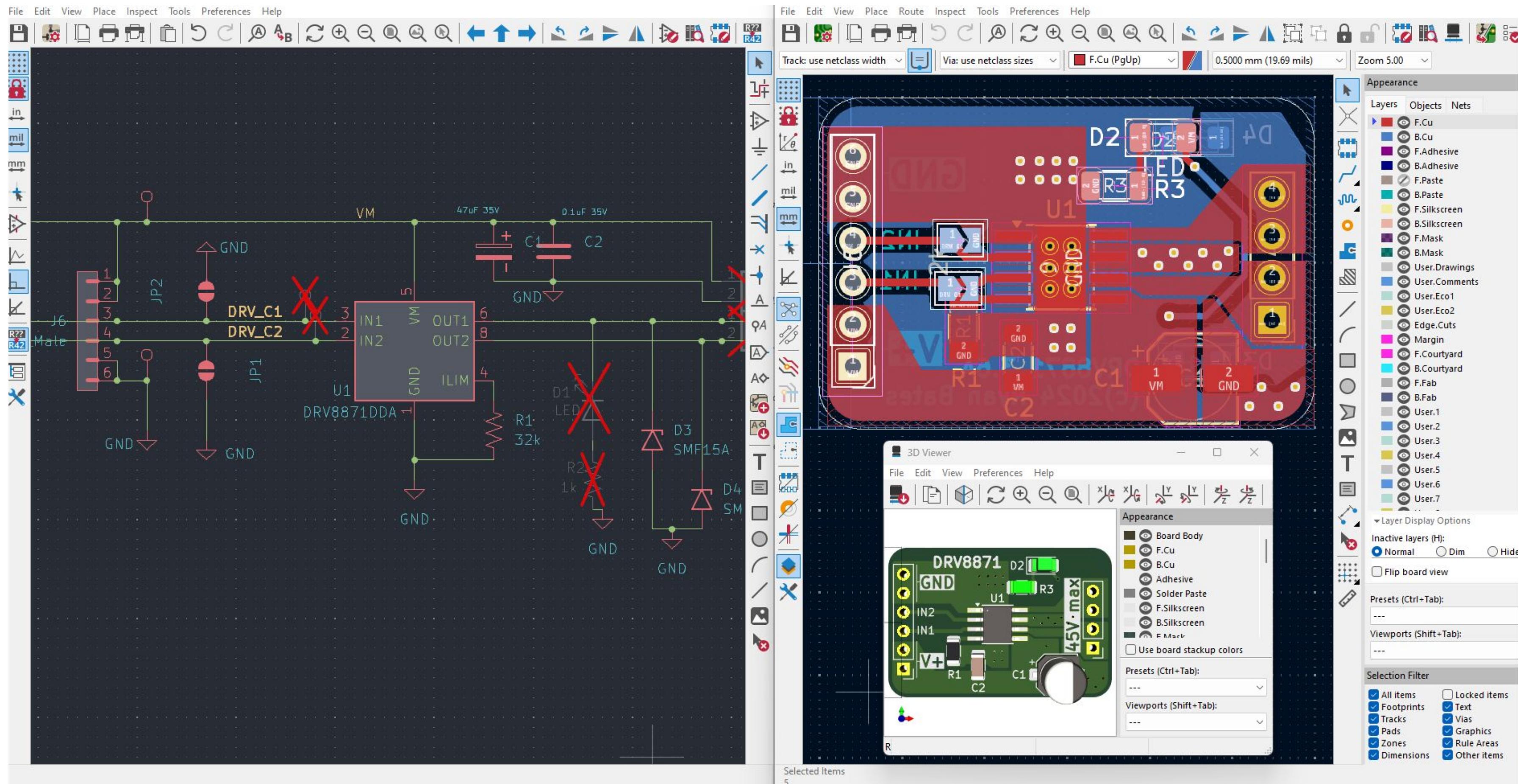


Example: Dell Laptop Charger

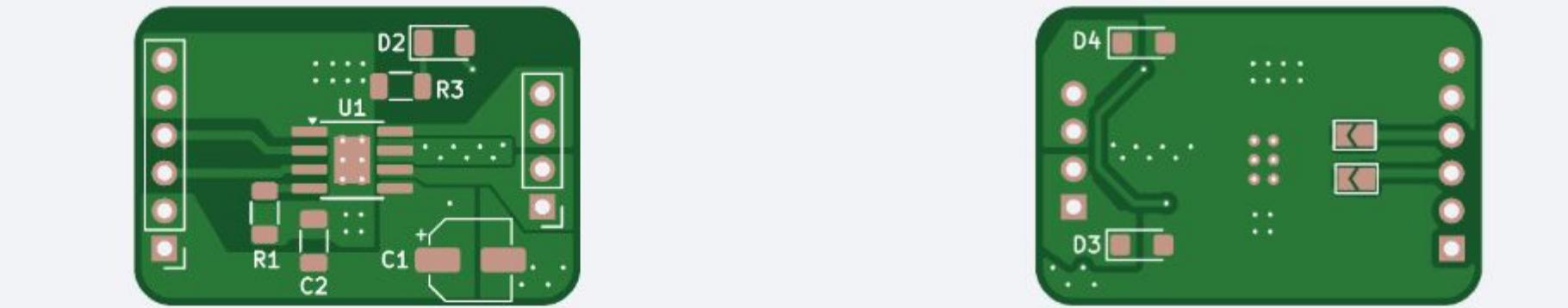


Electronic Design Automation (EDA Tools)

KiCAD, EasyEDA, Eagle (Autodesk Fusion), Altium, Cadence...



PCB Manufacturing Services



← Back to Upload File Detected 2 layer board of 20.07x29.97mm(0.79x1.18 inches). Gerber Viewer

Base Material: FR-4, Flex, Aluminum, Copper Core, Rogers, PTFE Teflon

Layers: 1, 2 (selected), 4, High Precision PCB (6, 8, 10, 12, 14, 16, More)

Dimensions: 29.97 * 20.07 mm

PCB Qty: 5

Product Type: Industrial/Consumer electronics (selected), Aerospace, Medical

PCB Specifications

Different Design: 1 (selected), 2, 3, 4,

Delivery Format: Single PCB (selected), Panel by Customer, Panel by JLCPCB

PCB Thickness: 0.4, 0.6, 0.8, 1.0, 1.2, 1.6 (selected), 2.0

PCB Color: Green (selected), Purple, Red, Yellow, Blue, White, Black

Silkscreen: White

Surface Finish: HASL(with lead) (selected), LeadFree HASL, ENIG

Charge Details

Special Offer	\$2.00
Via Covering	\$0.00
Surface Finish	\$0.00

Build Time

PCB:	<input checked="" type="radio"/> 2 days	\$0.00
	<input type="radio"/> 24 hours	\$7.30
	<input type="radio"/> 24 hours PCBA Only	\$0.00

Calculated Price: \$4.00 - \$2.00
Additional charges may apply for [special cases](#)

SAVE TO CART

Shipping Estimate: \$1.52
Global Standard Direct Line 8-13 business days

Weight: 0.13kg

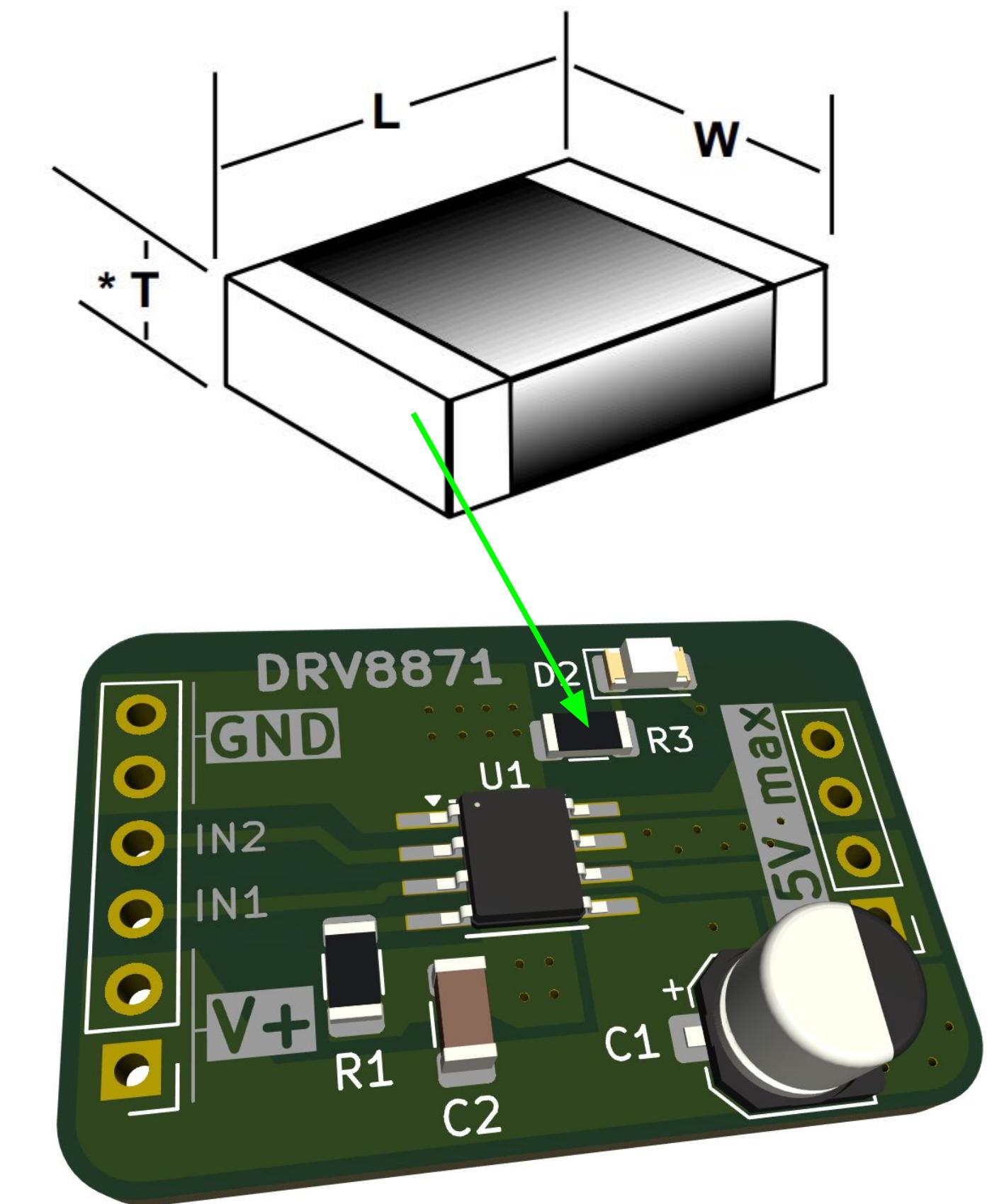
Coupons: [Save \\$30.00](#) [Save \\$9.00](#)

Online, turn-key manufacturing.

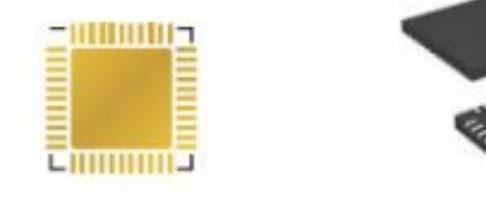
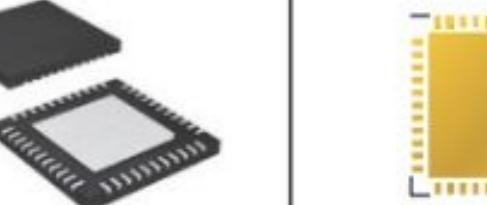
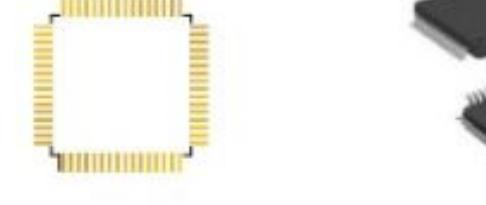
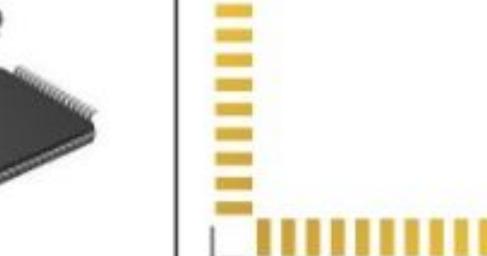
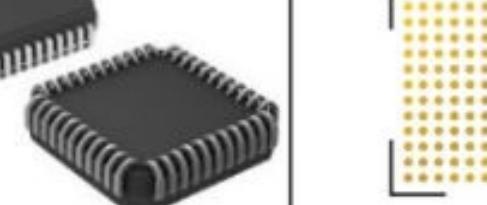
SMD Package Sizes (basic)

Flat chip nomenclature.

Size Code		Approximate Size (LxW)	
Inch	Metric	Inch	Metric
0402	1005*	.04" x .02"	1.0 x 0.5mm
0504	1210*	.05" x .04"	1.2 x 1.0mm
0603	1508	.06" x .03"	1.5 x 0.8mm
0805	2012	.08" x .05"	2.0 x 1.2mm
1005*	2512	.10" x .05"	2.5 x 1.2mm
1206	3216	.12" x .06"	3.2 x 1.6mm
1210*	3225	.12" x .10"	3.2 x 2.5mm
1812	4532	.18" x .12"	4.5 x 3.2mm
2225	5664	.22" x .25"	5.6 x 6.4mm



SMD (common parts)

 8-SOIC (0.154", 3.90 mm Wide)	 8-TSSOP, 8-MSOP (0.118", 3.00 mm Wide)	 SC-70, SOT-323	 SOT-23-3, TO-236-3, SC-59
 14-TSSOP (0.173", 4.40 mm Wide)	 TO-261-4, TO-261AA, SOT-223-3	 TO-252-3, DPak (2 Leads+Tab), SC-63	 TO-263-3, D²Pak (2 Leads+Tab), TO-263AB
 QFN-44 (7 mm x 7 mm)	 QFN-44 (8 mm x 8 mm)	 QFN-44 (9 mm x 9 mm)	
 TQFP-64	 PLCC-44	 BGA-169 (11 mm x 11 mm)	

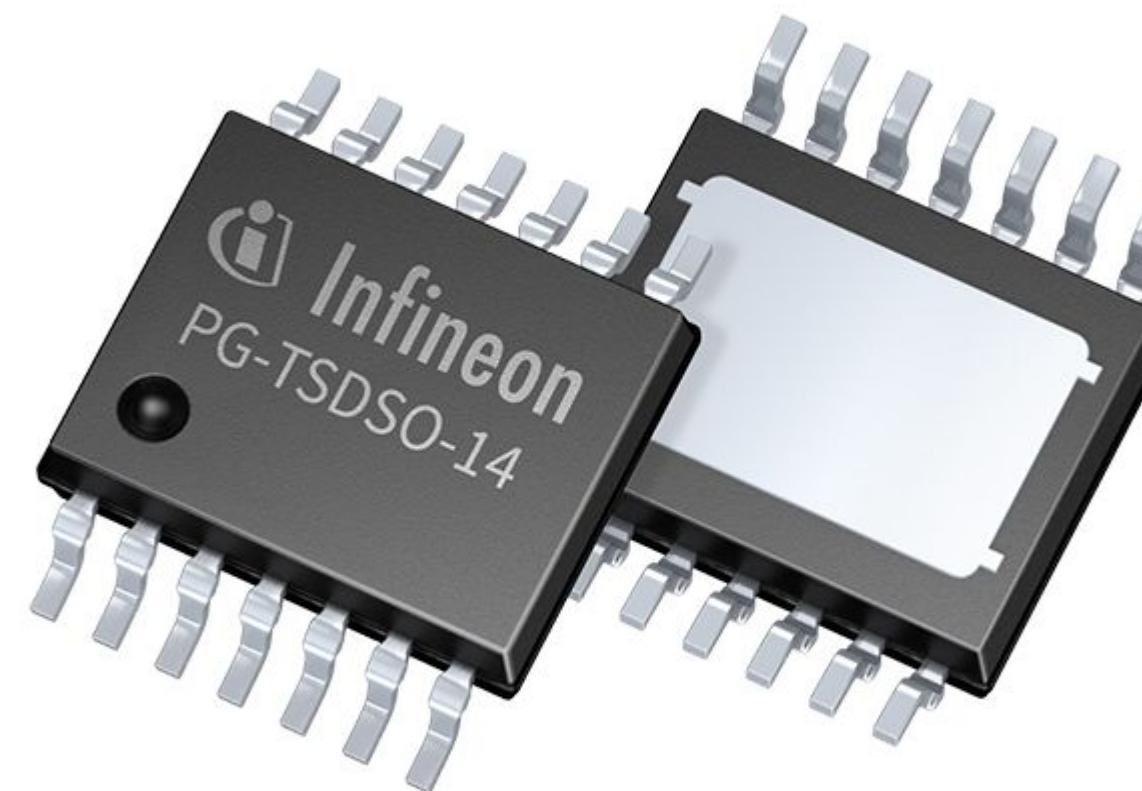
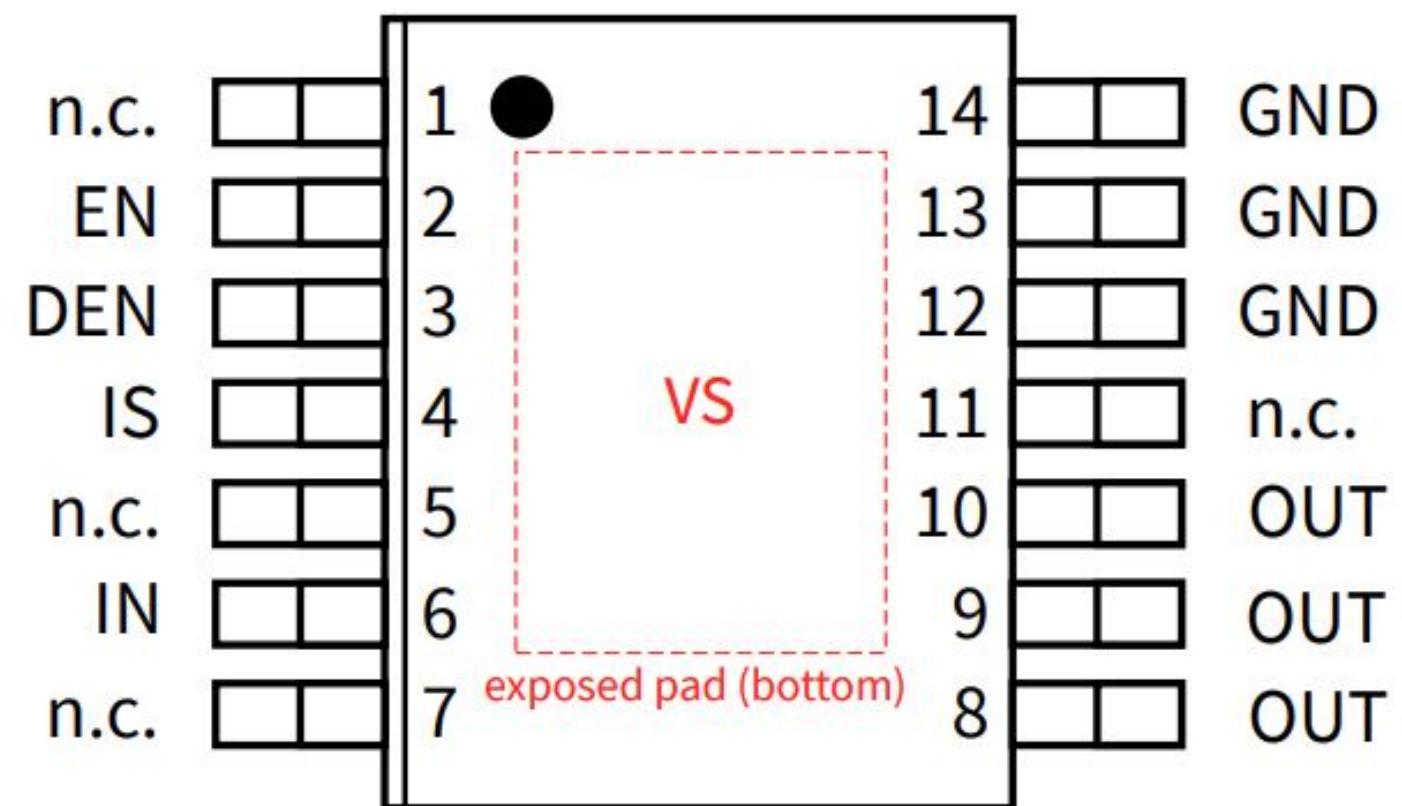
SMD (continued)

