PRINTED CIRCUIT BOARD (PCB) DESIGN AND LAYOUT

Circuit schematic is done; we will focus on design and layout of the PCB.

PRINTED CIRCUIT BOARD (PCB) DESIGN AND LAYOUT

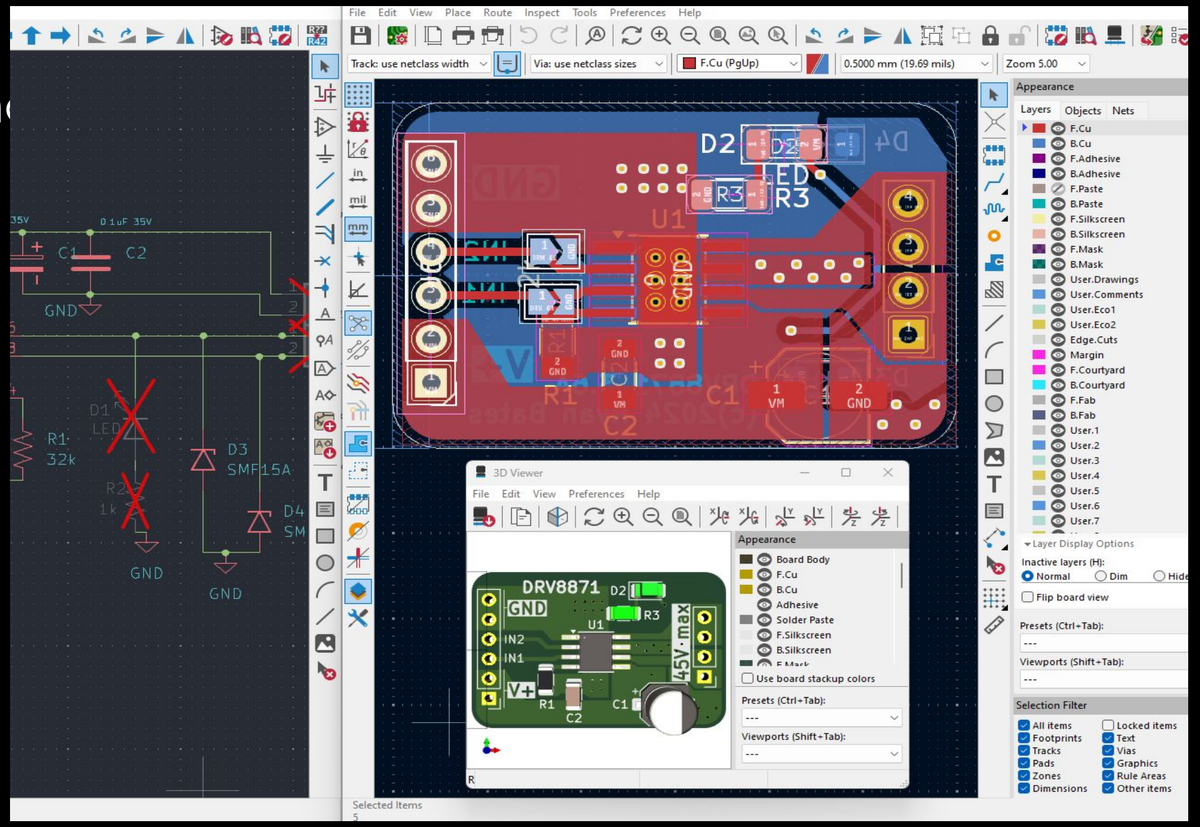
Today:

- Turn a circuit schematic(s) into PCB design(s).
- Turn-key-manufacturing to get your designs m
- Exercise our knowledge of PCB design

by creating a design;

- And another design
- And another
- And another.

- If you can read a schematic= yay!



HI!

Your Instructor: **Ryan Bates**

Edu: BSEE
Exp: 10yr + Electrical and
Hardware Engineering

(is not an expert)

Ask questions any time!

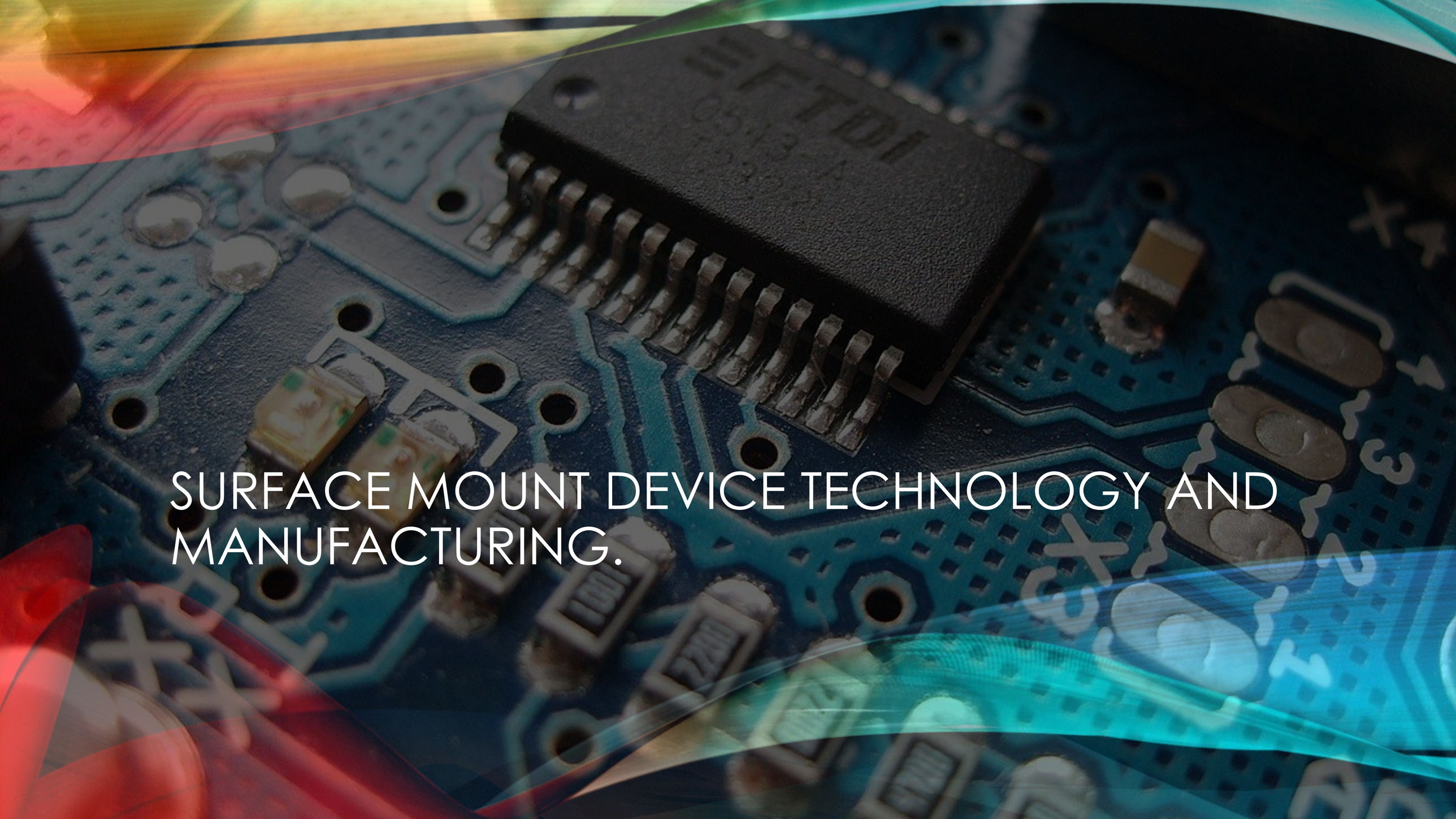
EDUCATION VS EXPERIENCE

Skills take time to learn.

Invest in skills that are difficult to master.

YOU MUST DESIGN & ASSEMBLE to gain experience (skill).

(ryan tells story about his first engineering job?)



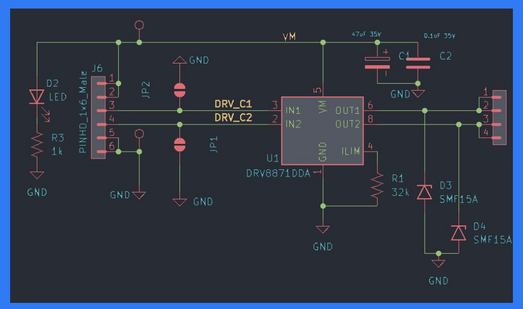
SURFACE MOUNT DEVICE TECHNOLOGY AND MANUFACTURING.