Small Outline	Dual Flat No Lead DFN	Quad Flat No Lead QFN	Plastic Shrink Small Outline SSOP	Plastic Small Outline SOIC
 Bumped Die (WLCSP)  3-lead DDPAK (EB)	 8-lead DFN (MC) $2 \times 3 \times 0.9 \text{ mm}$	 16-lead QFN (MG) $3 \times 3 \times 0.9 \text{ mm}$	 8-lead MSOP (MS)	 8-lead SOIC (SN)
 Die/Wafer (WLCSP)	 8-lead TDFN (MN) $2 \times 3 \times 0.75 \text{ mm}$	 20-lead QFN (ML) $4 \times 4 \times 0.9 \text{ mm}$	 10-lead MSOP (UN)	 8-lead SOIC (SM)
 3-lead SC70 (LB)	 5-lead DDPAK (ET)	 8-lead UDFN (MU) $2 \times 3 \times 0.5 \text{ mm}$	 20-lead QFN (MQ) $5 \times 5 \times 0.9 \text{ mm}$	 16-lead QSOP (QR)
 5-lead SC70 (LT)	 3-lead SOT-89	 8-lead DFN (MF) $3 \times 3 \times 0.9 \text{ mm}$	 28-lead UQFN (MV) $4 \times 4 \times 0.5 \text{ mm}$	 20-lead SSOP (SS)
 3-lead SOT-23 (TT/CB)	 3-lead TO-92 (TO/ZB)	 8-lead DFN (MD) $4 \times 4 \times 0.9 \text{ mm}$	 28-lead QFN (MQ) $5 \times 5 \times 0.9 \text{ mm}$	 28-lead SSOP (SS)
 5-lead SOT-23 (OT)		 8-lead DFN (MF) $6 \times 5 \times 0.9 \text{ mm}$	 28-lead QFN (MM & ML) $6 \times 6 \times 0.9 \text{ mm}$	 16-lead SOIC (SL)
 6-lead SOT-23 (OT/CH)		 Very Thin Thermal Leadless Array VTLA	 40-lead UQFN (MV) $5 \times 5 \times 0.5 \text{ mm}$	 18-lead SOIC (SO)
 3-SOT-223 (DB)	 5-lead TO-220 (AT)		 8-lead TSSOP (ST)	 20-lead SOIC (SO)
 4-lead SOT-143 (RC)		 36-lead VTLA (TL) $5 \times 5 \times 0.9 \text{ mm}$	 14-lead TSSOP (ST)	 28-lead SOIC (SO)
		 44-lead VTLA (TL) $6 \times 6 \times 0.9 \text{ mm}$	 20-lead TSSOP (ST)	
		 124-lead VTLA (TL) $9 \times 9 \times 0.9 \text{ mm}$		
		 64-lead QFN (MR) $9 \times 9 \times 0.9 \text{ mm}$		
Plastic Thin Shrink Small Outline TSSOP				

There are hundreds of packages / footprints.

Pin Indication, Polarity, Standards

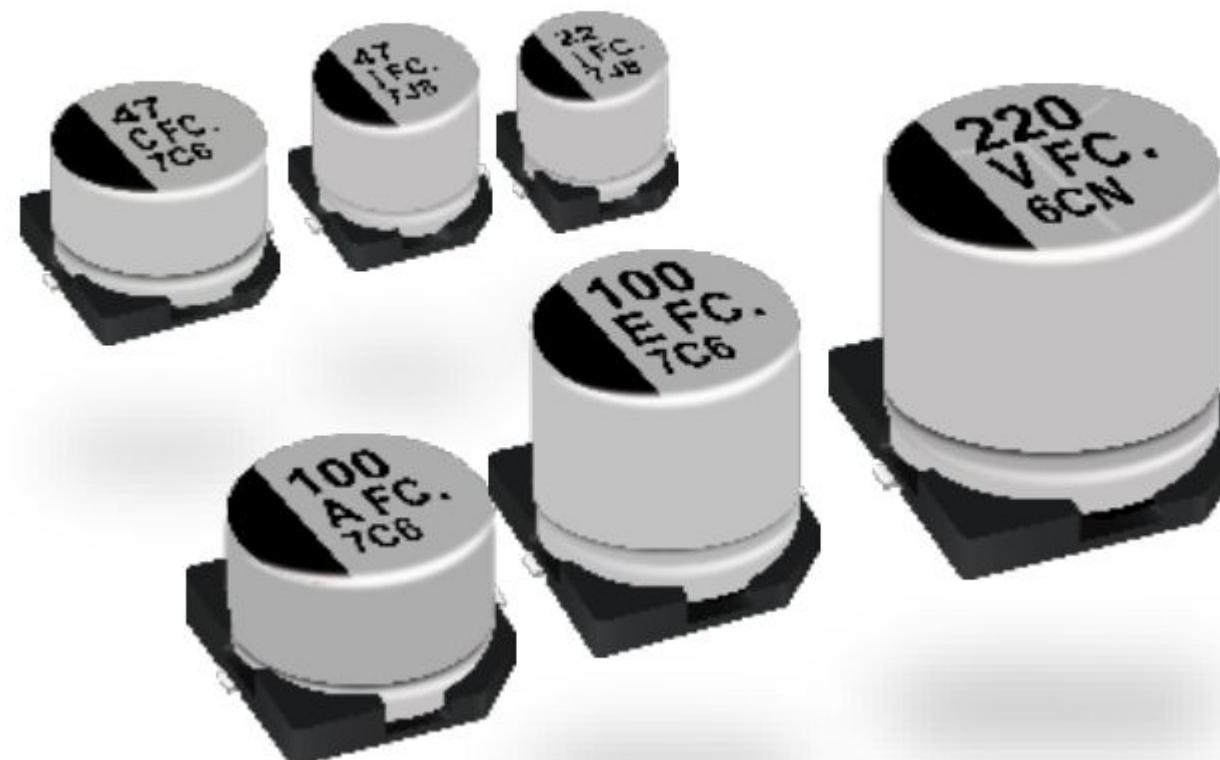
Fiducial mark



<https://www.digikey.com/en/products/detail/infineon-technologies/BTN70301EPAXUMA1/13898609>

Pin Indication, Polarity, Standards

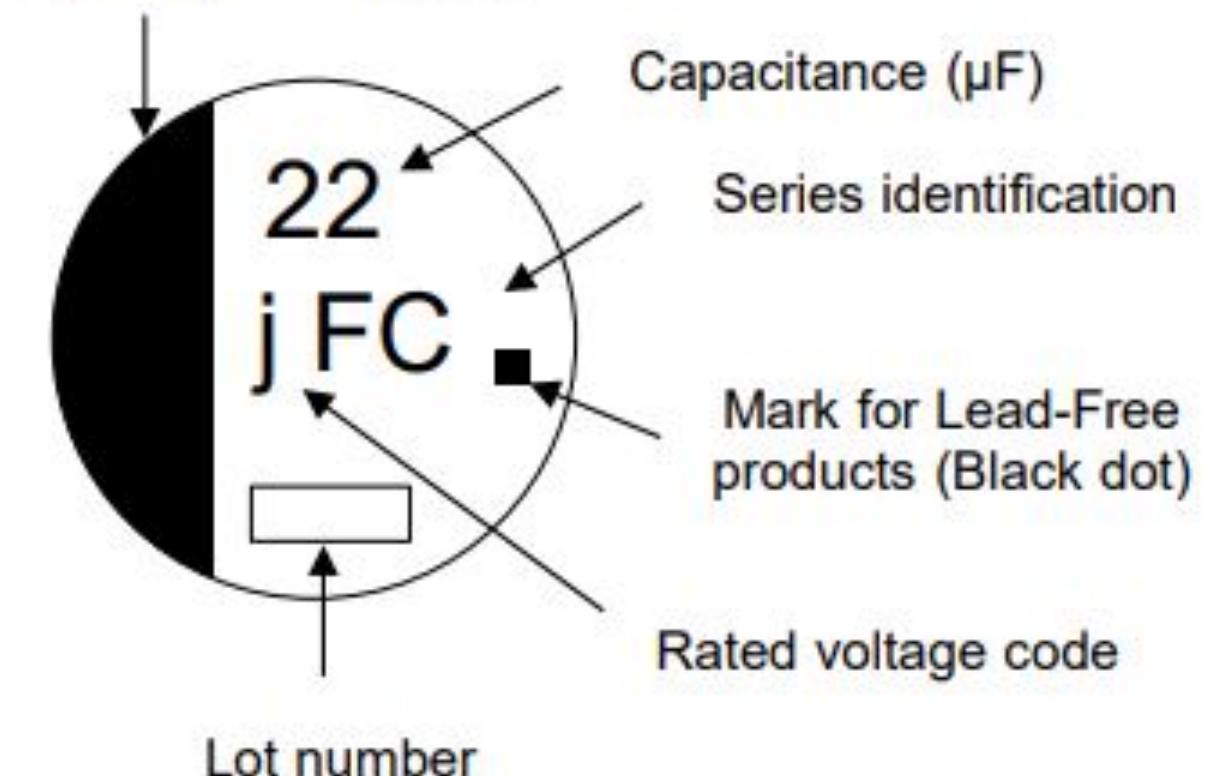
Polarity marking



Marking

Example : 6.3 V 22 μ F
Marking color : BLACK

Negative polarity marking (-)



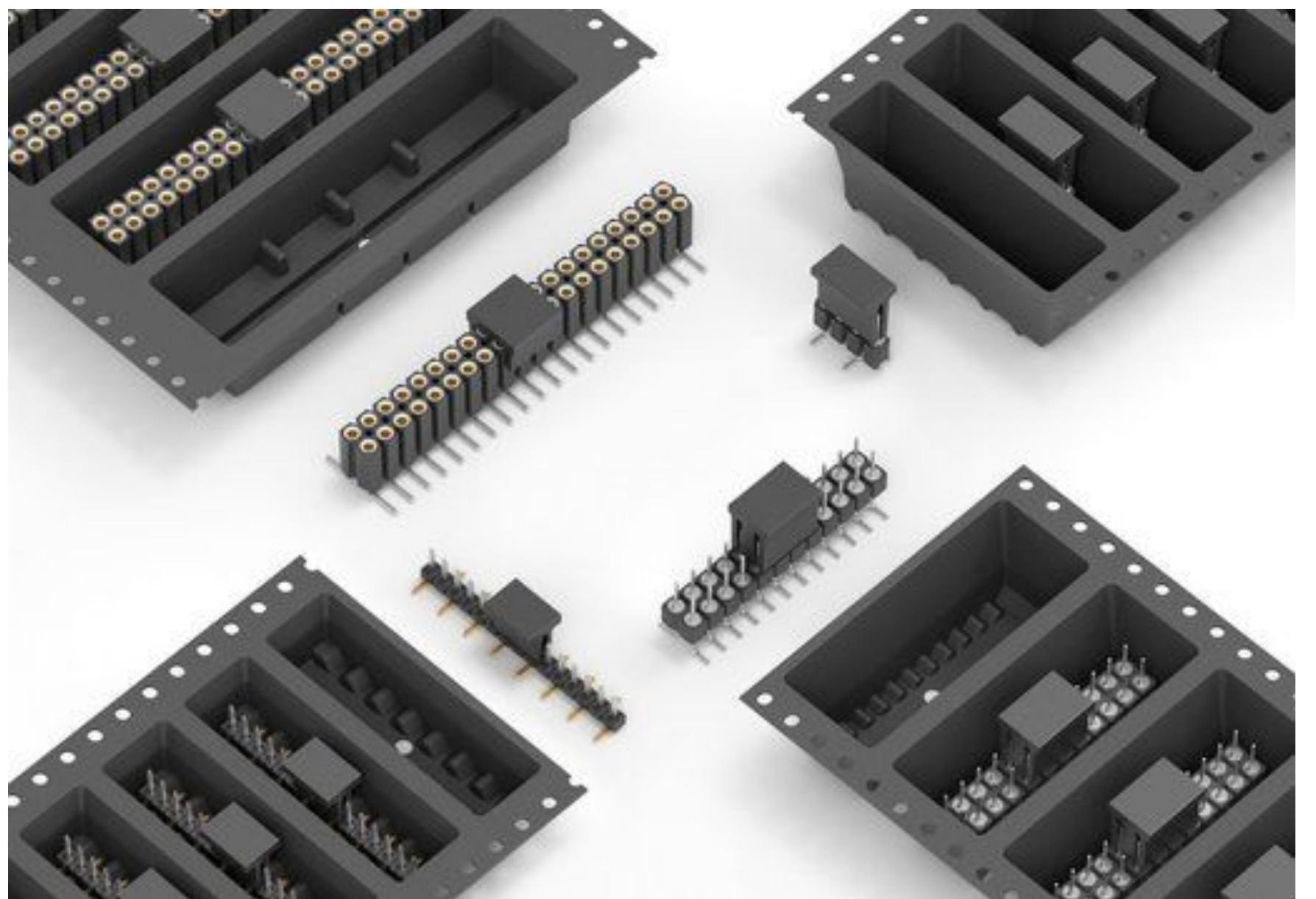
R.voltage code

Unit : V

j	6.3	E	25
A	10	V	35
C	16	H	50

Pin Indication, Polarity, Standards

Picking complexities



Where to Buy Parts

Pick reputable vendors.

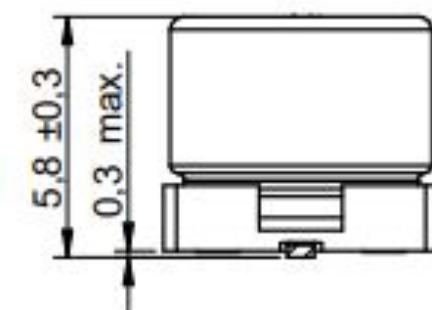
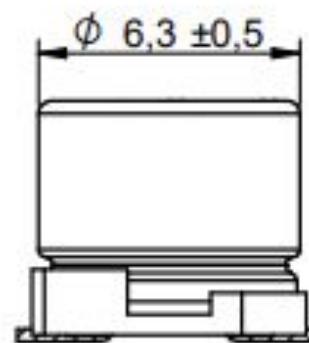
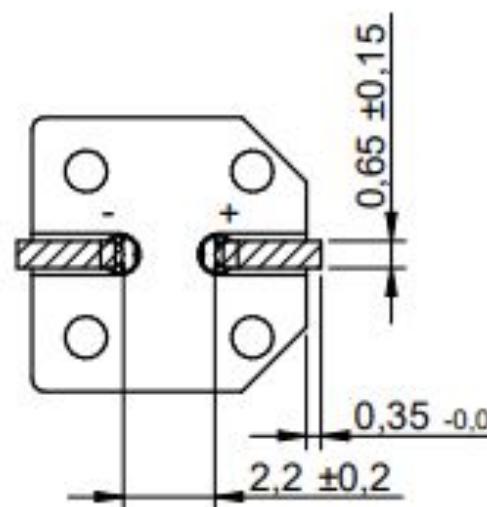


ARROW ELECTRONICS, INC.



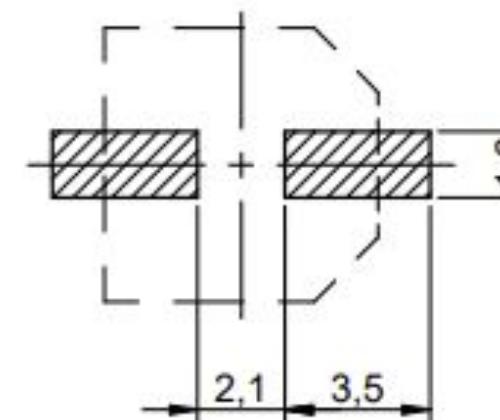
Datasheets!

Dimensions: [mm]



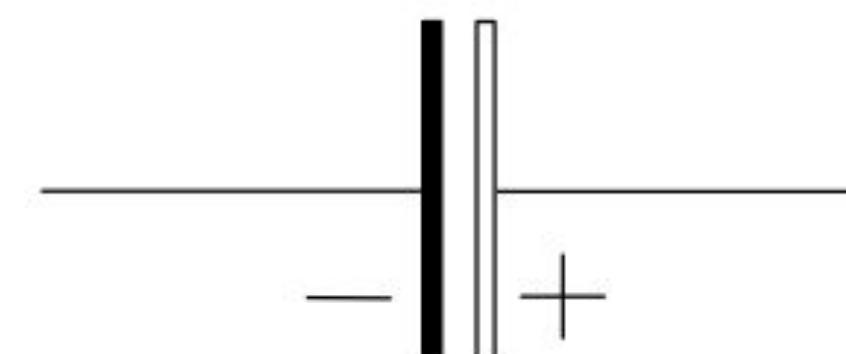
Scale - 3:1

Recommended Land Pattern: [mm]



Scale - 3:1

Schematic:



Scale - 3:1

Electrical Properties:

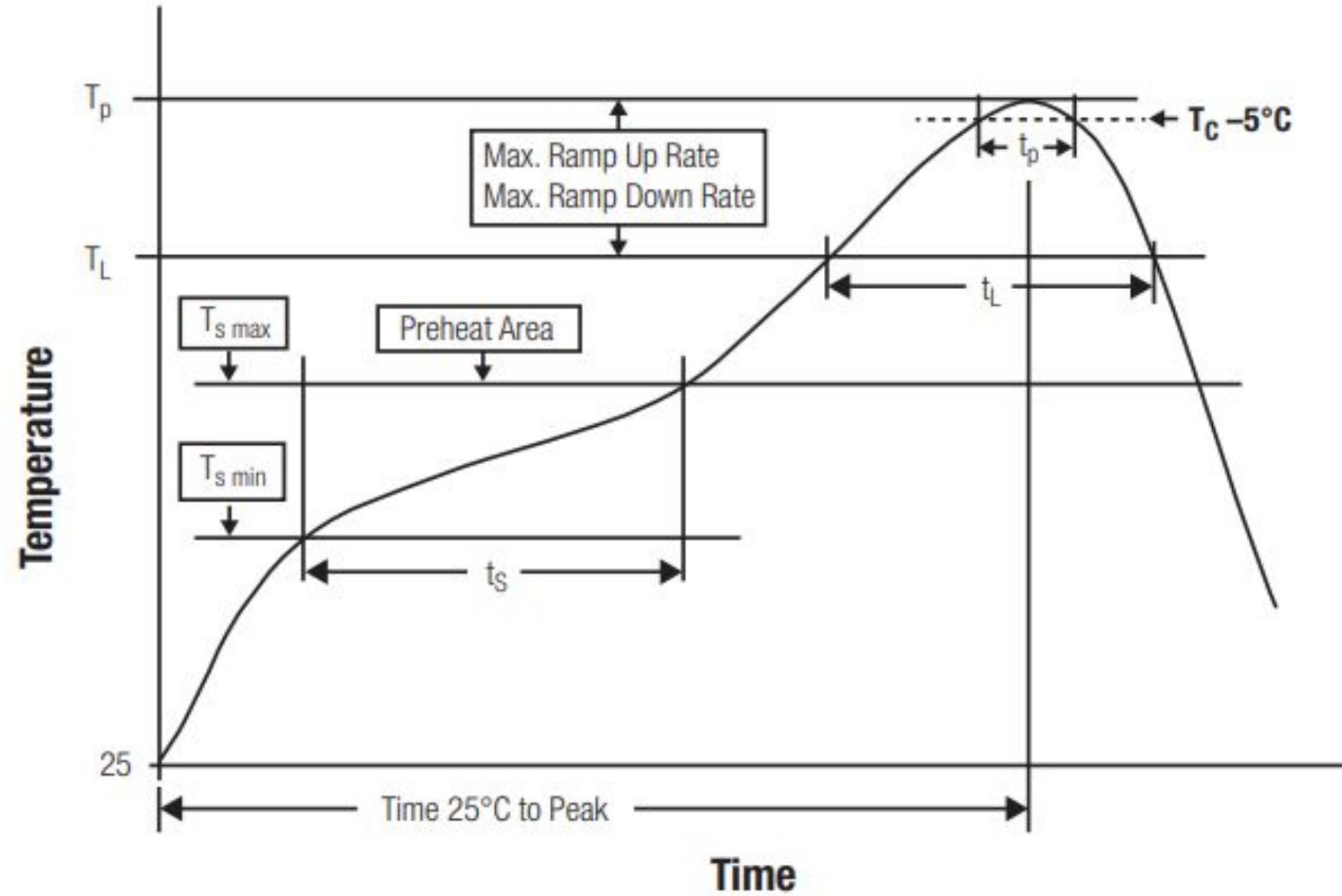
Properties	Test conditions	Value	Unit	Tol.	
Capacitance	C	0.25 V / 120 Hz / +20 °C	220	µF	±20%
Rated Voltage	V _R		10	V (DC)	max.
Surge Voltage	V _S	1000 cycles @ 20 °C	11.5	V (DC)	max.
Leakage Current	I _{Leak}	2 min. / +20 °C	300	µA	max.
Dissipation Factor	DF	0.25 V / 120 Hz / +20 °C	8	%	max.
Ripple Current	I _{RIPPLE}	100 kHz @ 105 °C	1970	mA	max.
ESR	R _{ESR}	0.25 V / 100 kHz / +20 °C	30	mΩ	max.