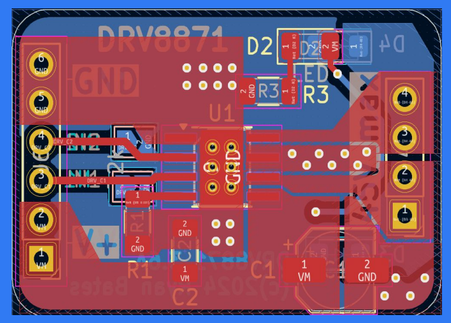
SURFACE MOUNT TECHNOLOGY (SMT)

Automated Manufacturing

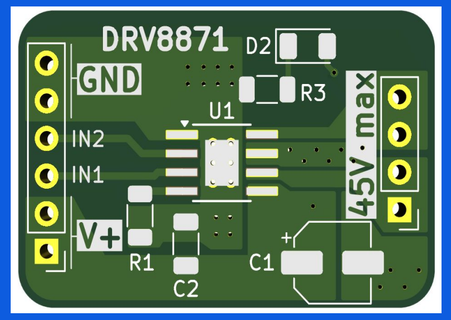
WE ARE HERE

Design

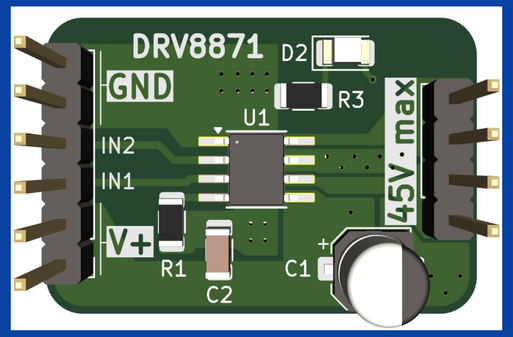




PCB Fabrication



PCB Assembly

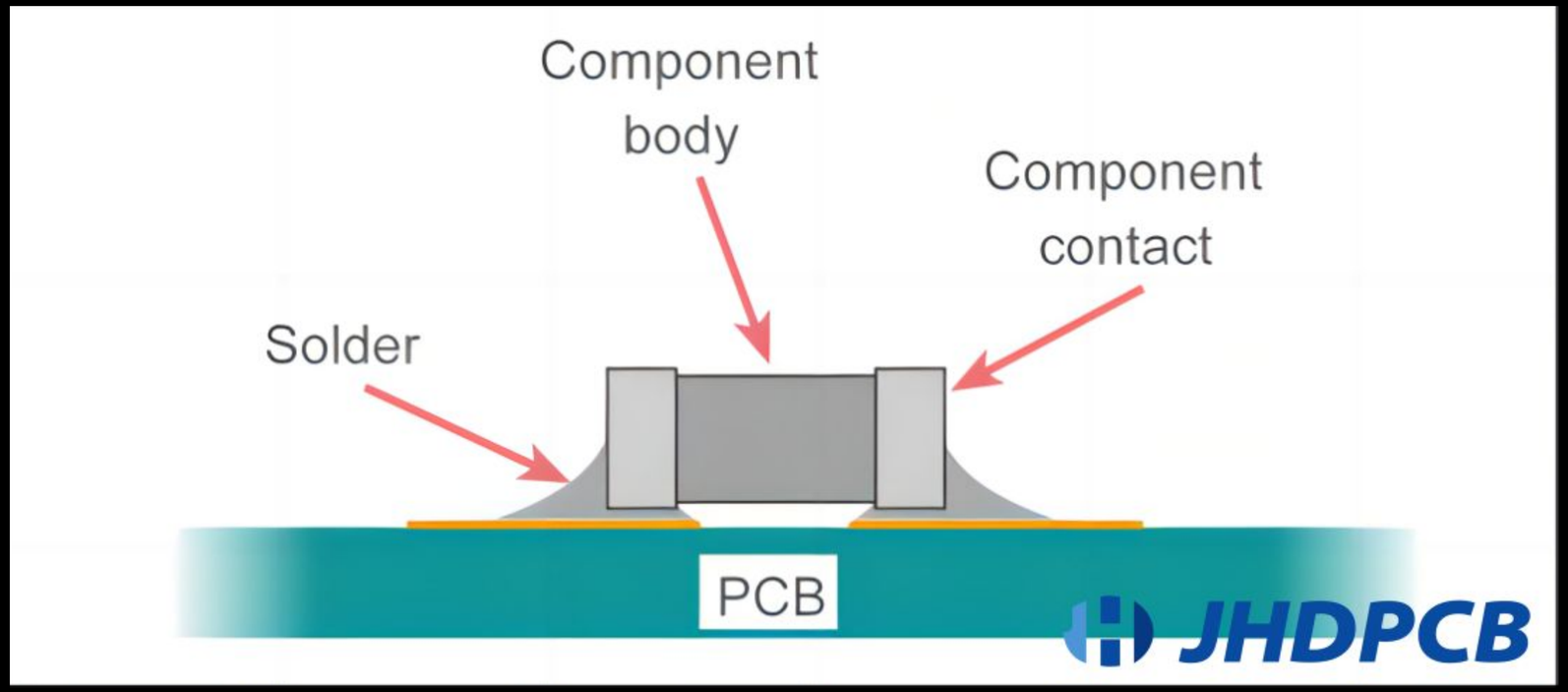


https://circuitspedia.medium.com/surface-mount-technology-smt-explained-f4a2484e4ac3

SURFACE MOUNT TECHNOLOGY

SURFACE MOUNT TECHNOLOGY (SMT)

Electronics Manufacturing.

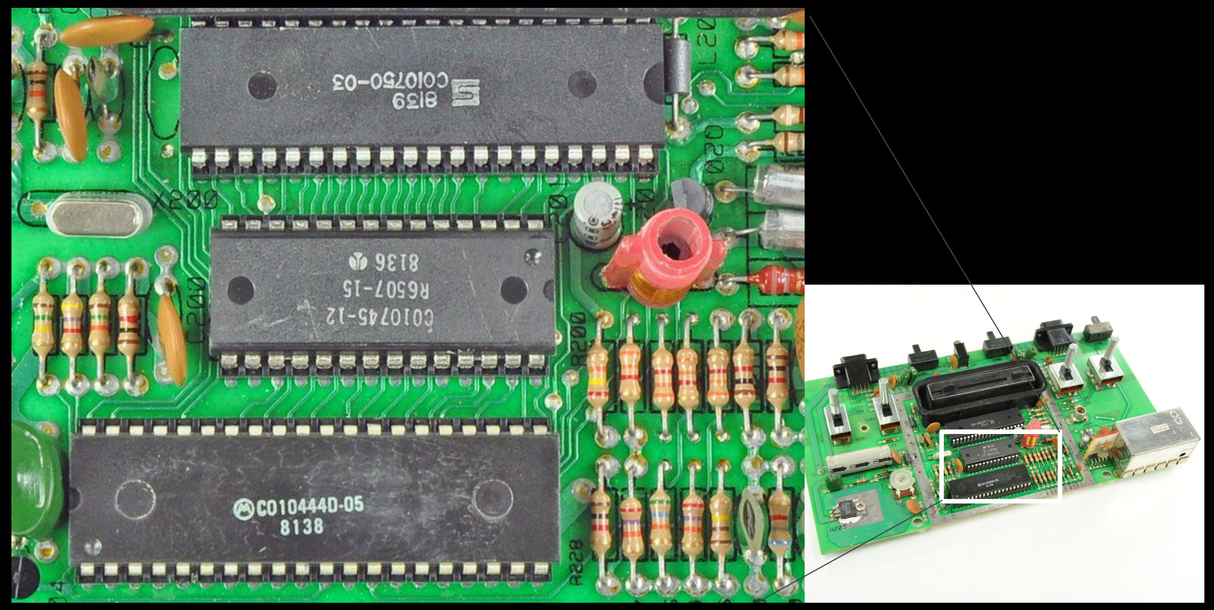


https://circuitspedia.medium.com/surface-mount-technology-smt-explained-f4a2484e4ac3

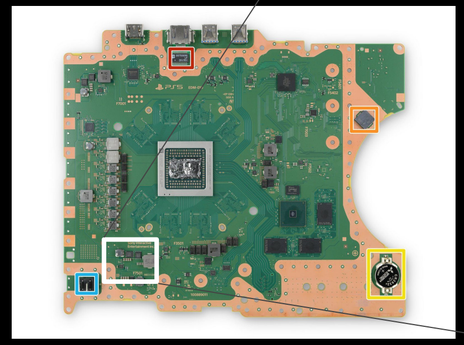
INTRODUCTION TO SMT

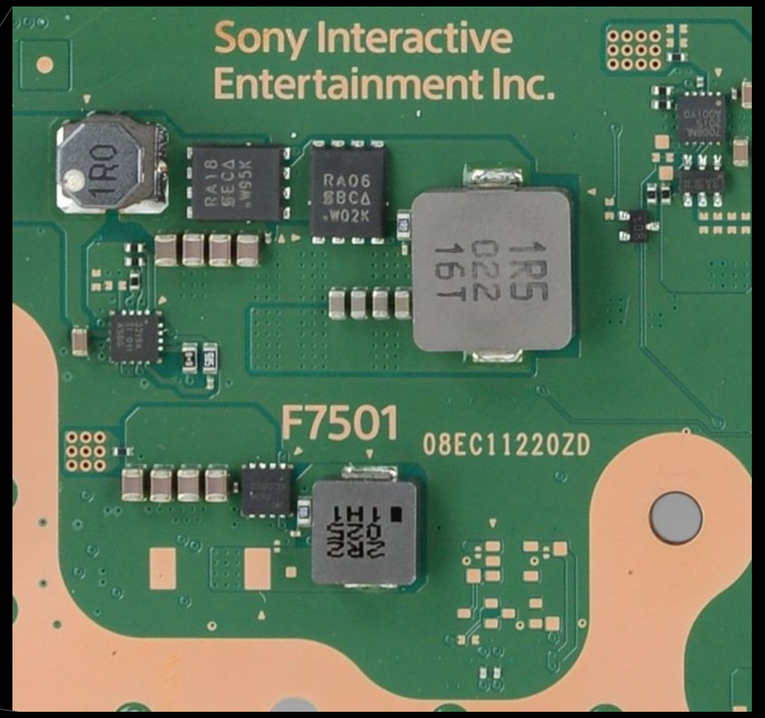
SMT = Surface Mount Technology.

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/VV5iq3vUCpG5fpOI.huge

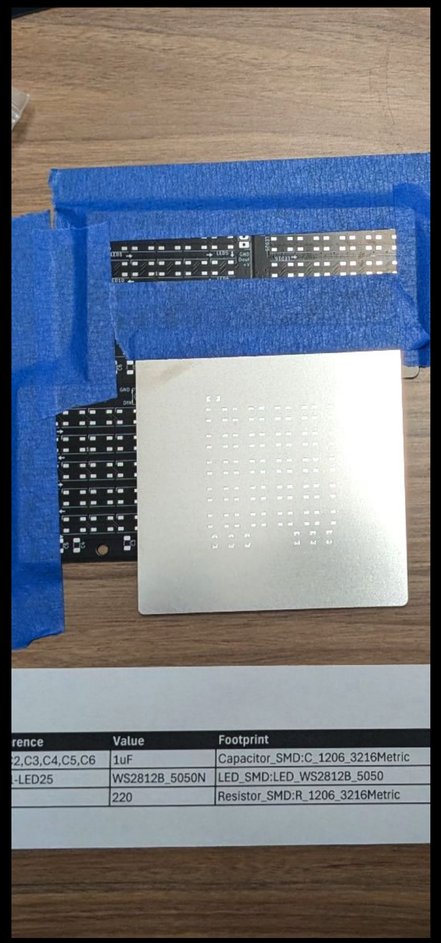


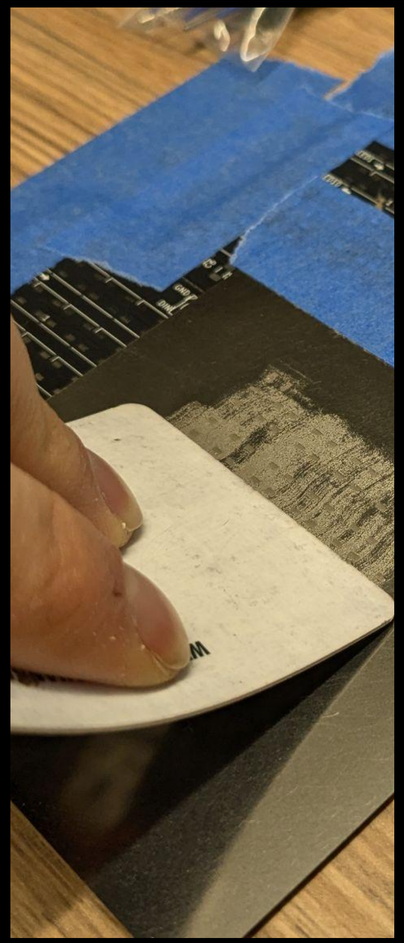


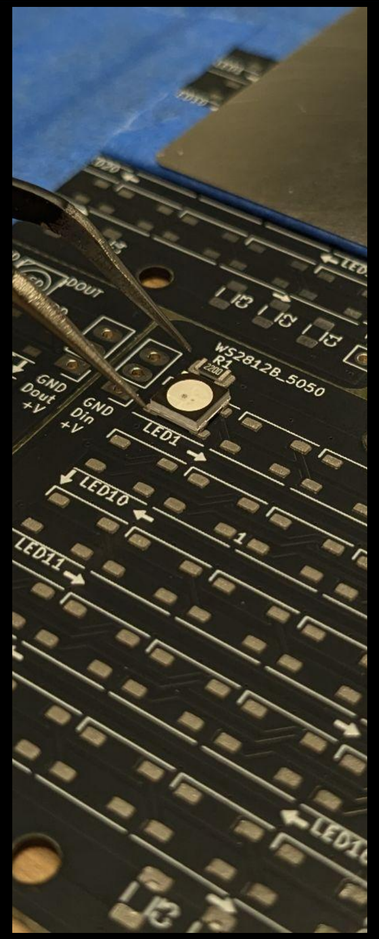
PlayStation 5 motherboard (2020)
© ifixit https://guide-images.cdn.ifixit.com/igi/FUGnem5h2EmFLwlA.huge

SMD ASSEMBLY STEPS (BY HAND)