General Information:

Aluminum Polymer Capacitors	
Operating Temperature	-55 up to +105 °C
Storage Conditions (in original packaging)	5 °C up to + 35 °C; 10 % up to 75 % RH
Endurance	2000 h
Moisture Sensitivity Level (MSL)	1
Test conditions of electrical properties: +20 °C, 35 % RH if not specified differently	
FIT according to separate documentation	
Surge Voltage: charging time 30 s, discharging time 330 s for a cycle	

Datasheets!!

Classification Reflow Profile for SMT components:



Classification Reflow Soldering Profile:

Profile Feature	Value
Preheat Temperature Min	$T_{s \min}$ 150 °C
Preheat Temperature Max	$T_{s \max}$ 200 °C
Preheat Time t_s from $T_{s \min}$ to $T_{s \max}$	t_s 60 - 120 seconds
Ramp-up Rate (T_L to T_p)	3 °C/ second max.
Liquidous Temperature	T_L 217 °C
Time t_L maintained above T_L	t_L 60 - 150 seconds
Peak package body temperature	T_p $T_p \leq T_c$, see Table below
Time within 5°C of actual peak temperature	t_p 20 - 30 seconds
Ramp-down Rate (T_p to T_L)	6 °C/ second max.
Time 25°C to peak temperature	8 minutes max.

refer to IPC/ JEDEC J-STD-020E

Package Classification Reflow Temperature (T_c):

Properties	Volume mm ³ <350	Volume mm ³ 350-2000	Volume mm ³ >2000
PB-Free Assembly Package Thickness < 1.6 mm	260 °C	260 °C	260 °C
PB-Free Assembly Package Thickness 1.6 mm - 2.5 mm	260 °C	250 °C	245 °C
PB-Free Assembly Package Thickness > 2.5 mm	250 °C	245 °C	245 °C

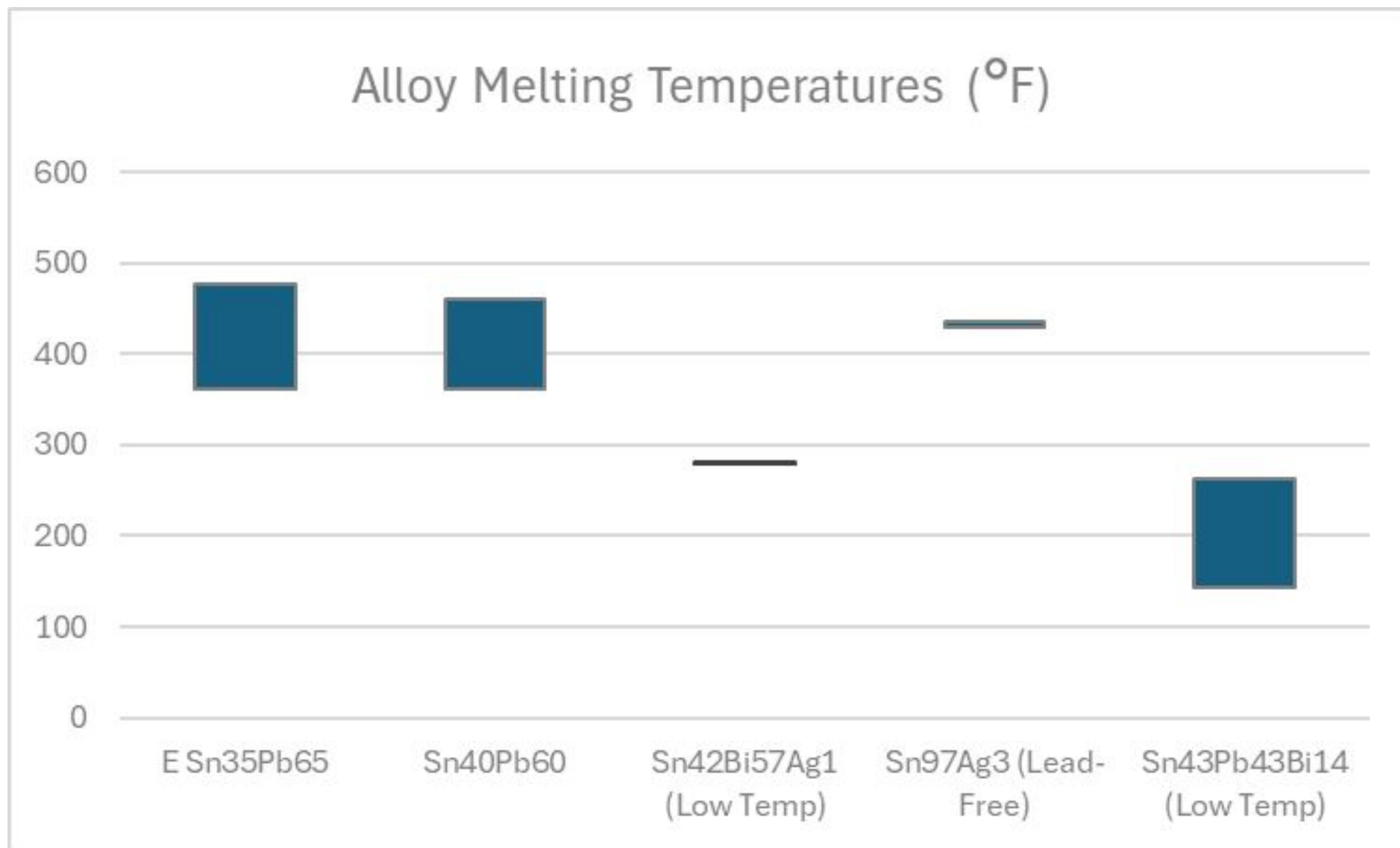
refer to IPC/ JEDEC J-STD-020E

Temperature

- Solder alloys have different melting temperatures
- SMD are not immune to heat.



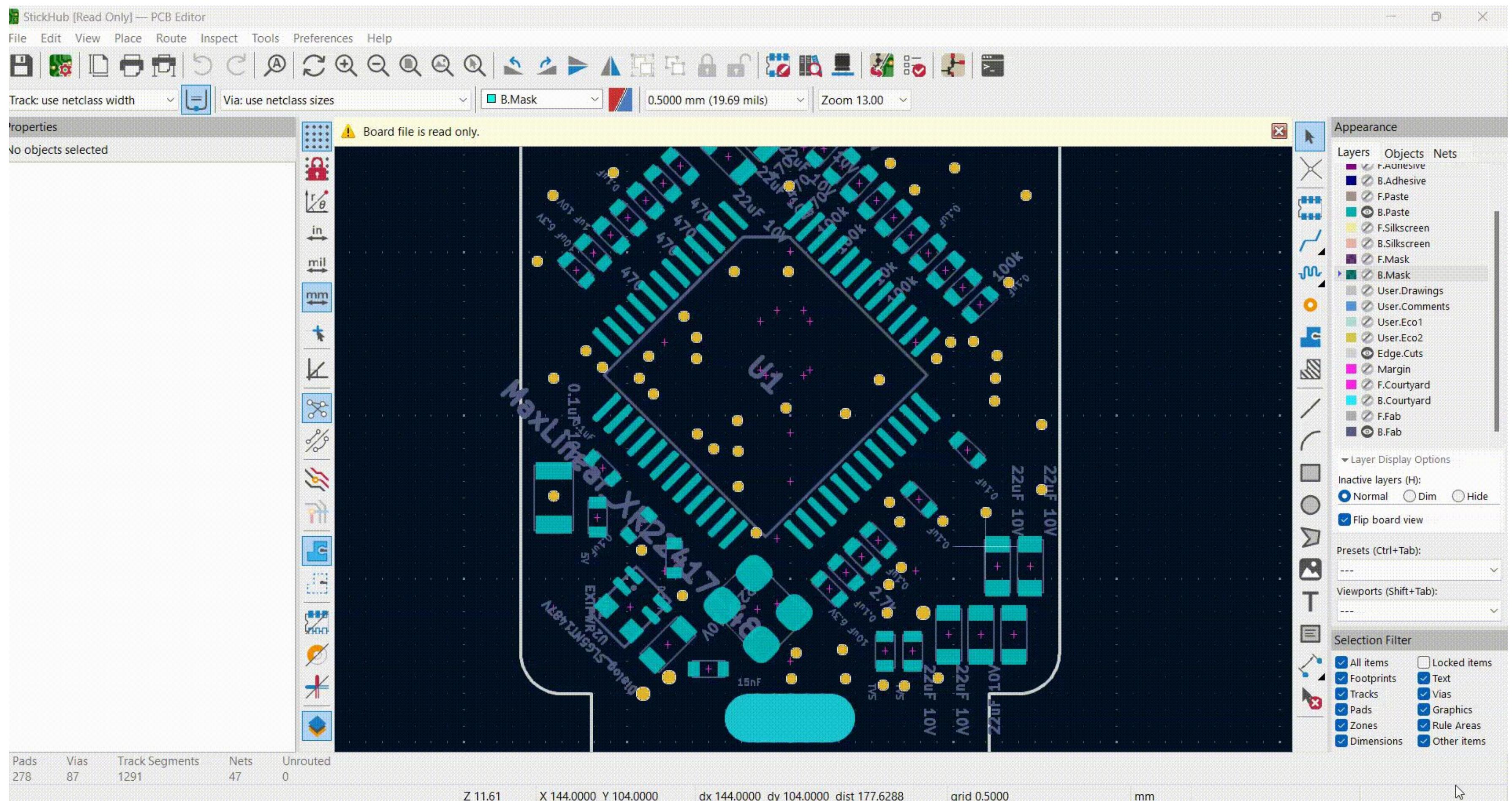
Alloy Temperatures



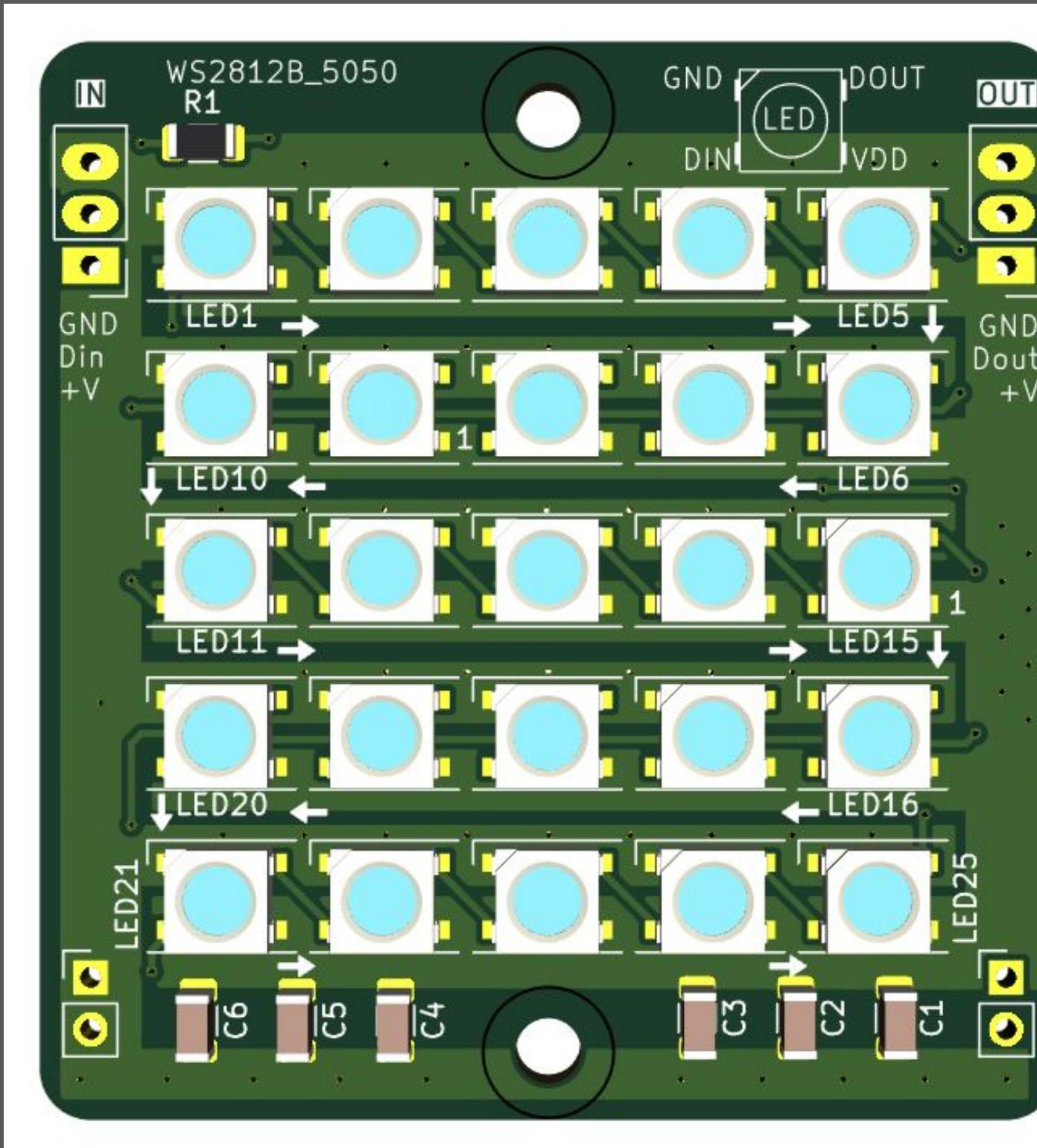
Automated Assembly: Pick and Place



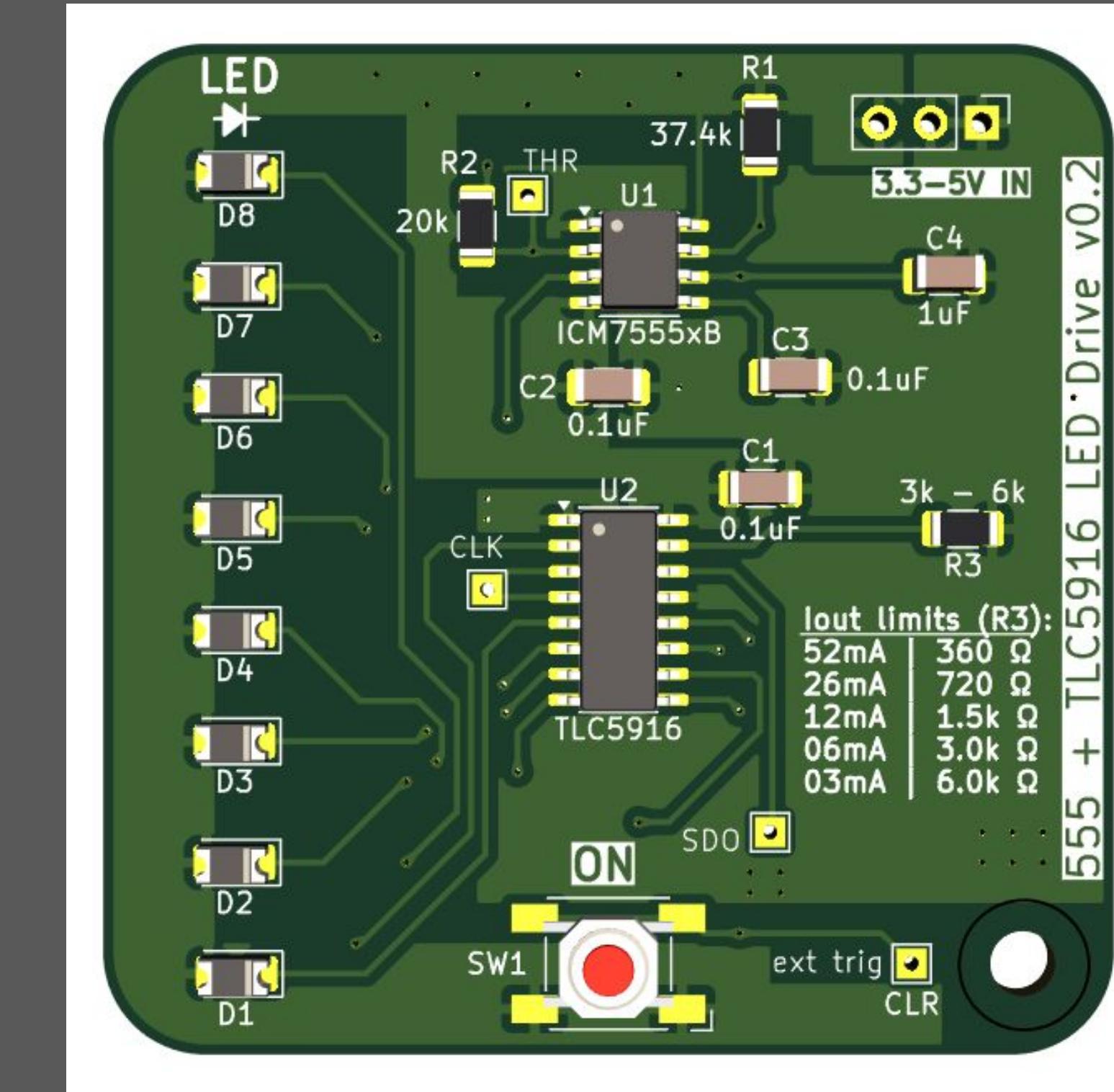
Pick and Place: Position Data



Let's Make: Two SMD Soldering Projects!