Setup → Paste → SMD place → Reflow → Inspect/ Rework

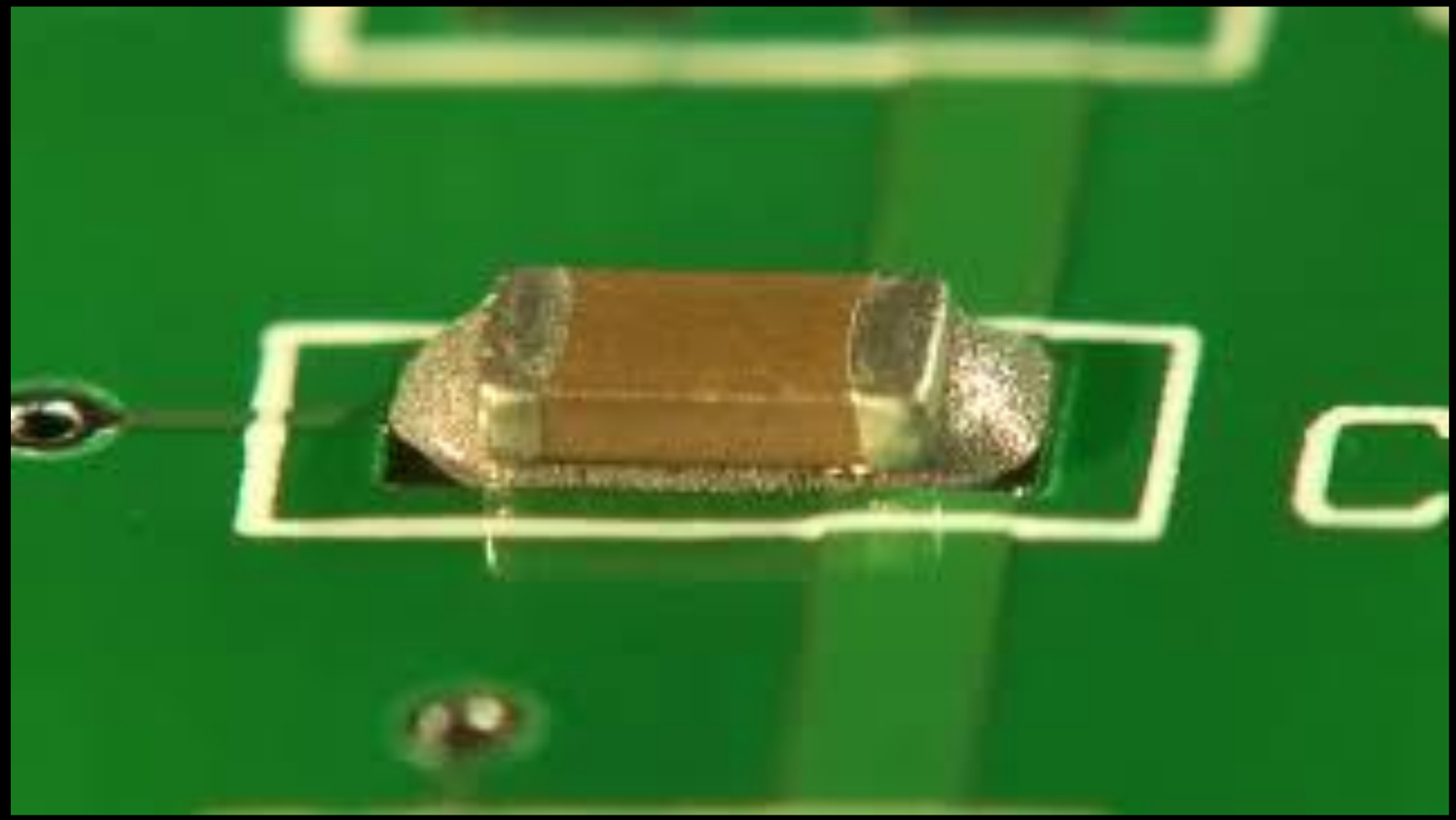






BENEFITS OF SMT

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



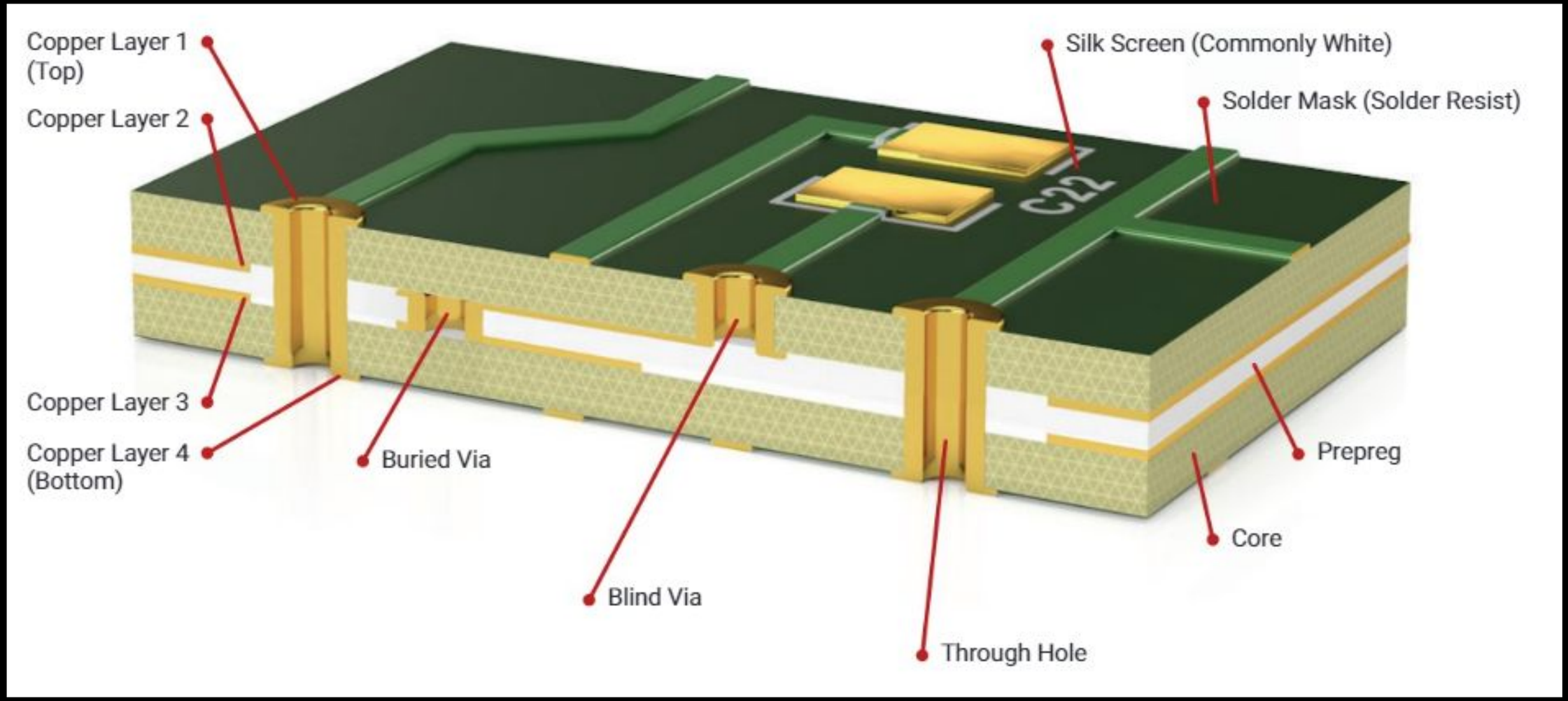
https://www.youtubeeducation.com/watch?v=wkkoVMnc4eQ

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.

(Basically EVERYTHING)

PCB LAYERS VOCAB



https://emedia.digikey.com/view/61501429/28/#zoom=true

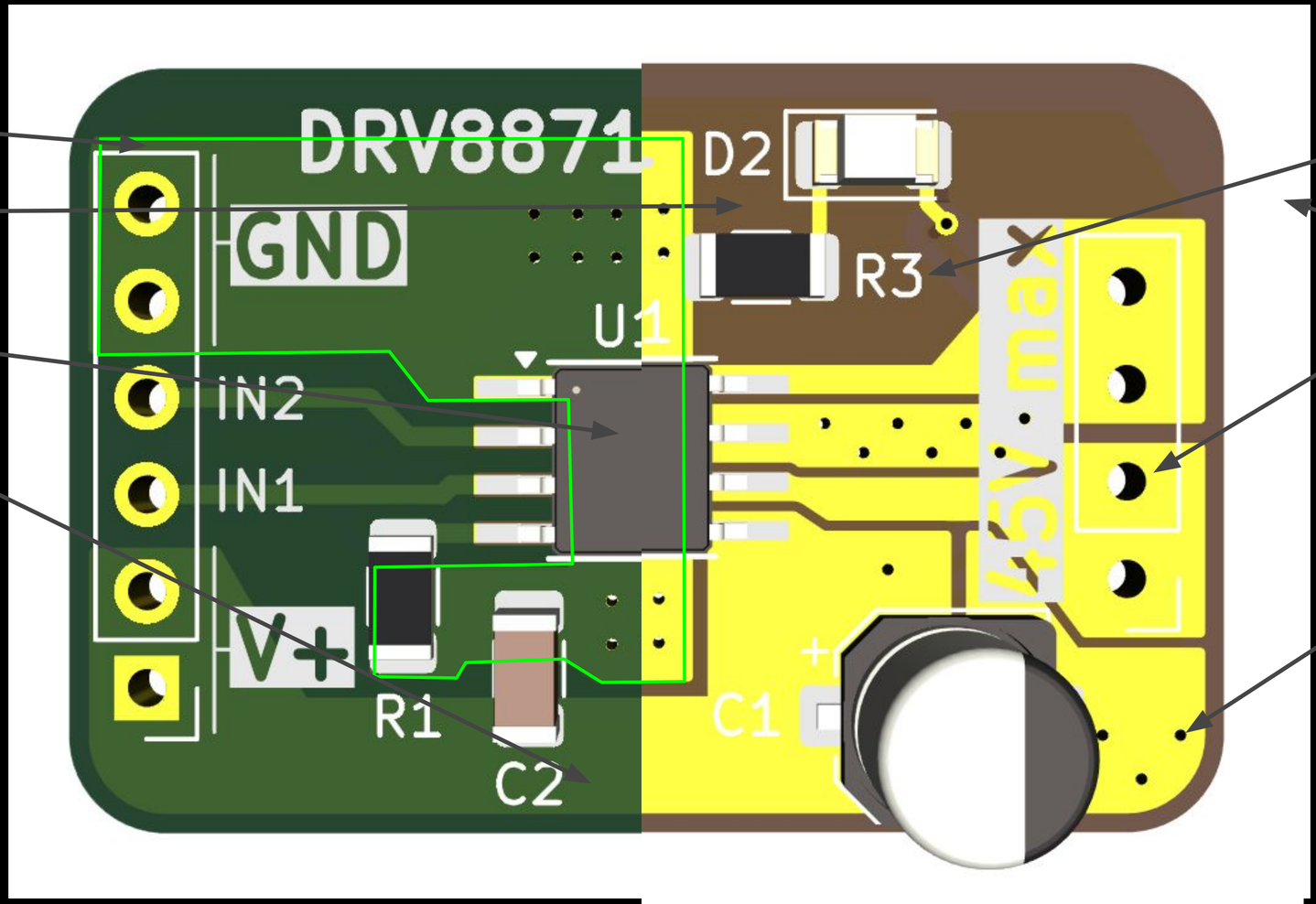
PCB BASIC VOCABULARY

Copper Layer

Substrate

SMD

Solder Mask



Silkscreen

Surface Finish

Through-Hole

Via

PCB BASIC VOCABULARY
(SURFACE FINISH)

Two common examples:

-HASL (Hot Air Surface Level)

-ENIG (Electroless Nickel Immersion Gold)

Conformal Coating

...a dozen more

ELECTRONIC DESIGN AUTOMATION (EDA TOOLS)

Totally Free. Open Source (is pretty good)

$100/ year

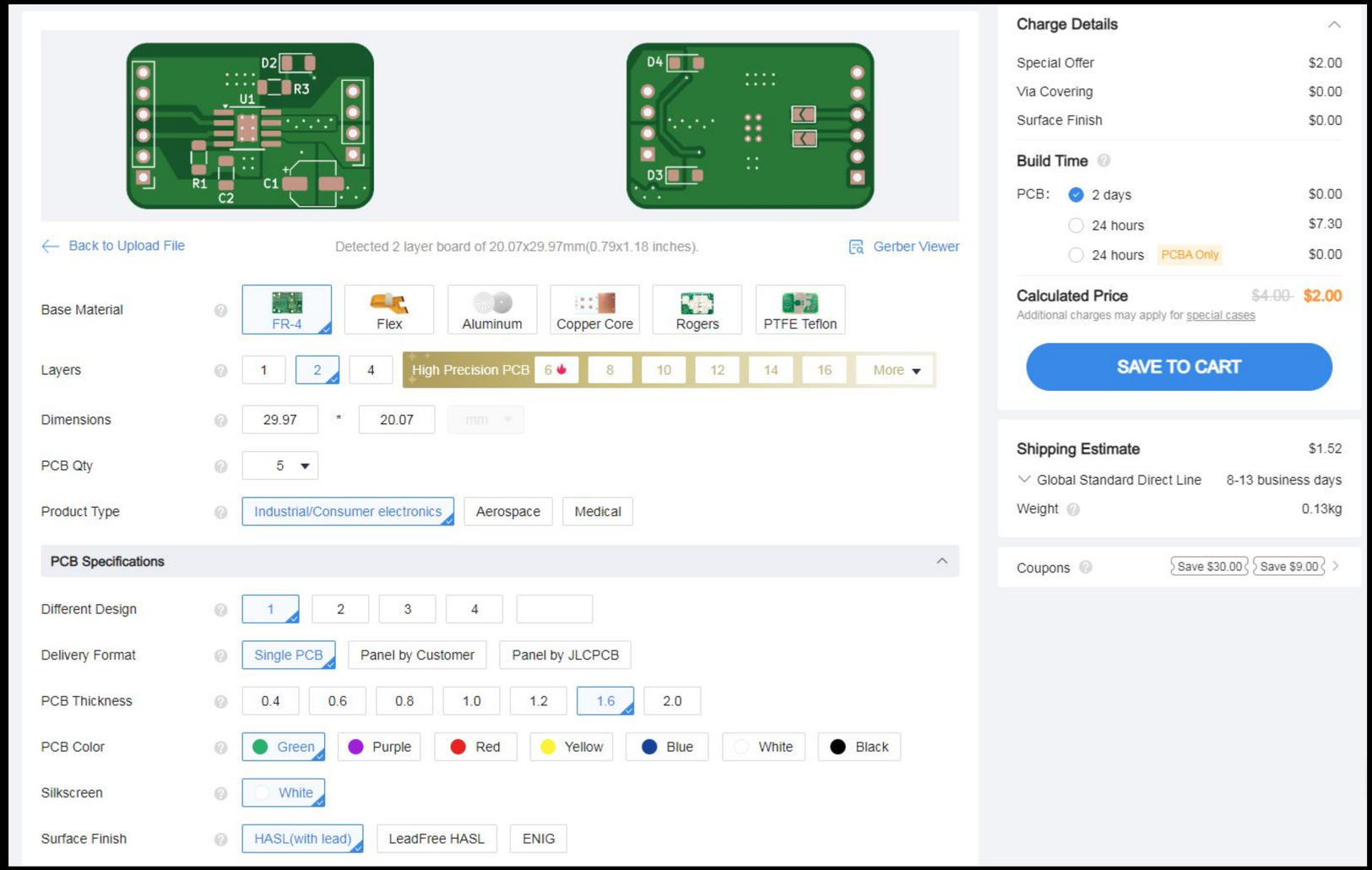
$4,200/ year (is very complex, can do fancy stuff. Professional tool)

OrCAD

$1,280/year

Don't be concerned about which software tool.
Just start learning the skill of design/layout.

PCB MANUFACTURING SERVICES

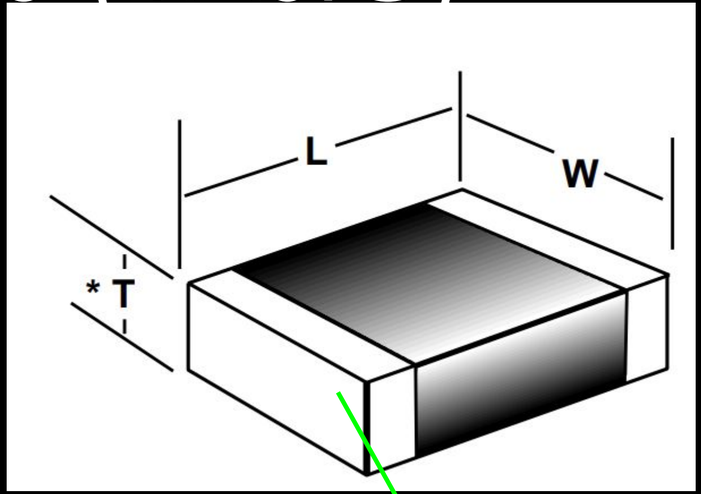


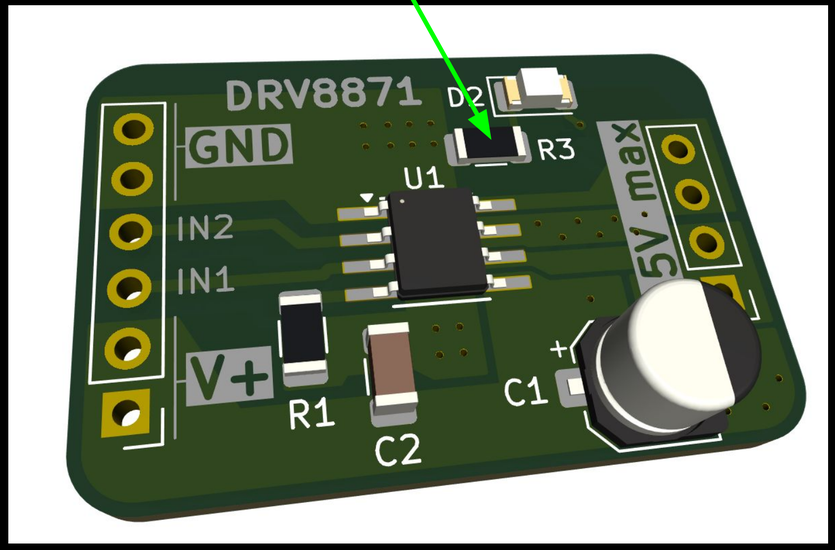
Online, turn-key manufacturing.