Beginner



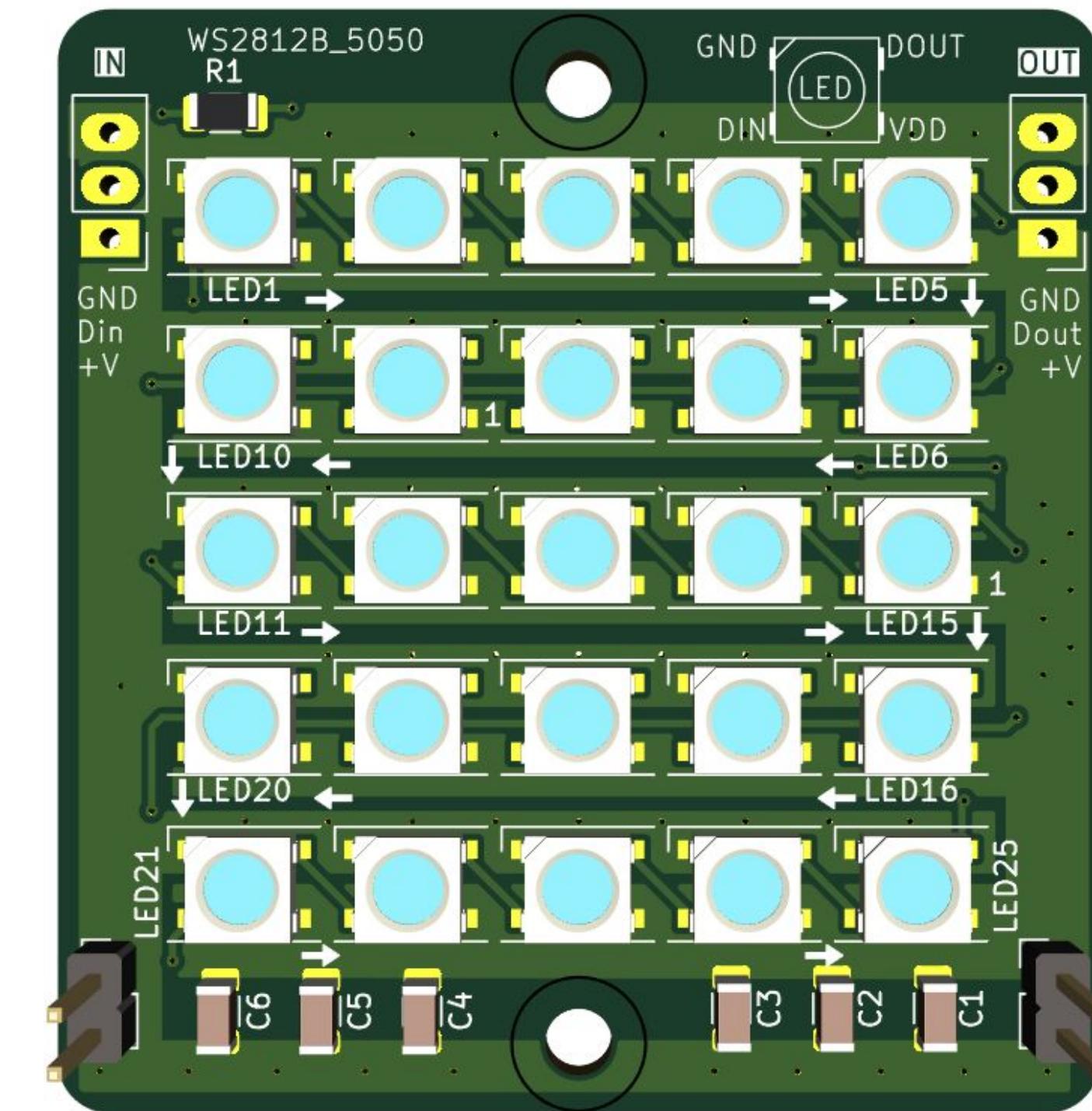
Intermediate

Soldering Tools and Supplies

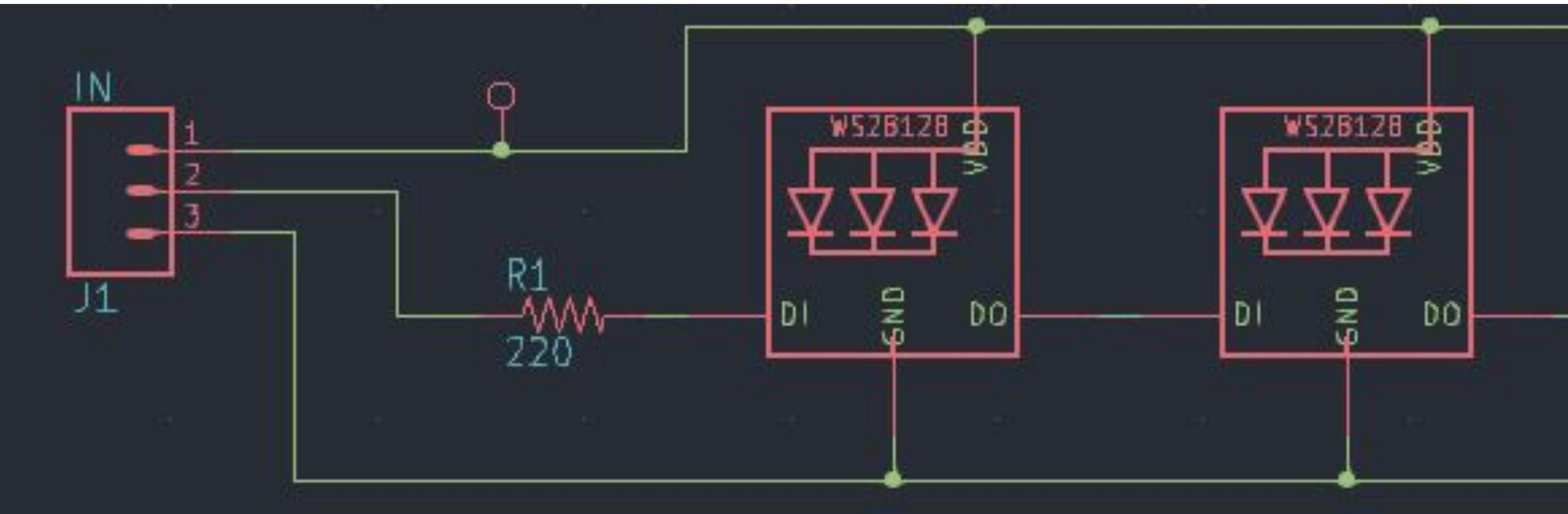
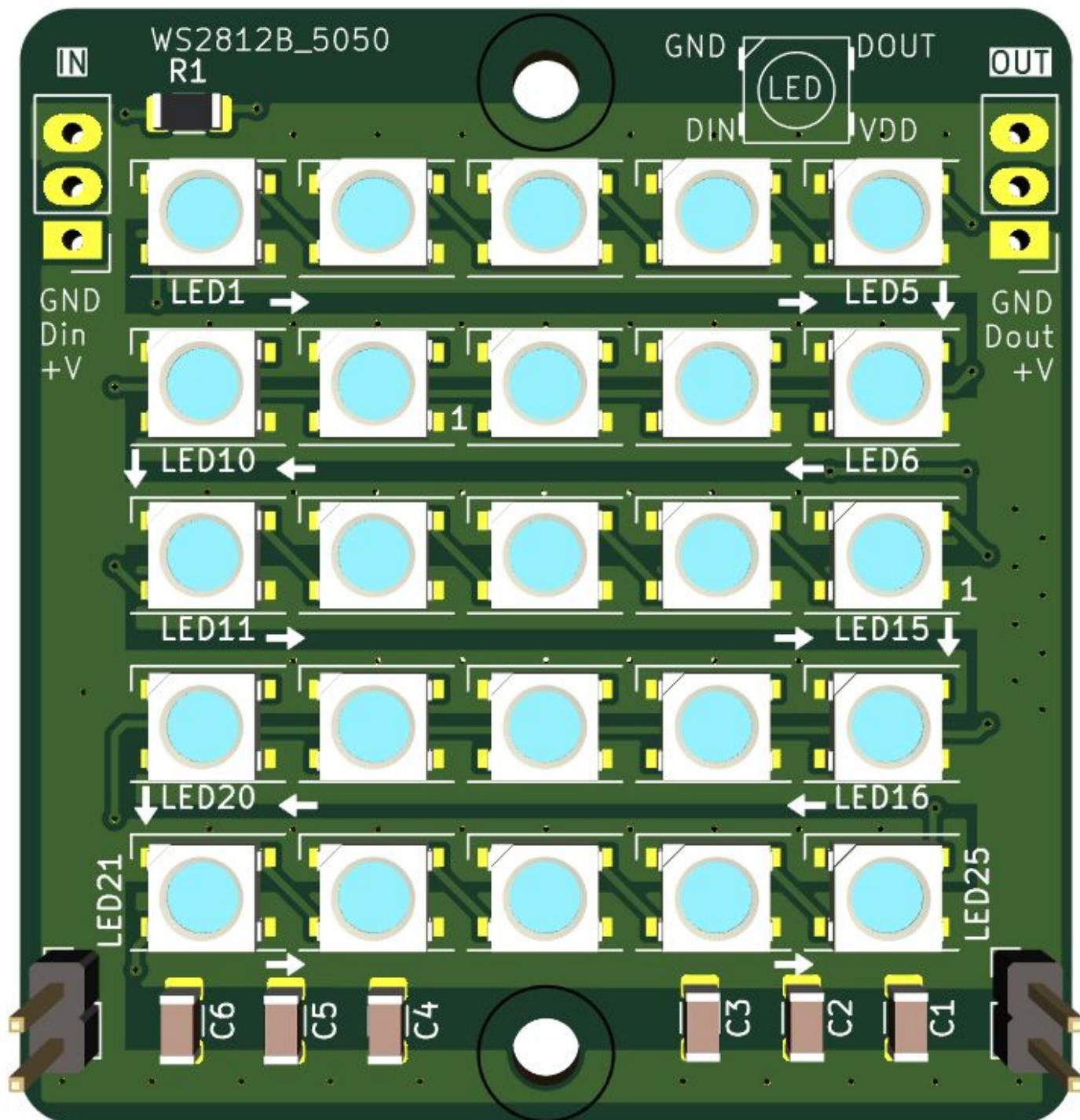
1. Soldering iron with appropriate tip
2. Solder (lead-free vs. leaded)
3. Flux (liquid, gel, and paste). No Clean/ Clean. (Plumbing [acid] Flux= Bad)
4. Cleaning solvents: IPA, Flux remover, Ultrasonic bath
5. Tweezers and pick-up tools (suction)
6. Soldering mat or station
7. Loupe, Microscope (USB or eyepiece-less stereo microscopes)
8. Kapton [polyimide] tape
9. Stick-vice or blue tape
10. Flush cutter, wire strippers,

Exercise 1: Hand Solder SMD

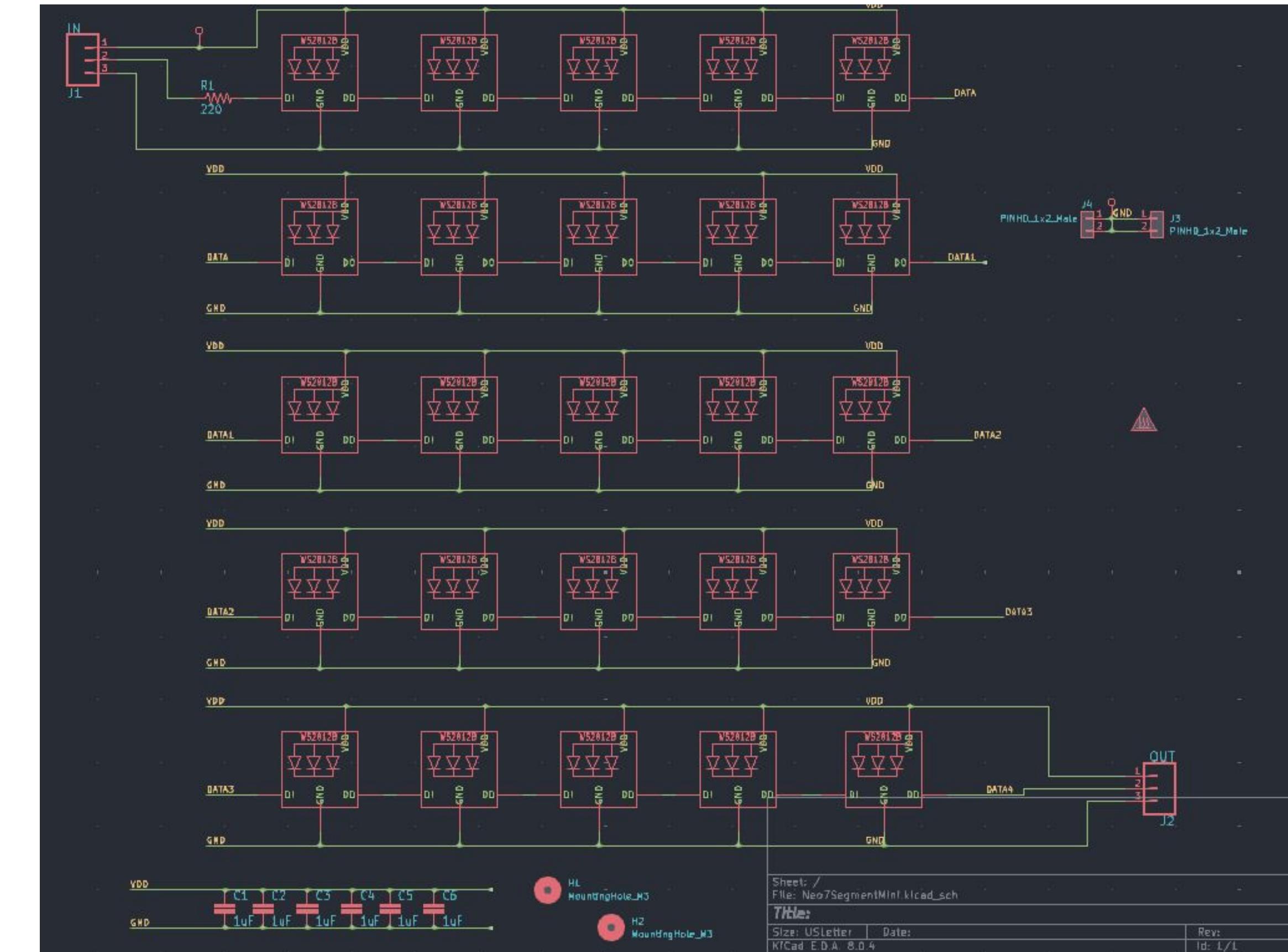
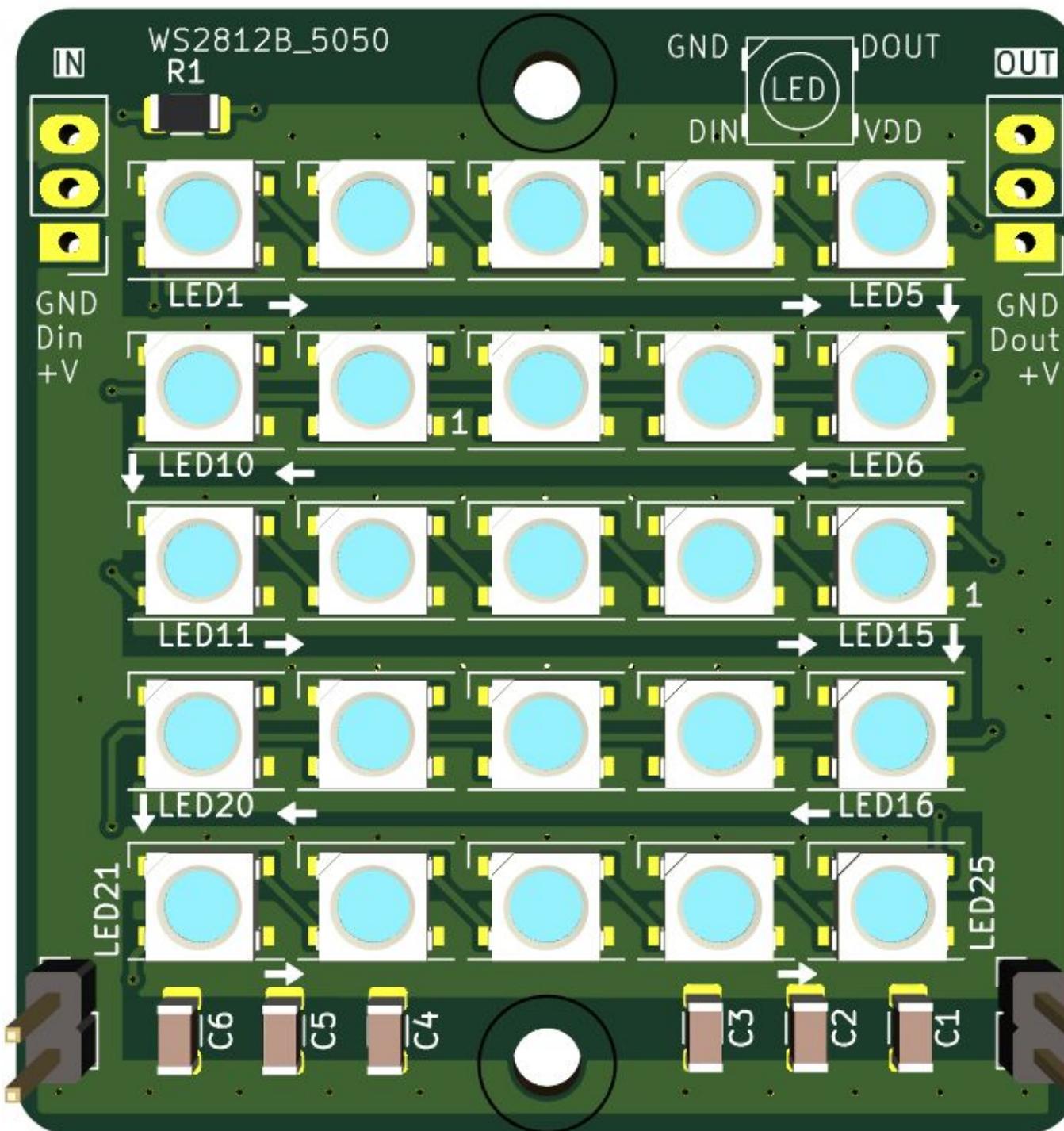
~~Manual Stencil Solder Paste
Solder Iron
Reflow (Hot Plate)~~



Exercise 1: Circuit



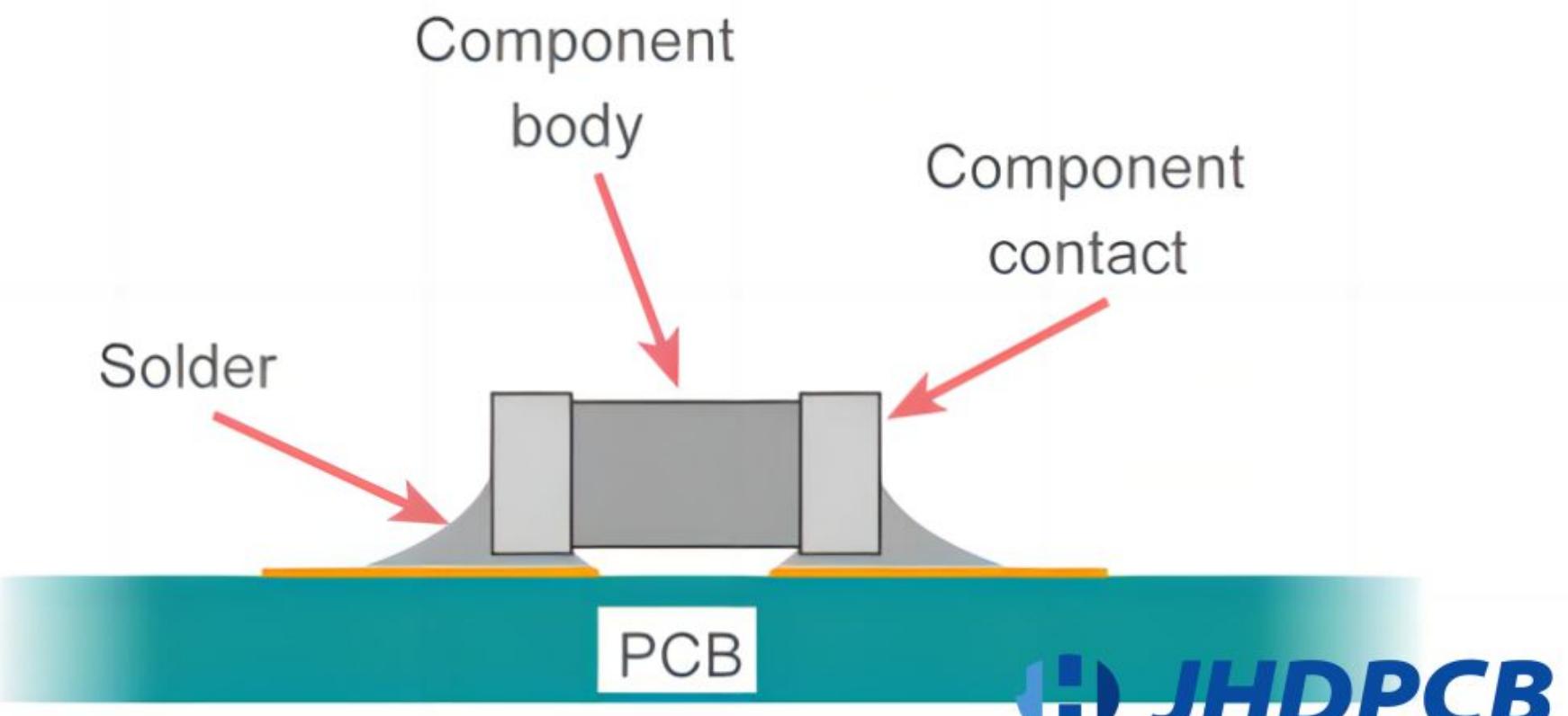
Exercise 1: Circuit (complete)



Solder Paste + Flux

Solder Paste: Balls of solder suspended in flux

Flux: removes oxidation and contaminants from components and PCB's pads.