SMD PACKAGE SIZES (BASIC)

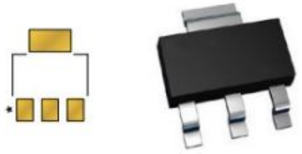
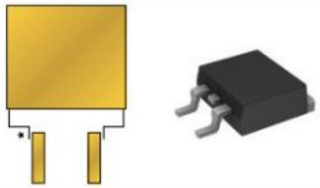
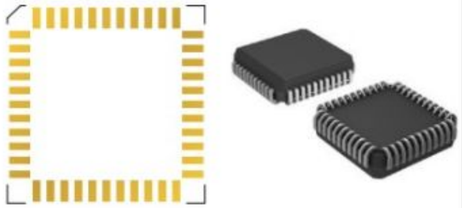
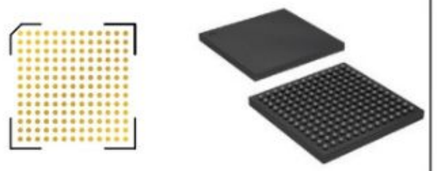
Flat chip nomenclature.
Size range: spec of sand to grain of rice

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

Bumped Die (WLCSP)

Die/Wafer (WLCSP)

3-lead SC70 (LB)

5-lead SC70 (LT)

3-lead SOT-23 (TT/CB)

5-lead SOT-23 (OT)

6-lead SOT-23 (OT/CH)

3-SOT-223 (DB)

4-lead SOT-143 (RC)

3-lead DDPAK (EB)

5-ead DDPAK (ET)

3-lead SOT-89

3-lead TO-92 (TO/ZB)

5-lead TO-220 (AT)

Dual Flat No Lead DFN

8-lead DFN (MC)
2 × 3 × 0.9 mm

8-lead TDFN (MN)
2 × 3 × 0.75 mm

8-lead UDFN (MU)
2 × 3 × 0.5 mm

8-lead DFN (MF)
3 × 3 × 0.9 mm

8-lead DFN (MD)
4 × 4 × 0.9 mm

8-lead DFN (MF)
6 × 5 × 0.9 mm

Very Thin Thermal Leadless Array VTLA

36-lead VTLA (TL)
5 × 5 × 0.9 mm

44-lead VTLA (TL)
6 × 6 × 0.9 mm

124-lead VTLA (TL)
9 × 9 × 0.9 mm

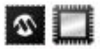
Quad Flat No Lead QFN

16-lead QFN (MG)
3 × 3 × 0.9 mm

20-lead QFN (ML)
4 × 4 × 0.9 mm

20-lead QFN (MQ)
5 × 5 × 0.9 mm

28-lead UQFN (MV)
4 × 4 × 0.5 mm



28-lead QFN (MQ)
5 × 5 × 0.9 mm

28-lead QFN (MM & ML)
6 × 6 × 0.9 mm

40-lead UQFN (MV)
5 × 5 × 0.5 mm

44-lead QFN (ML)
8 × 8 × 0.9 mm

64-lead QFN (MR)
9 × 9 × 0.9 mm

Plastic Shrink Small Outline SSOP

8-lead MSOP (MS)

10-lead MSOP (UN)

16-lead QSOP (QR)

20-lead SSOP (SS)

28-lead SSOP (SS)

Plastic Thin Shrink Small Outline TSSOP

8-lead TSSOP (ST)

14-lead TSSOP (ST)

20-lead TSSOP (ST)

Plastic Small Outline SOIC

8-lead SOIC (SN)

8-lead SOIC (SM)

14-lead SOIC (SL)

16-lead SOIC (SL)

18-lead SOIC (SO)

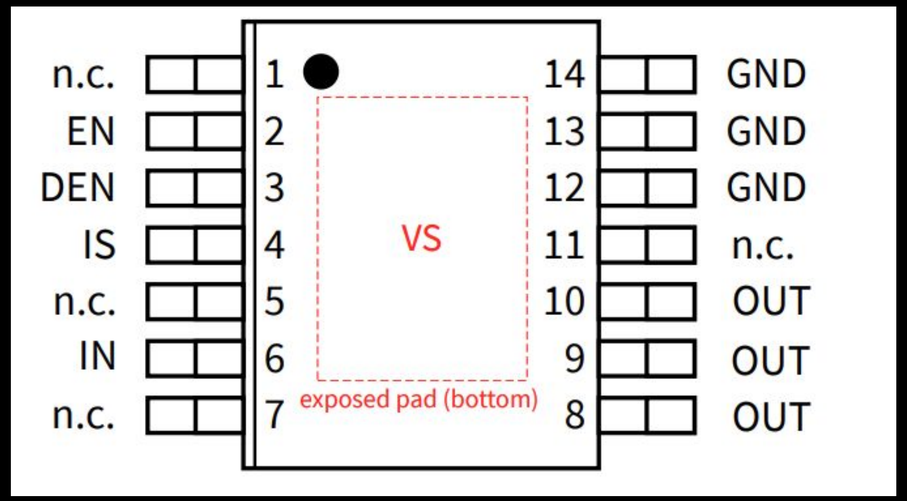
20-lead SOIC (SO)

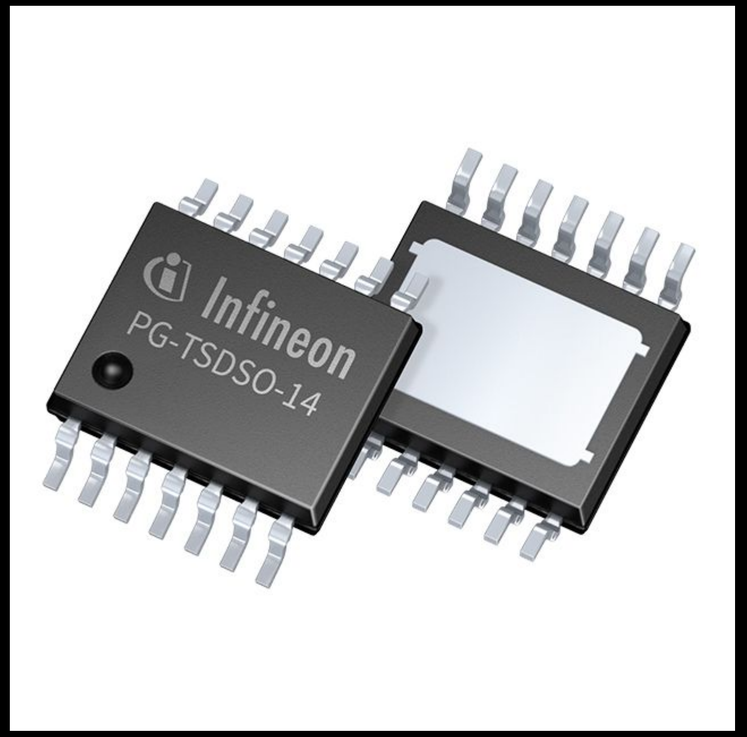
28-lead SOIC (SO)

There are hundreds of packages / footprints.

PIN INDICATION, POLARITY, STANDARDS

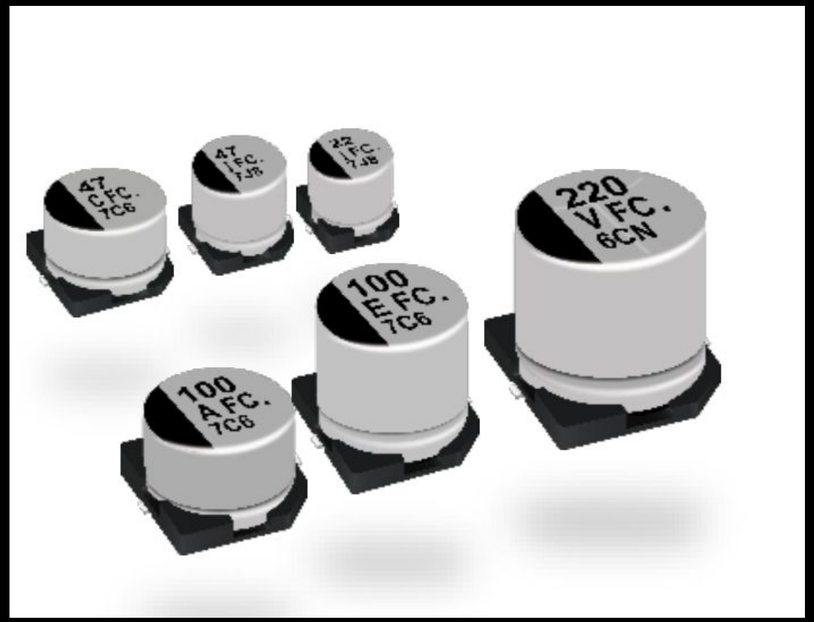
Fiducial mark





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

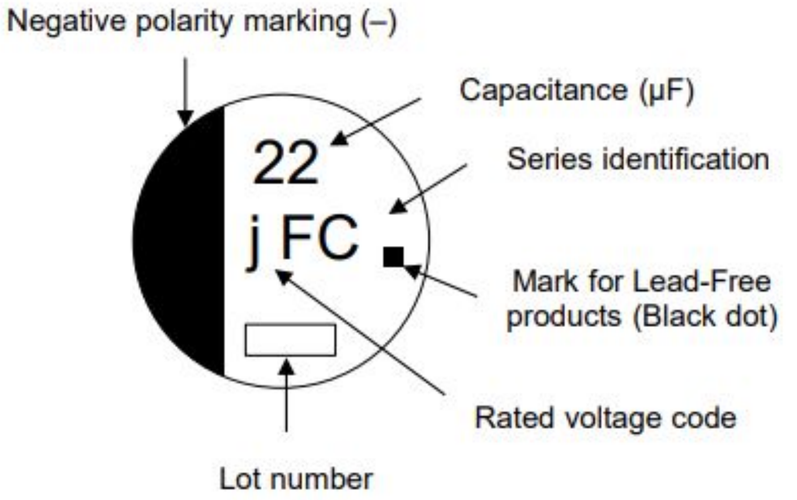
PIN INDICATION, POLARITY, STANDARDS



Polarity marking

Marking

Example : 6.3 V 22 µF
Marking color : BLACK

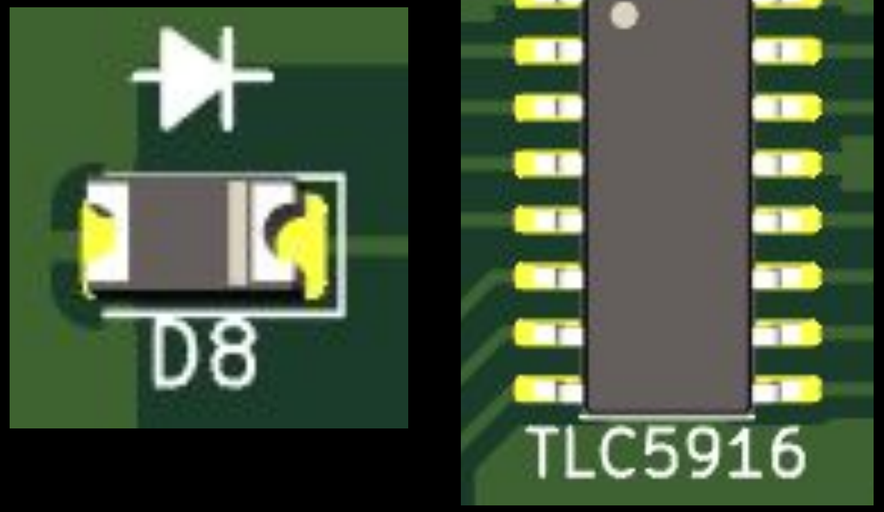


R.voltage code — Unit : V

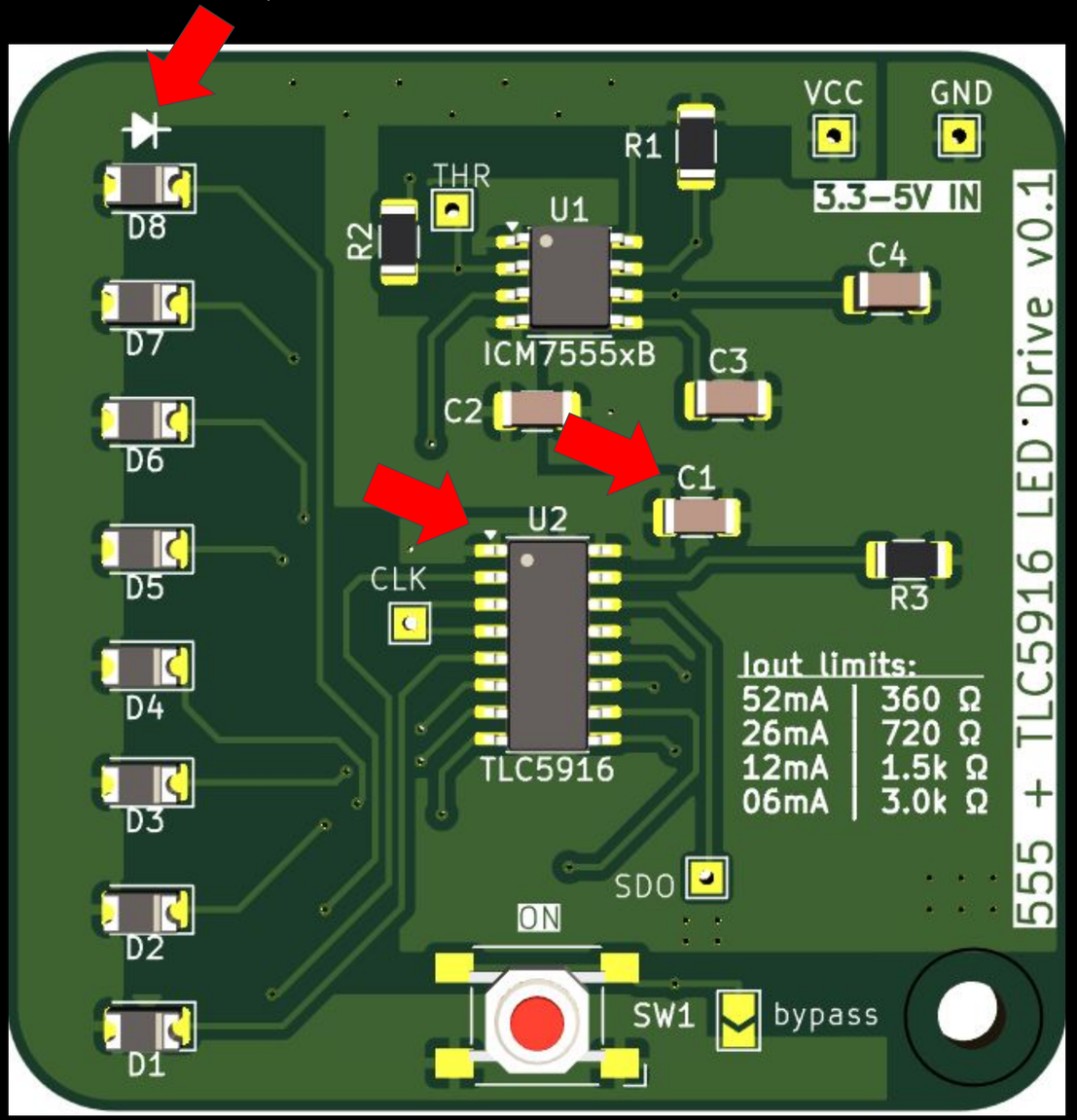
j	6.3	E	25
A	10	V	35
C	16	H	50

https://www.digikey.com/en/products/detail/panasonic-electronic-components/EEE-FC1C100R/817404

PIN INDICATION, POLARITY, REFERENCE Markers



(Polarity markings)