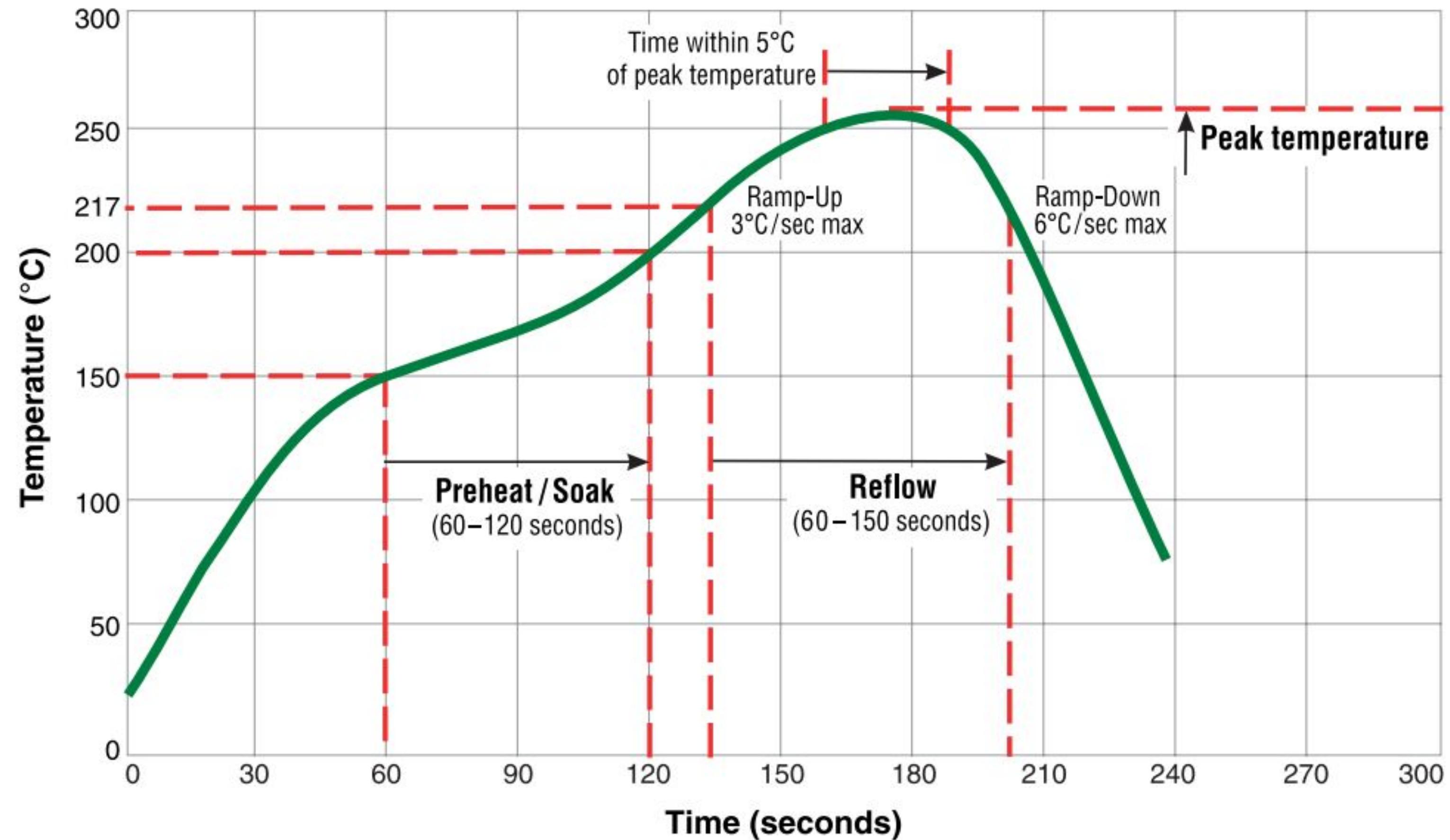


<https://www.adafruit.com/product/2667>

JHDPCB

Hands on Reflow

Temperature
& Flux



Exercise 1: Parts

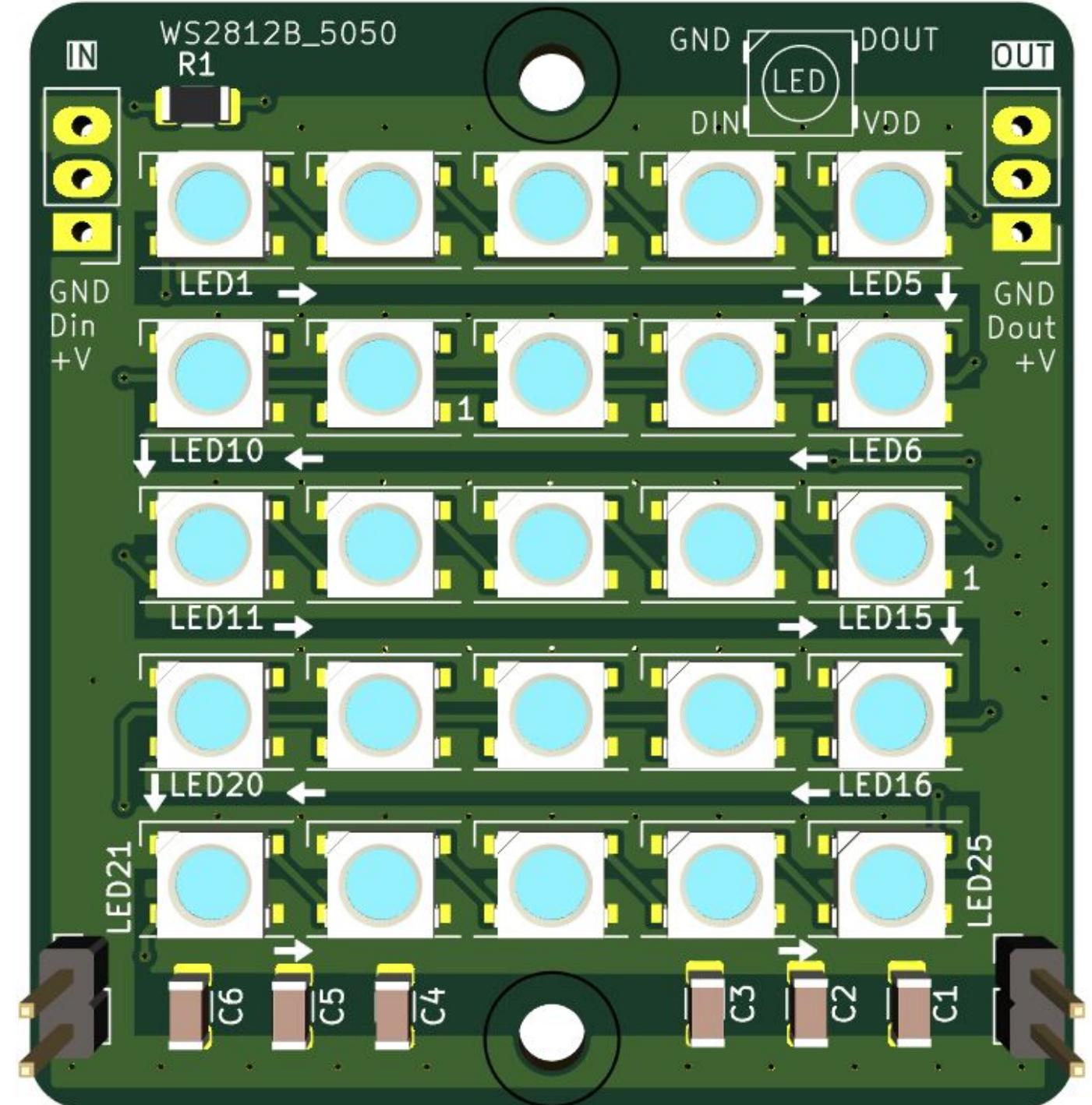
Resistor



LED (x25)



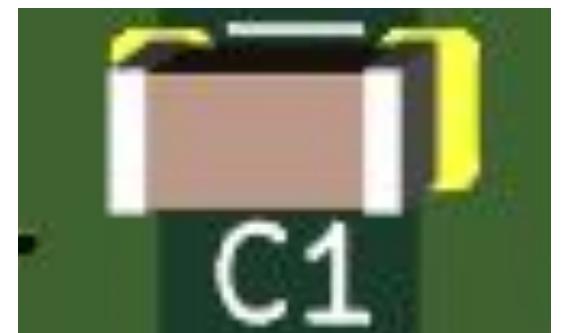
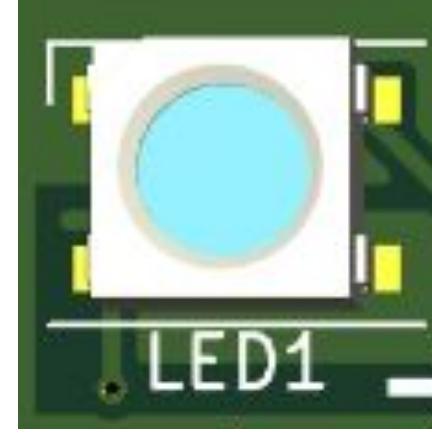
Capacitor (x6)



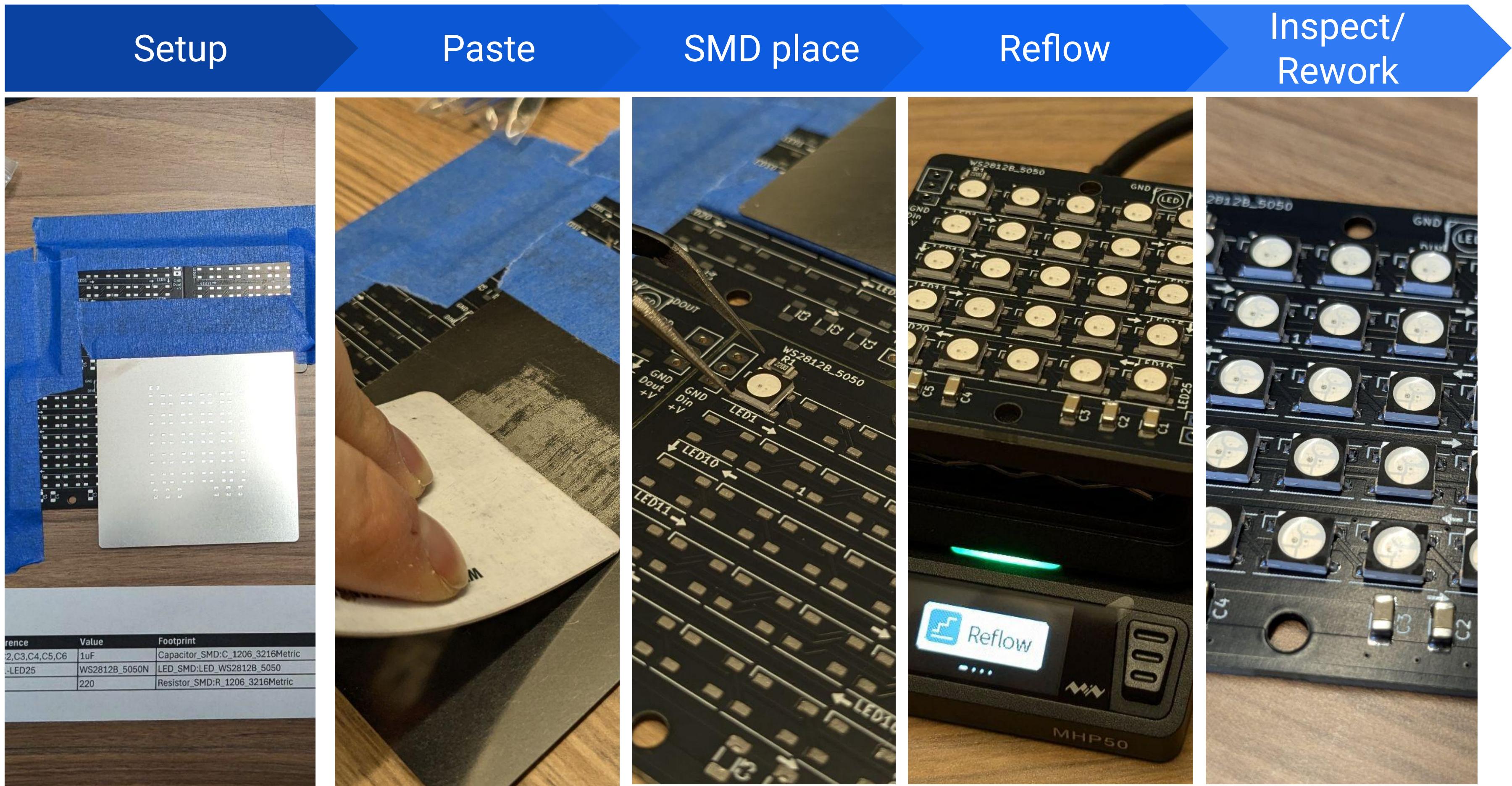
Exercise 1: Parts on tape and reel



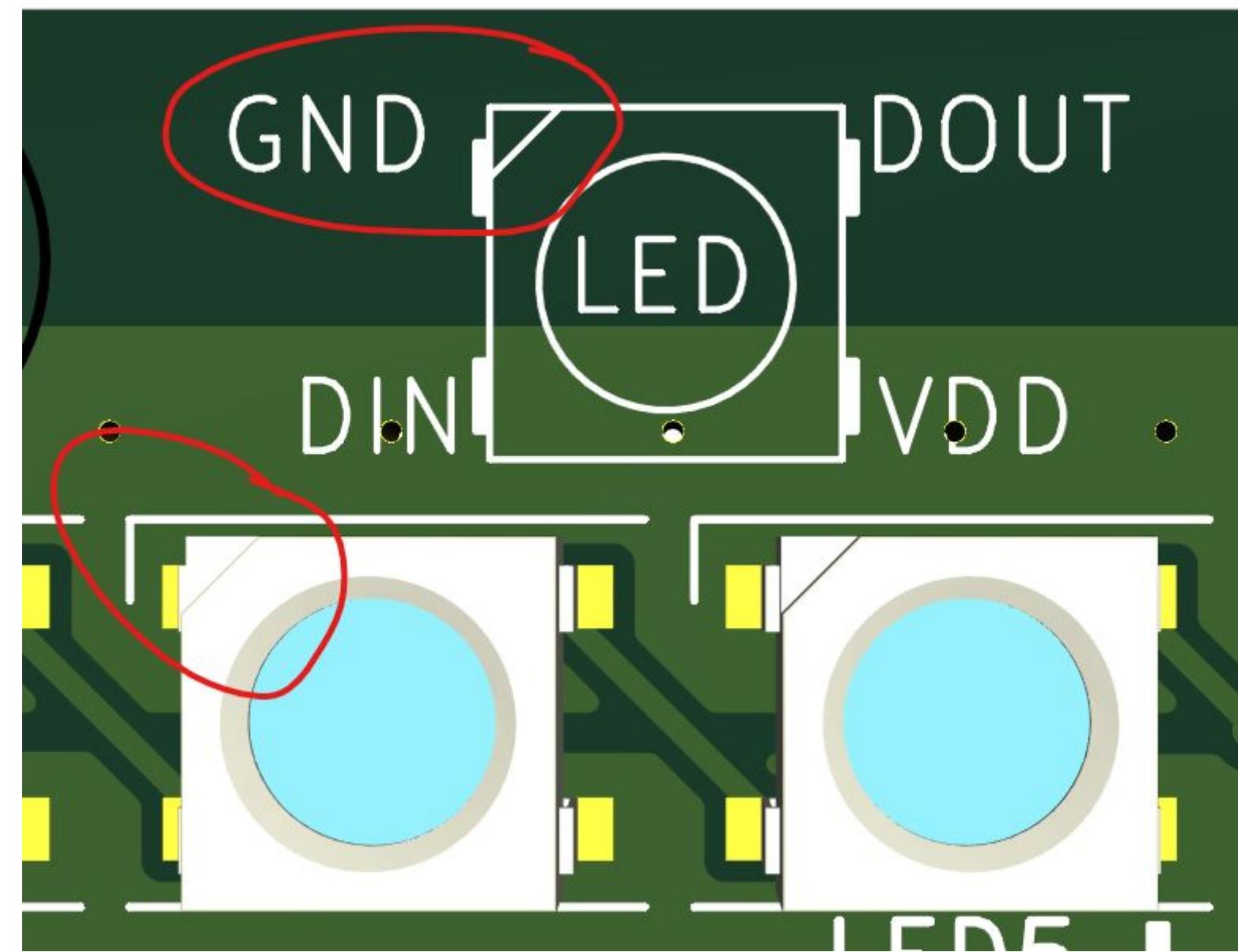
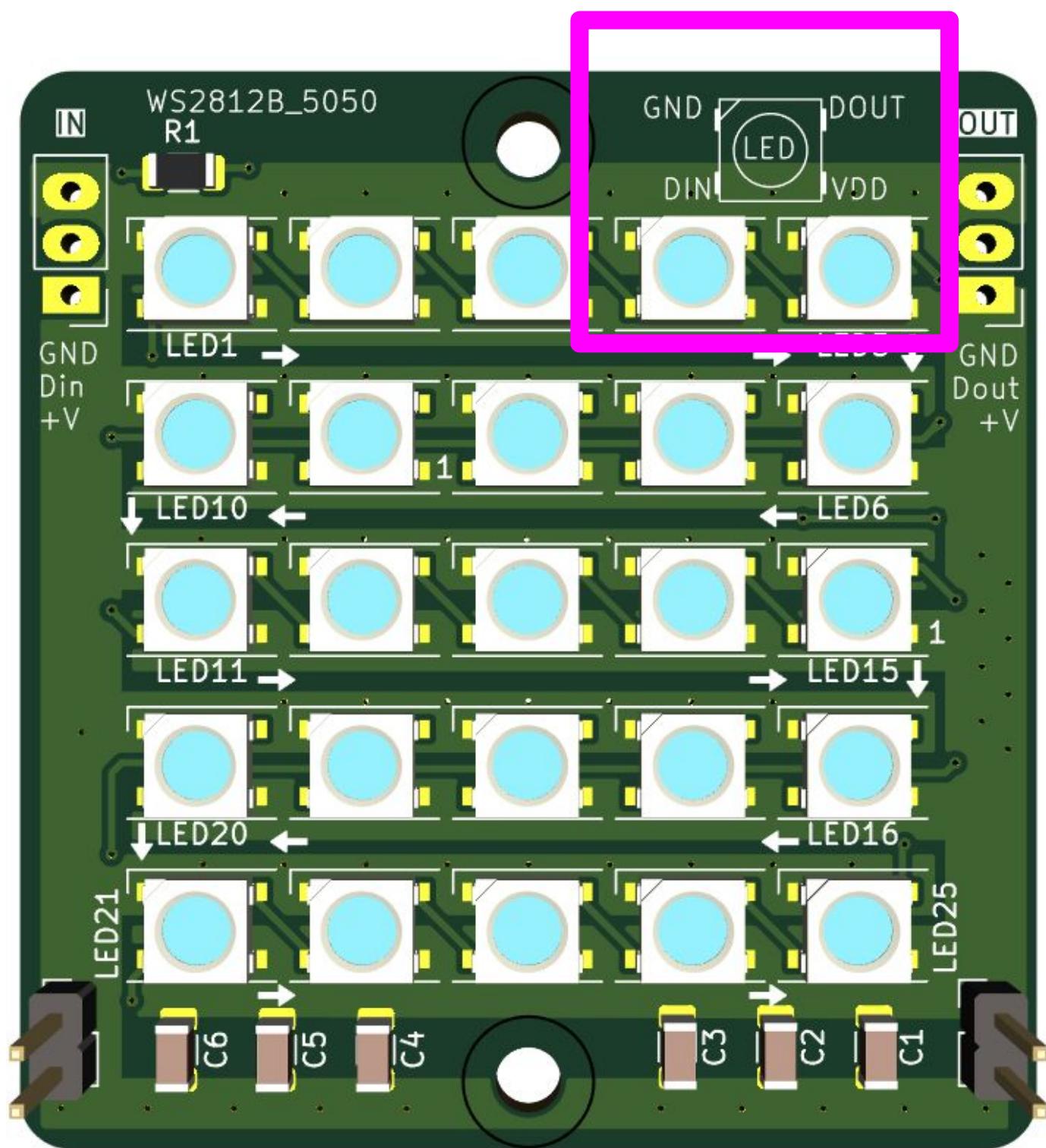
Exercise 1: Parts (Bill of Materials)