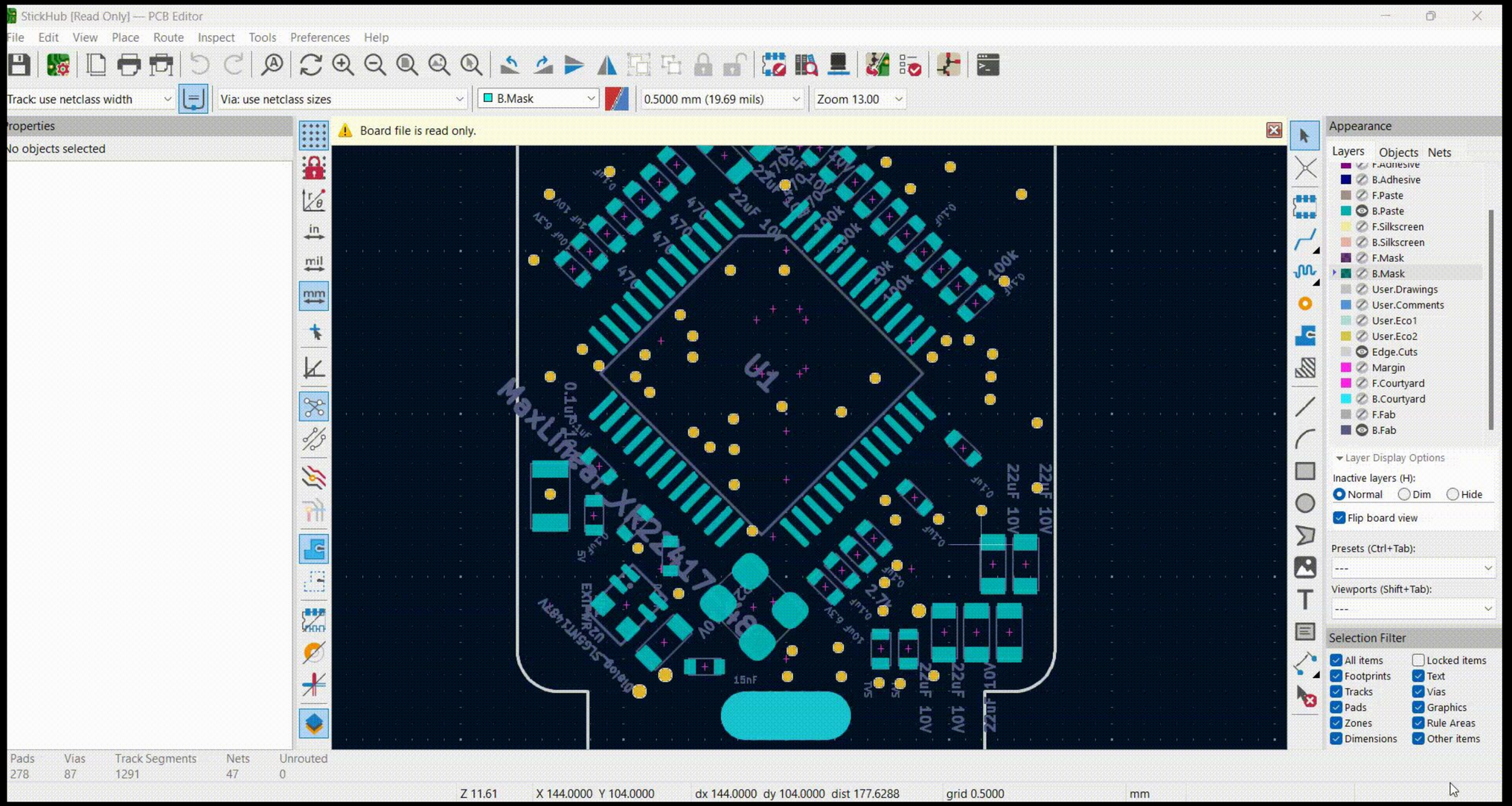


Bill of Materials (BoM)

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	

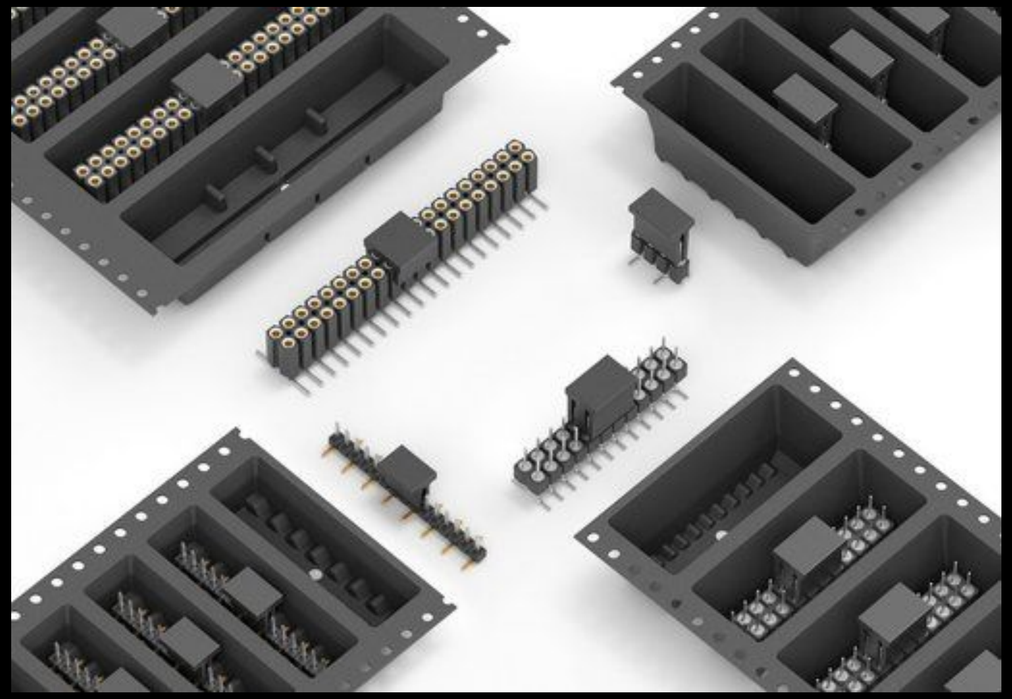
AUTOMATED ASSEMBLY: PICK AND PLACE

PICK AND PLACE: POSITION DATA



PIN INDICATION, POLARITY, STANDARDS

Picking complexities



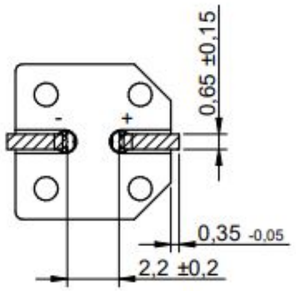
https://www.surfacemountprocess.com/component-placement-process.html

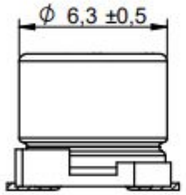
WHERE TO BUY PARTS

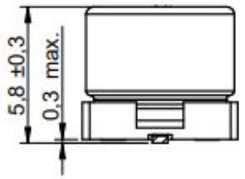
Pick reputable vendors. There are 100k's + of SMD parts. You must trust the source to trust what you produce.

DATASHEETS!

Dimensions: [mm]

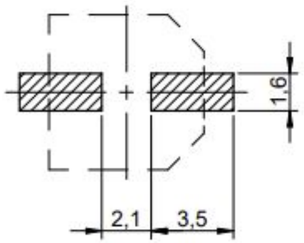






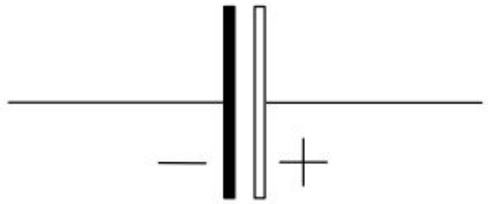
Scale - 3:1

Recommended Land Pattern: [mm]



Scale - 3:1

Schematic:



Electrical Properties:

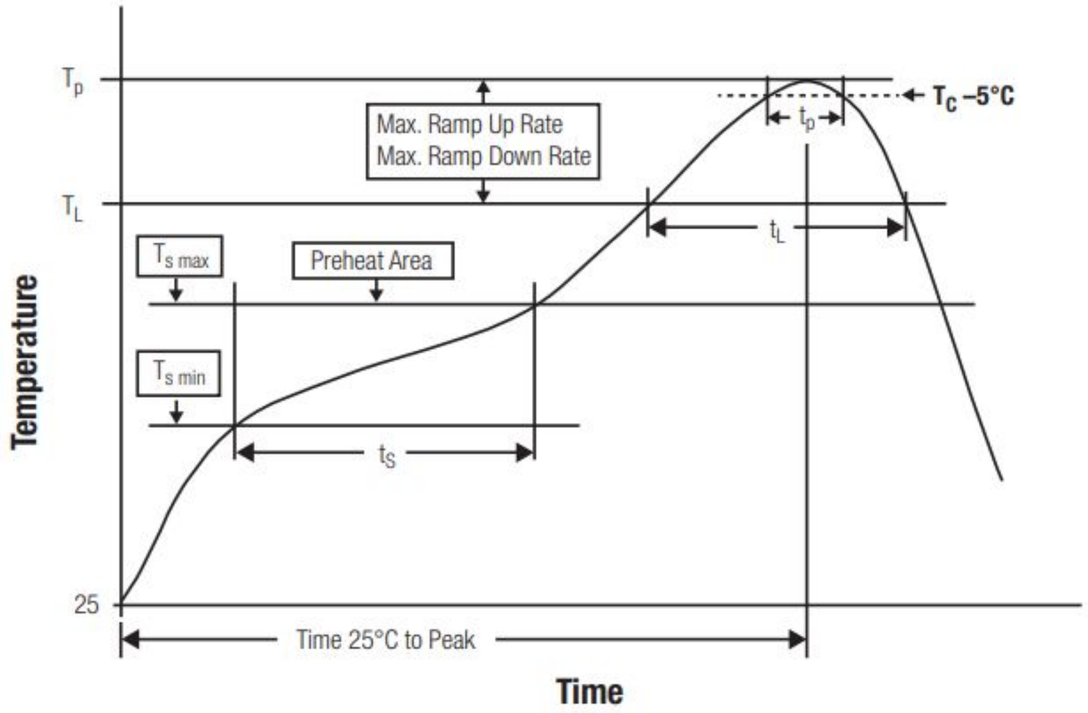
Properties		Test conditions	Value	Unit	Tol.
Capacitance	C	0.25 V/ 120 Hz/ +20 °C	220	µF	±20%
Rated Voltage	V_R		10	V (DC)	max.
Surge Voltage	V_S	1000 cycles @