Reference	Description	Qty	Part
C1,C2,C3,C4,C5,C6	1uF Capacitor, 1206	6	 C1
LED1-25	WS2812B_5050N	25	 LED1
R1	220 Ohm Resistor, 1206	1	 R1

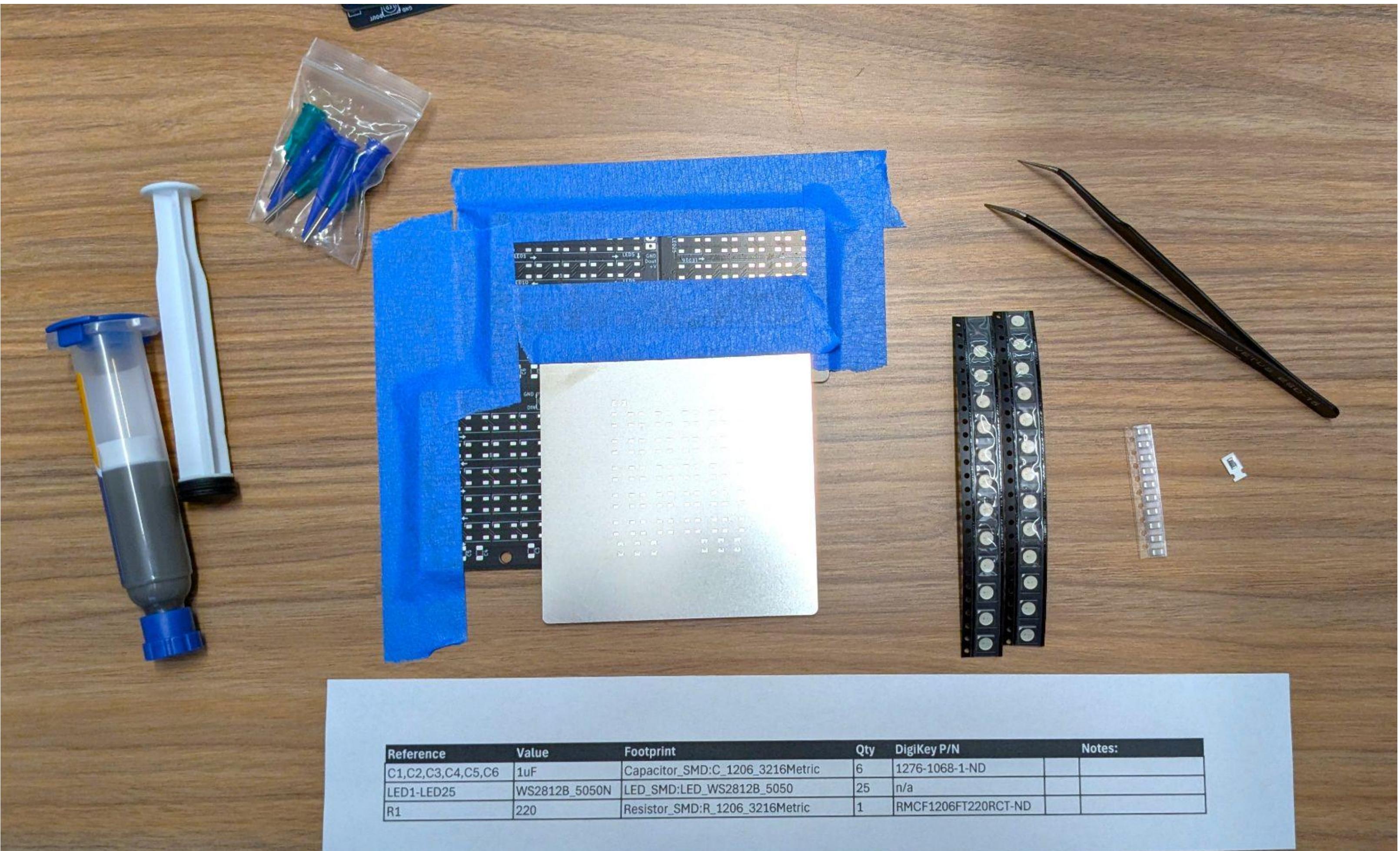
Exercise 1: Assembly Steps



Exercise 1: Part Orientation



Exercise 1: Setup



Exercise 1: Microcontroller Code?

The screenshot shows the Arduino IDE interface. On the left, the Library Manager is open, displaying several FastLED-related libraries:

- FastLED by Daniel Garcia**: Version 3.9.4, installed.
- ColourKit by Michael Nixon**: Version 1.0.2, available for download.
- FastLED NeoMatrix by Marc Merlin**: Version 1.1.0, available for download.
- FastLED NeoPixel by David Madison**: Version 1.0.3, available for download.
- FastLEDHub by Stephan Rumswinkel**: Available for download.

The main window shows a sketch named `strandtest.ino` for an `Arduino Nano`. The code implements a theater marquee effect:

```
1 void setup() {
2     // put your setup code here, to run once:
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52
53 // loop() function -- runs repeatedly as long as board is on -----
54
55 void loop() {
56     // Fill along the length of the strip in various colors...
57     colorWipe(strip.Color(255, 0, 0), 50); // Red
58     colorWipe(strip.Color(0, 255, 0), 50); // Green
59     colorWipe(strip.Color(0, 0, 255), 50); // Blue
60
61     // Do a theater marquee effect in various colors...
62     theaterChase(strip.Color(127, 127, 127), 50); // White, half brightness
63     theaterChase(strip.Color(127, 0, 0), 50); // Red, half brightness
64     theaterChase(strip.Color(0, 127, 0), 50); // Blue, half brightness
65
66     rainbow(10); // Flowing rainbow cycle along the whole strip
67     theaterChaseRainbow(50); // Rainbow-enhanced theaterChase variant
68 }
```

The status bar at the bottom indicates: Sketch uses 3984 bytes (12%) of program storage space. Maximum is 30720 bytes. Global variables use 41 bytes (2%) of dynamic memory, leaving 2007 bytes for local variables. Maximum is 20480 bytes.

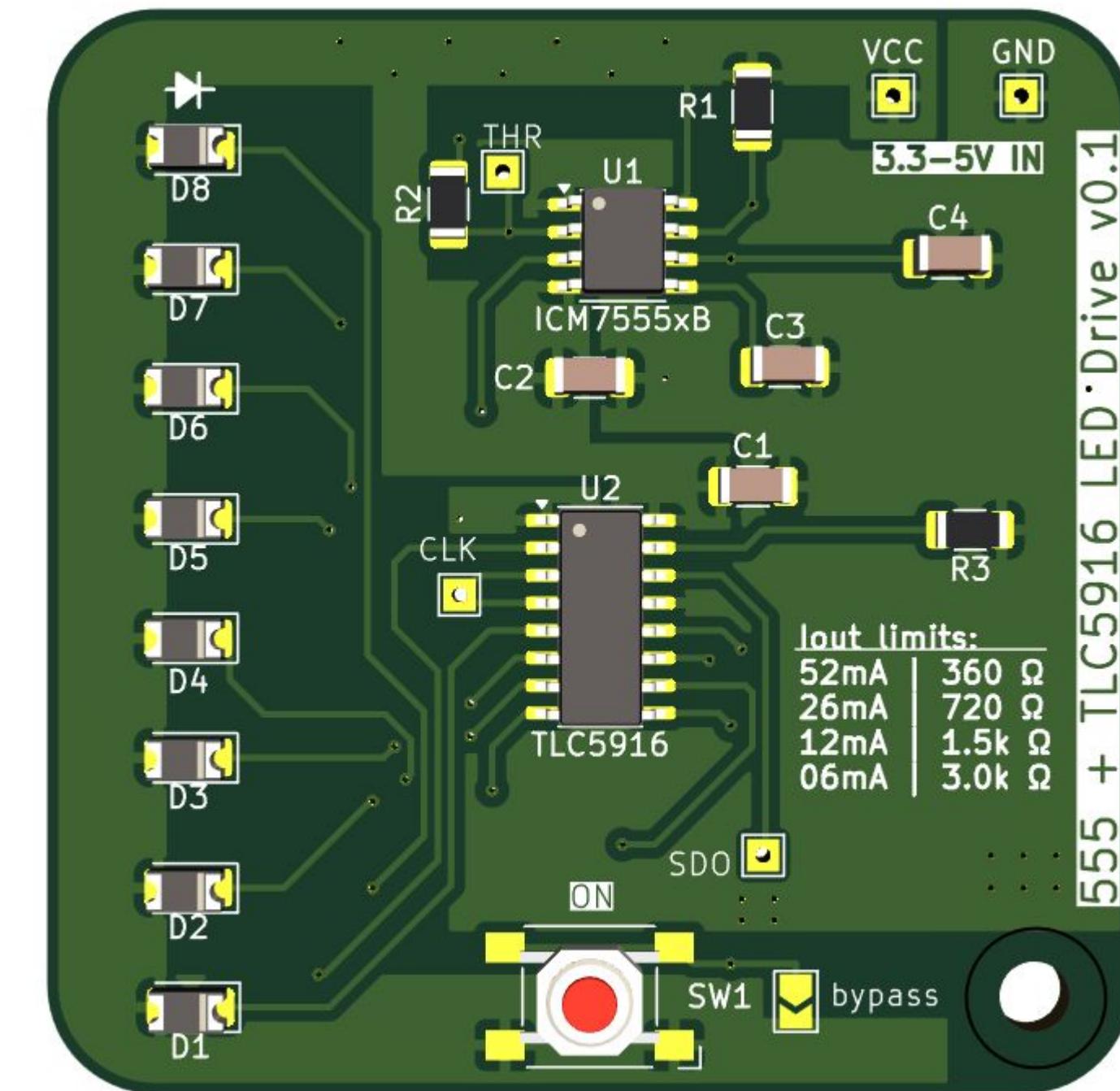


intentionally blank

clean up, re organize, break time.
prepare for next soldering project.

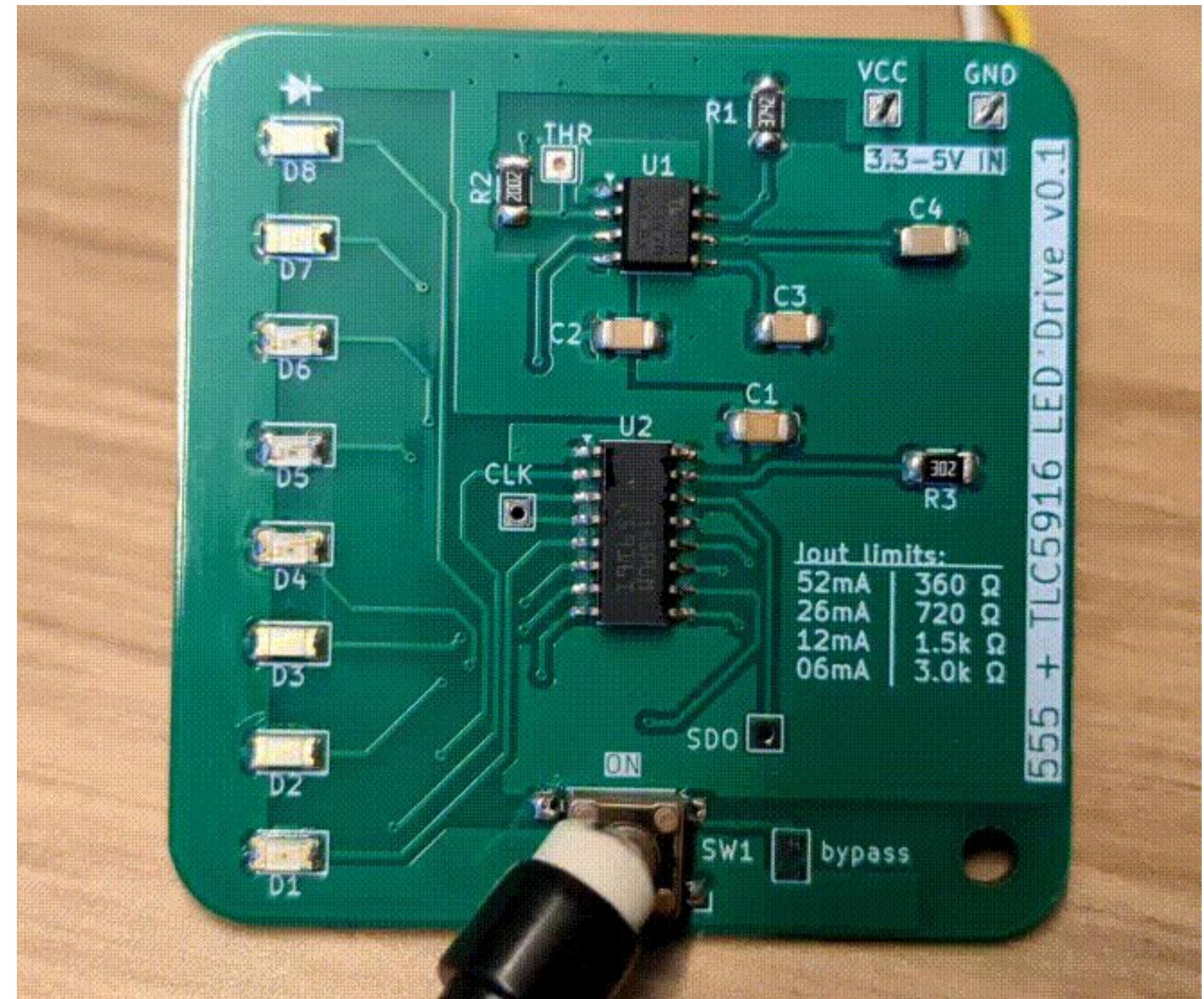
Exercise 2: Hand Solder SMD

Manual Solder Paste
~~Solder Iron~~
Reflow (Hot Plate)



Exercise 2: What is it?

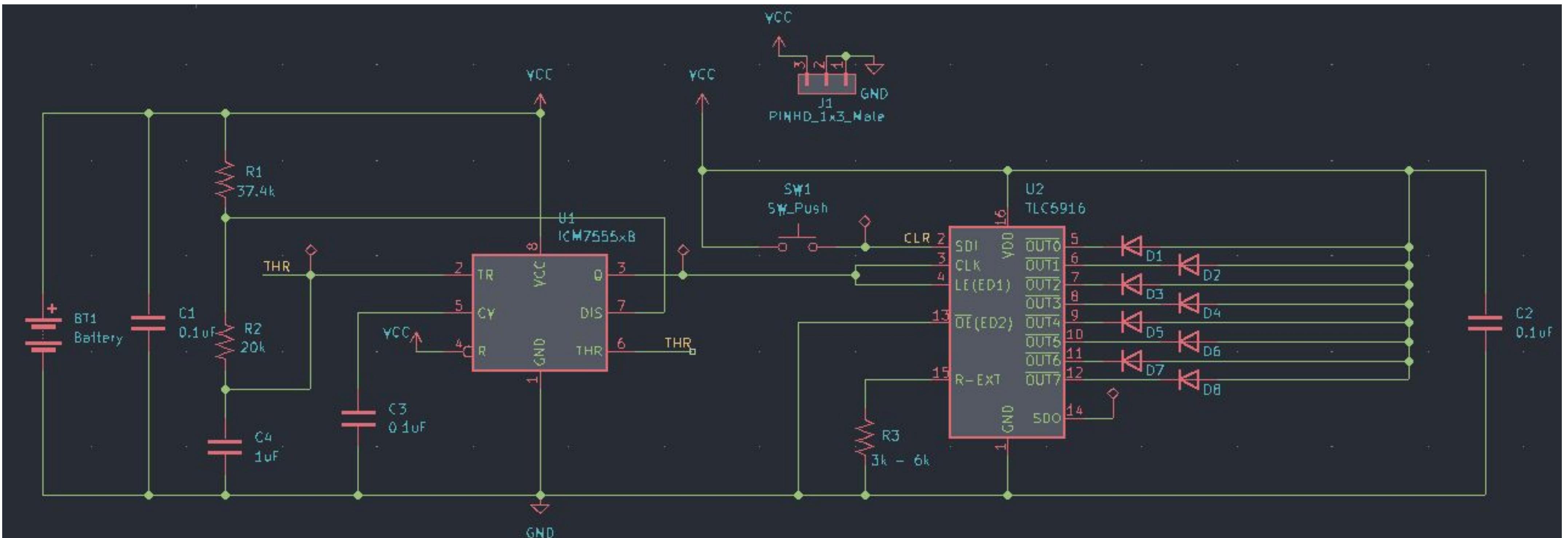
Turn on lights (LEDs)
without a microcontroller.



Exercise 2: What is it?

[Technical paper by Texas Instruments](#)

Circuit:



SMD Reflow Overview

Setup

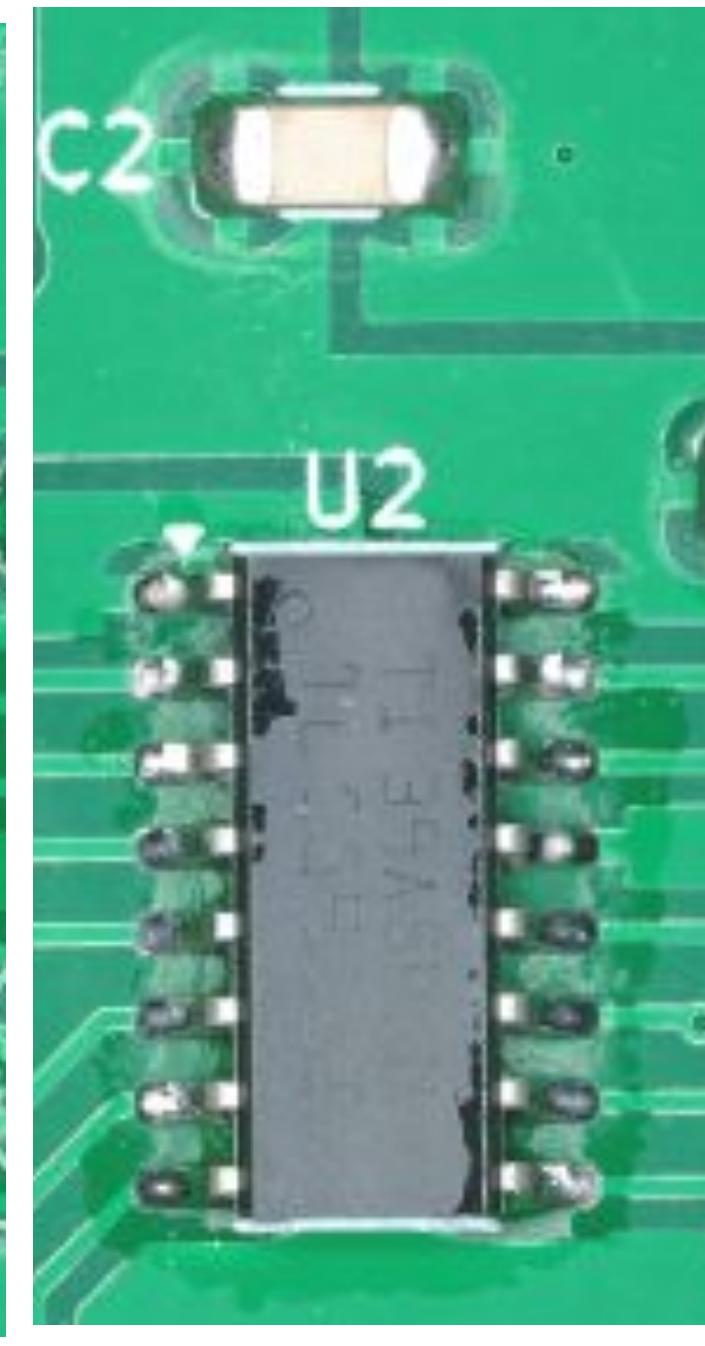
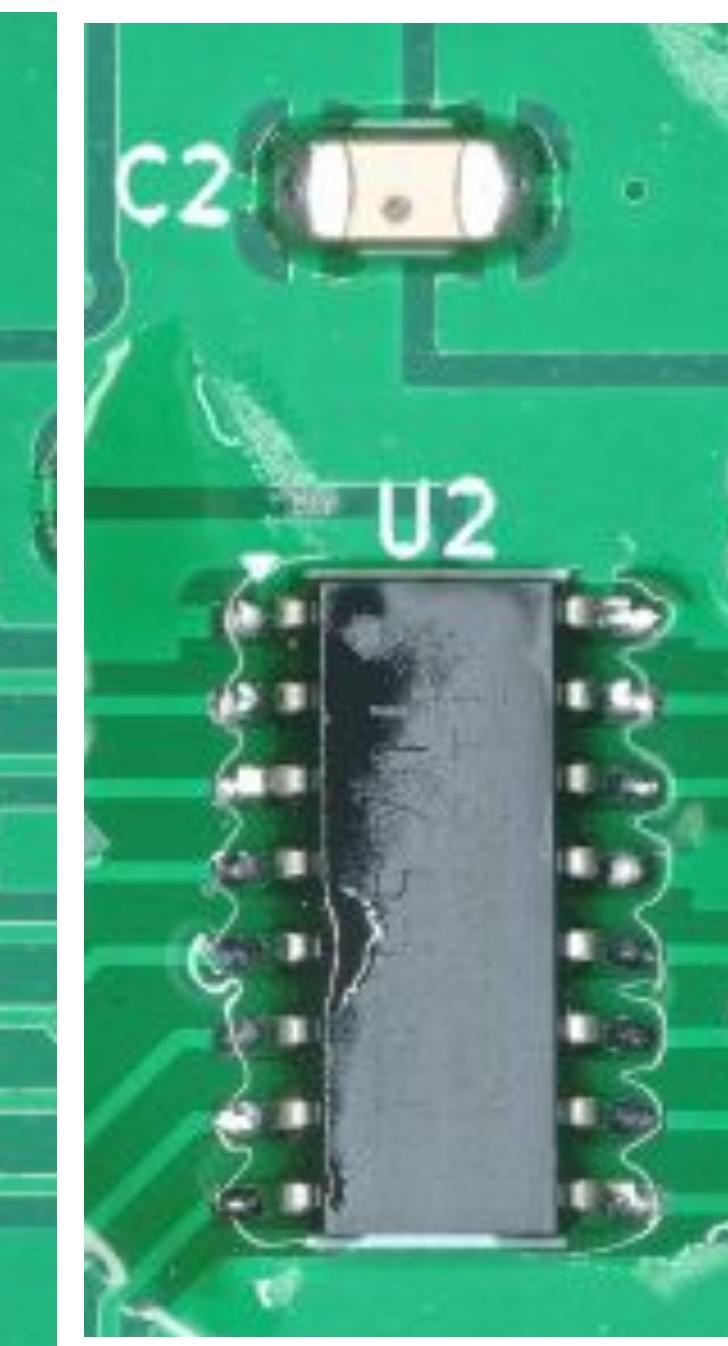
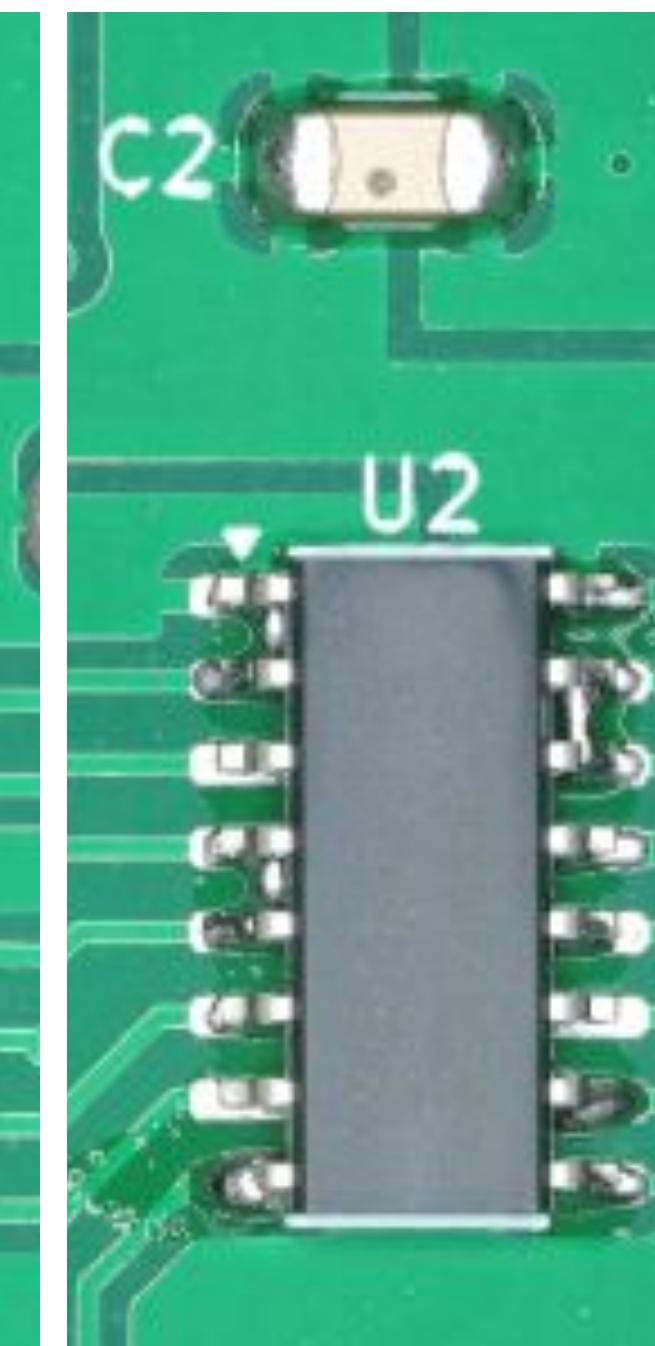
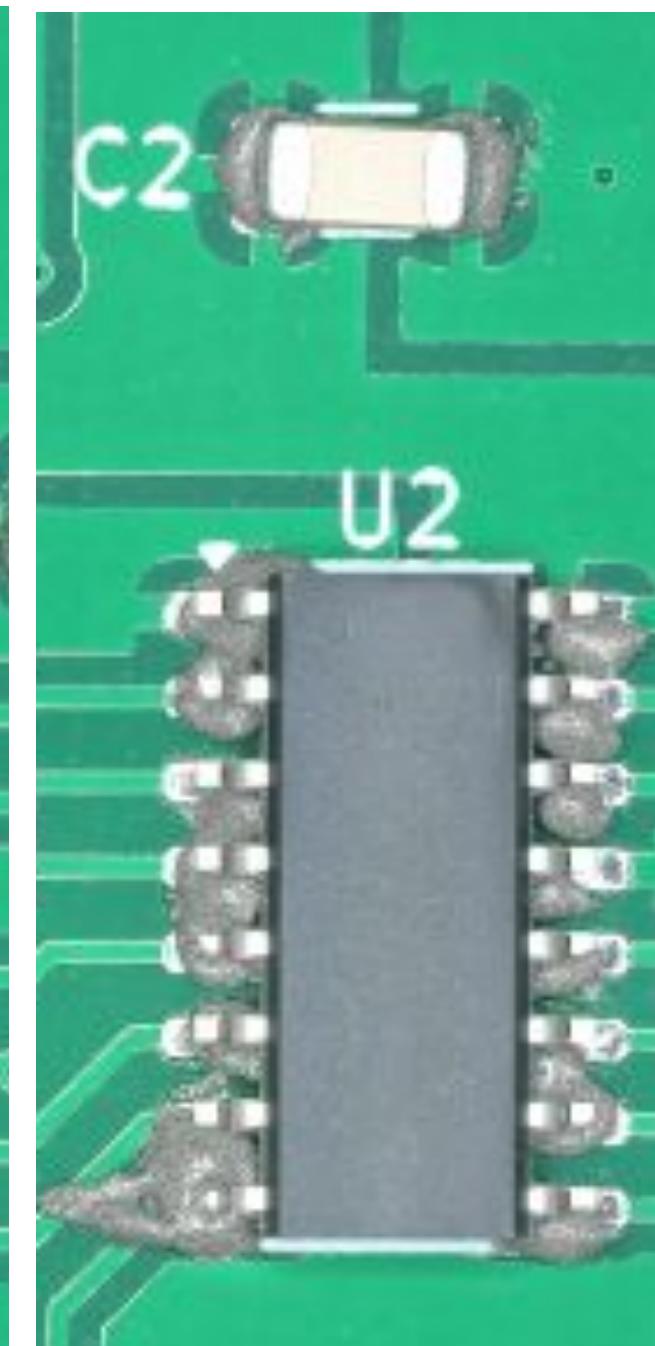
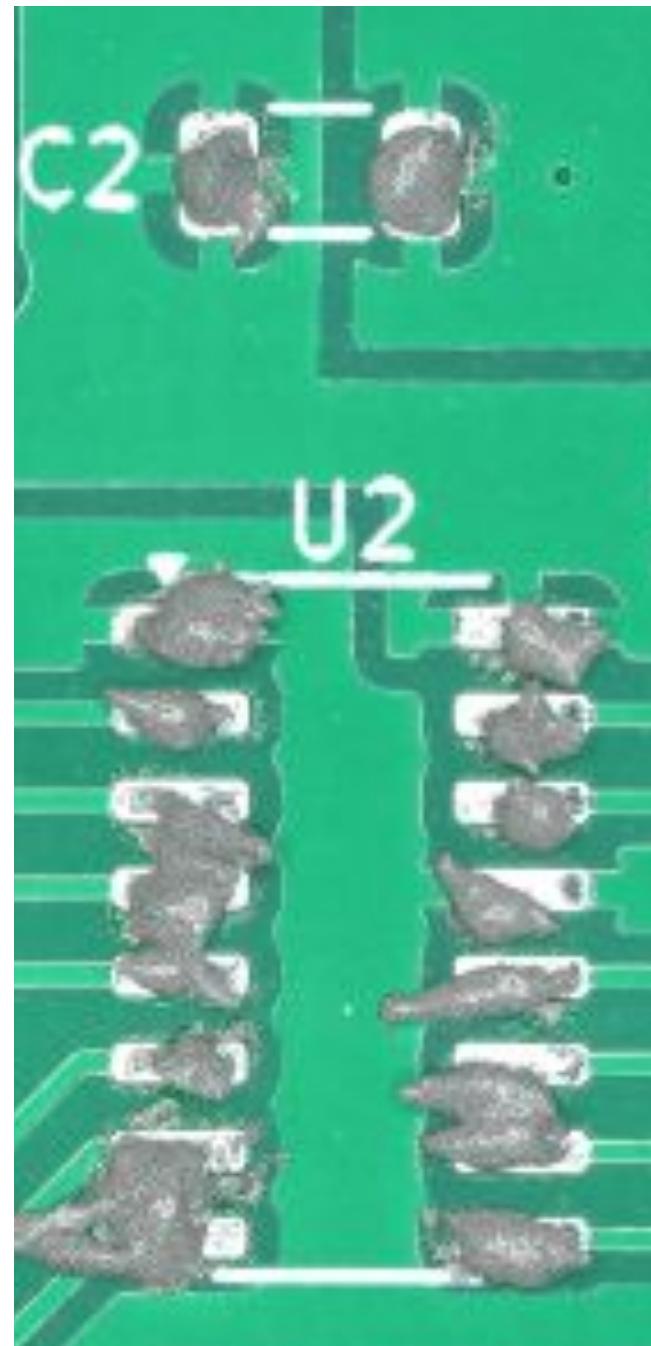
Paste

SMD place

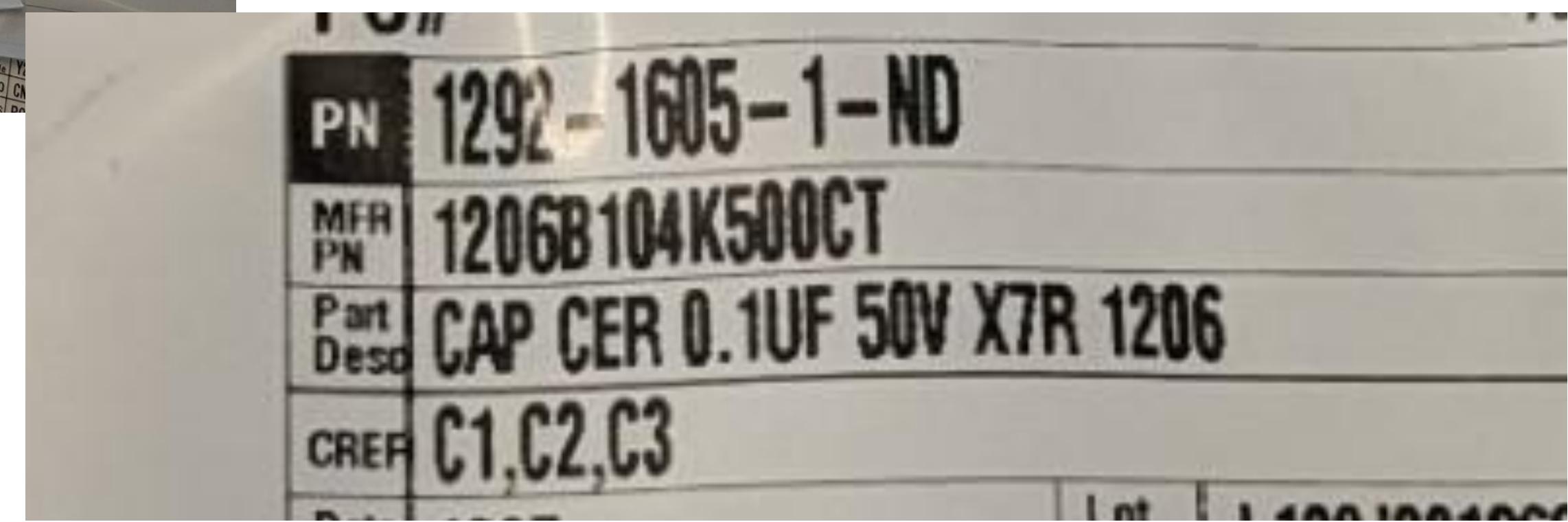
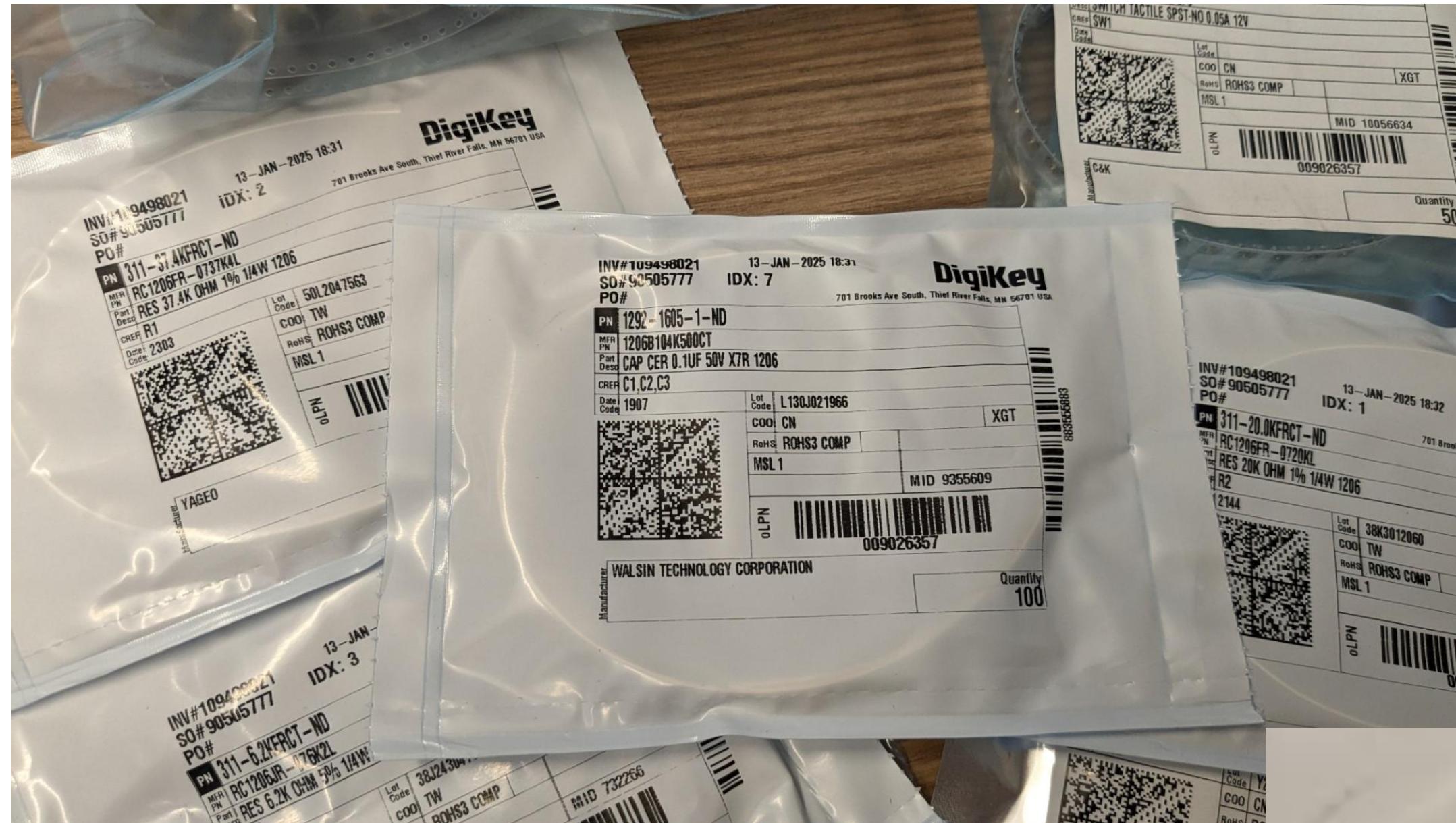
Reflow

Inspect/
Rework

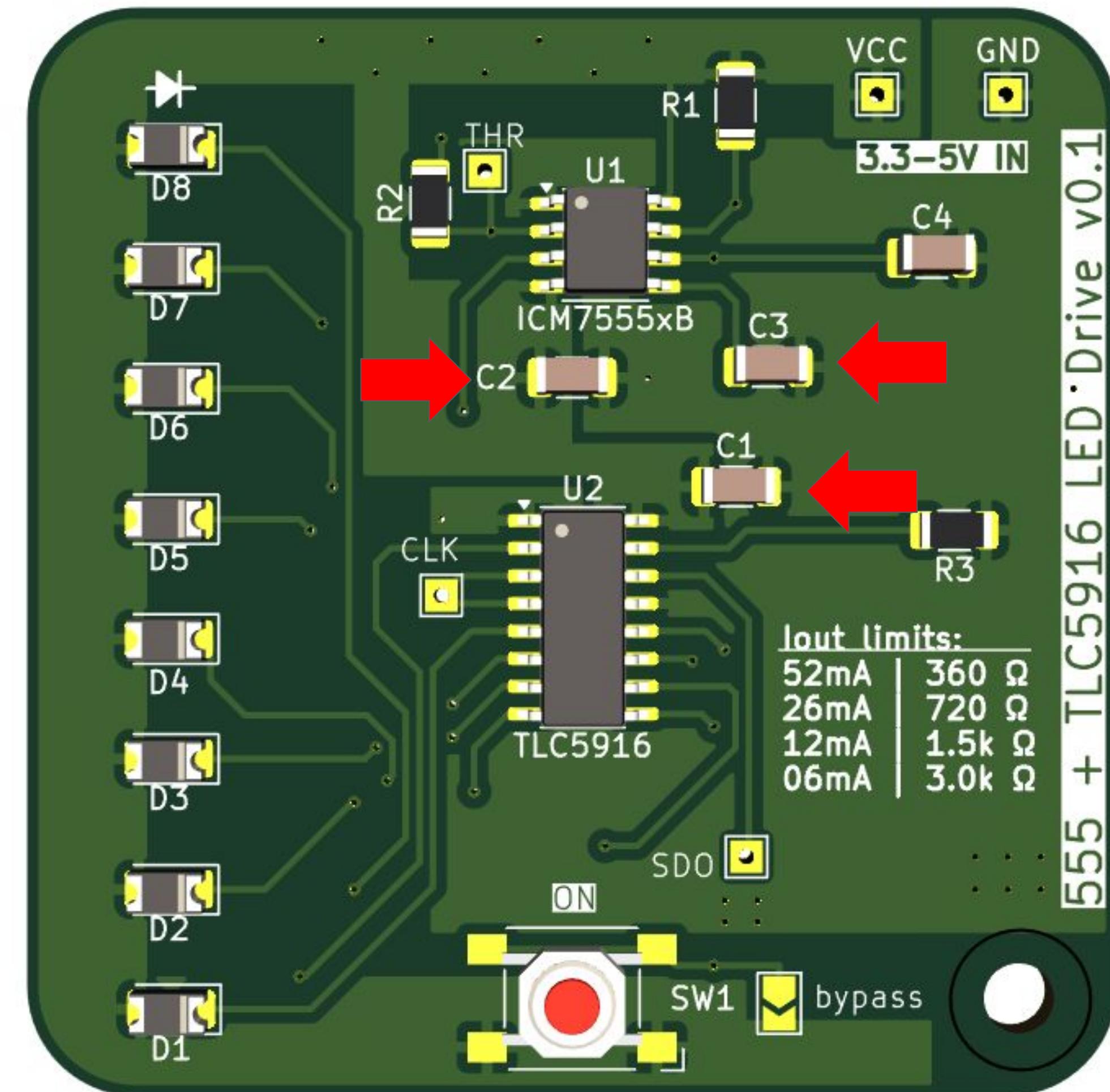
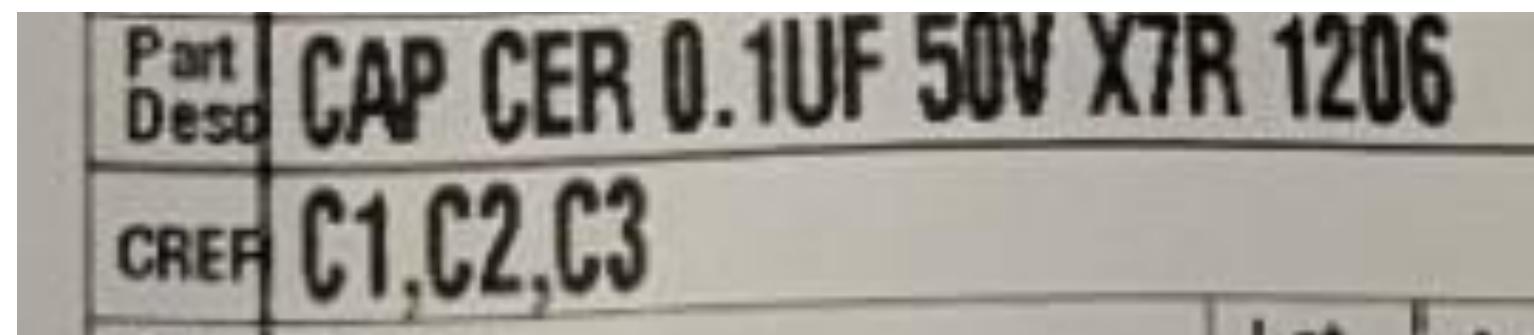
Clean



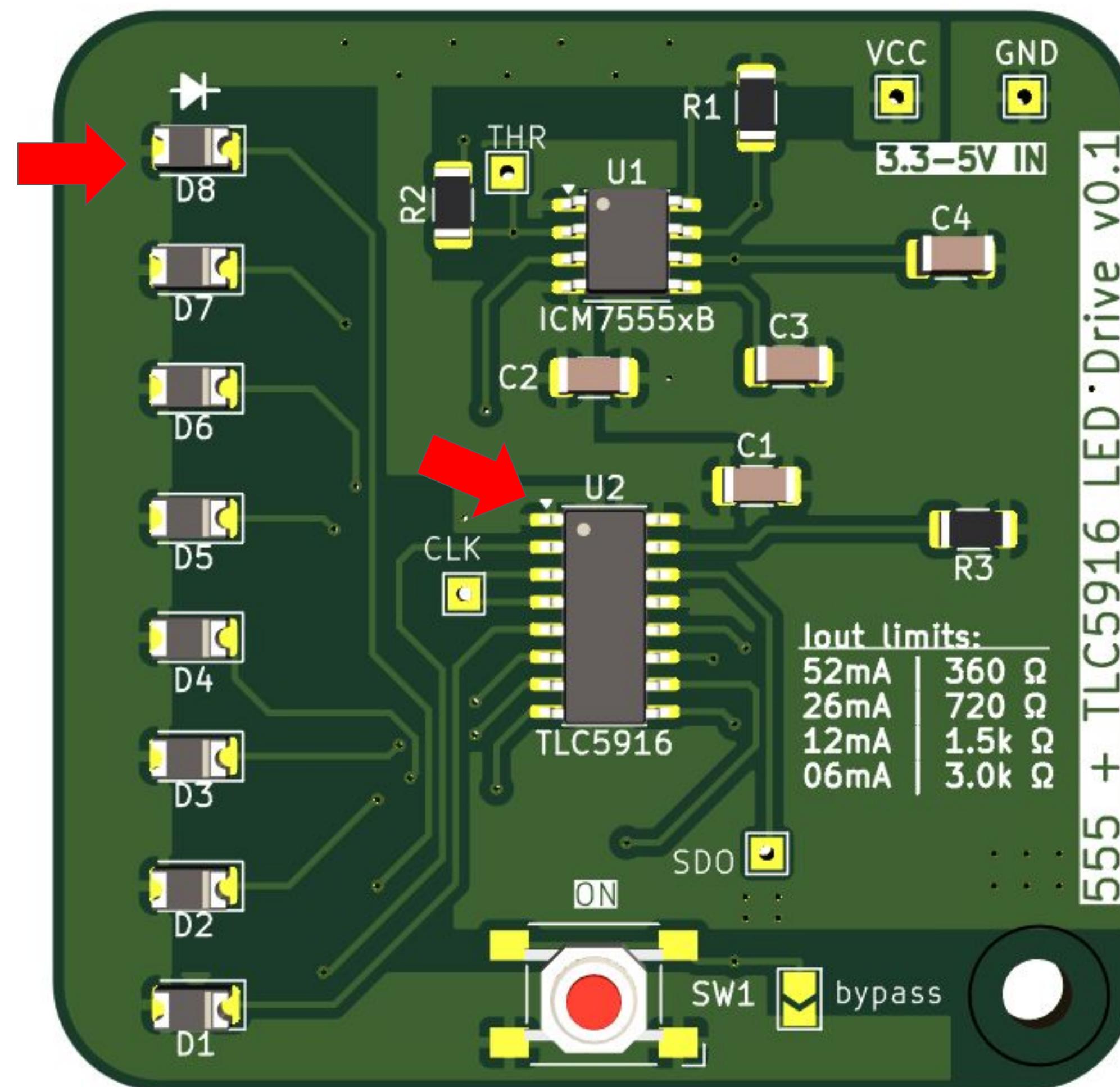
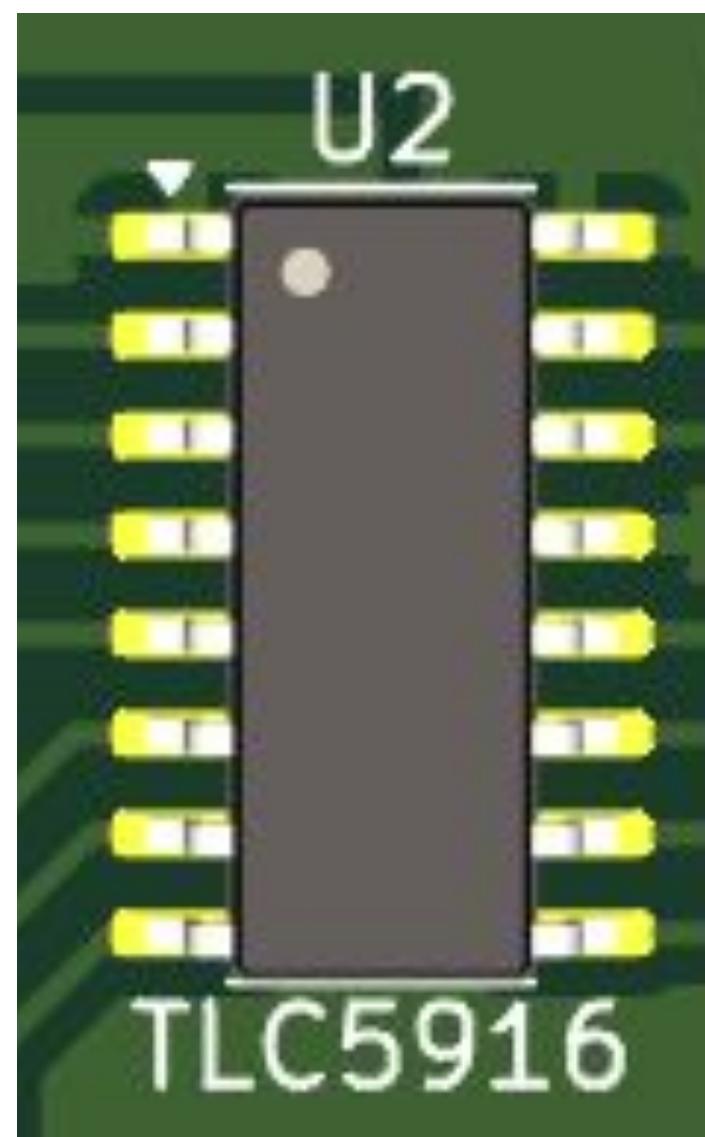
SMD Part Numbers, Reference Designators



SMD Part Numbers, Reference Designators



SMD Part Orientation (Polarity, Pin Markers)



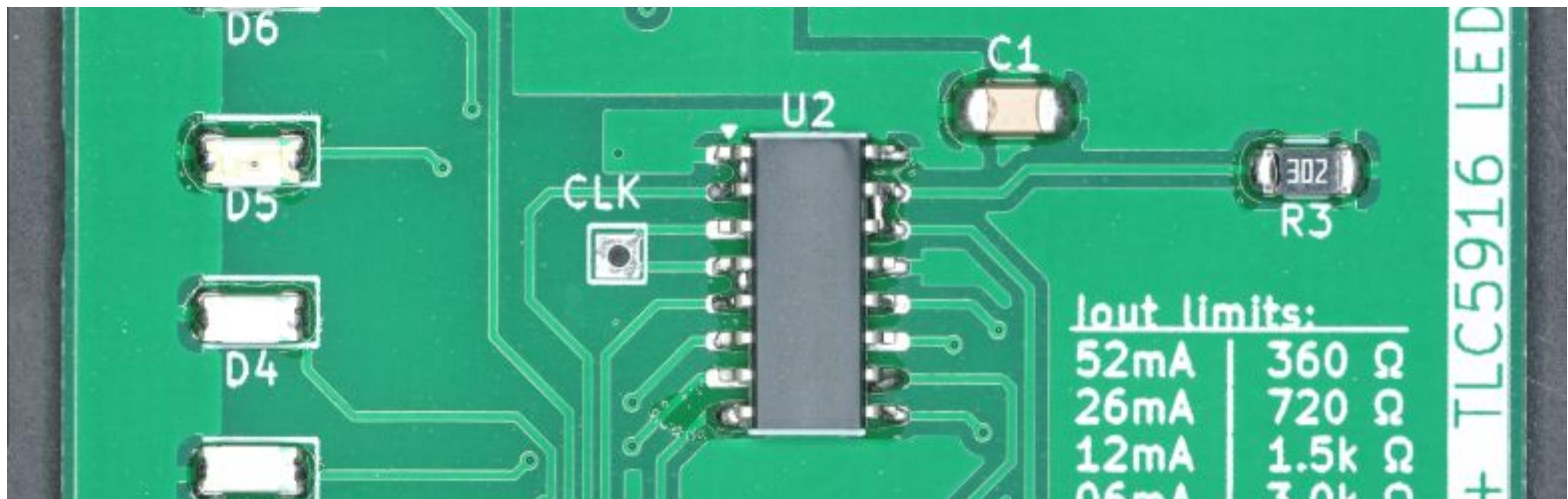
555 + TLC5916 LED Drive v0.1

Iout limits:	
52mA	360 Ω
26mA	720 Ω
12mA	1.5k Ω
06mA	3.0k Ω

SMD Part Numbers, Reference Designators

Reference	Value	DigiKey P/N	Unit Cost	Picked?
BT1	Battery	BU2032SM-GCT-ND	\$1.25	
C1,C2,C3	0.1uF	1292-1605-1-ND	\$0.10	
C4	1uF	1276-1068-1-ND	\$0.14	
D1,D2,D3,D4,D5,D6,D7,D8	LED, Red	67-1359-1-ND	\$0.17	
R1	37.4k	311-37.4KFRCT-ND	\$0.10	
R2	20k	311-20.0KFRCT-ND	\$0.10	
R3	6.2k	311-6.2KERCT-ND	\$0.10	
SW1	SW_Push	CKN12221-1-ND	\$0.17	
U1	ICM7555xB	296-1336-1-ND	\$0.55	
U2	TLC5916	296-22710-1-ND	\$1.29	

Inspect & Rework.



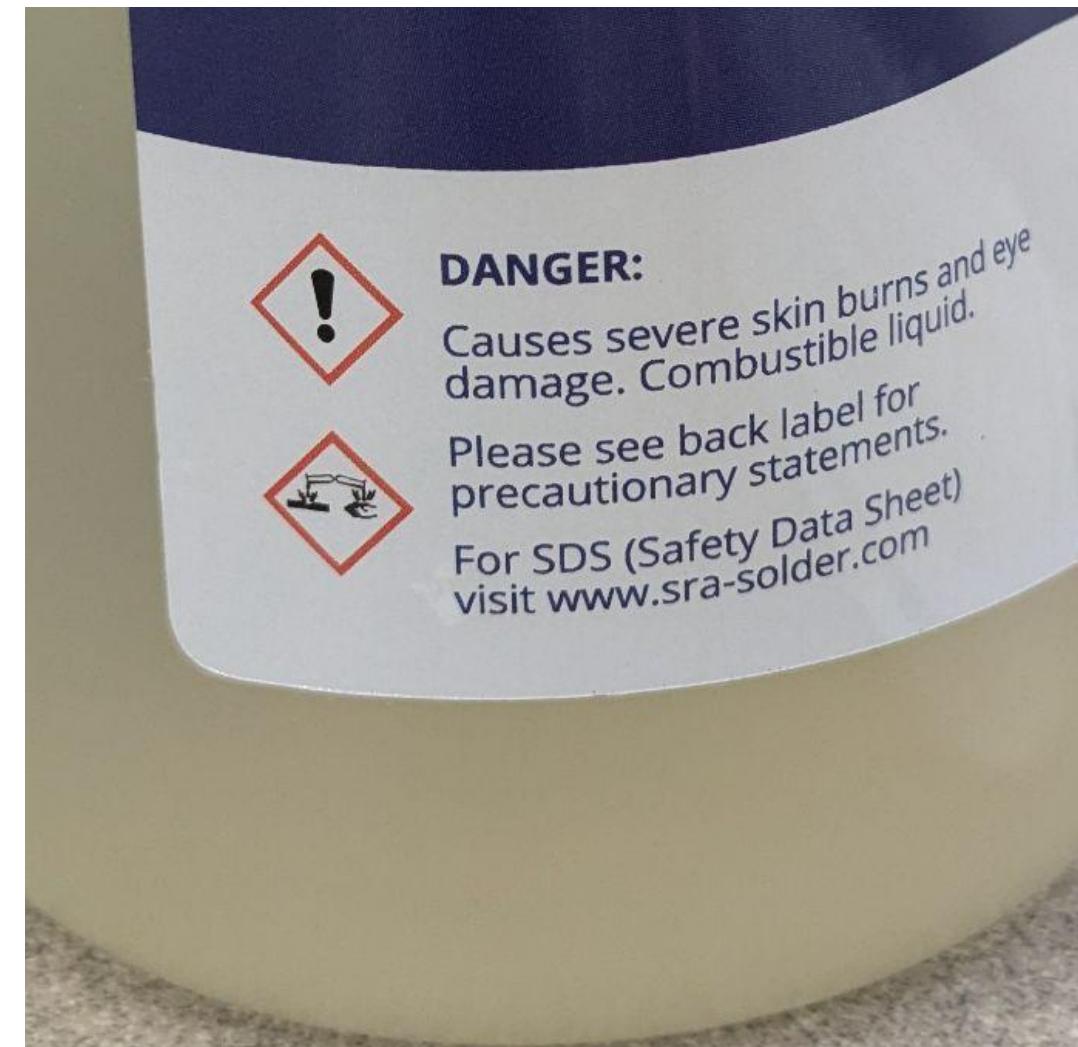
Post Assembly: Rework Tools

Hot Air Station
Hot Tweezers



Post Assembly: Cleaning

Ultrasonic Bath Chemicals



Post Assembly: Cleaning

Remove Flux Residue

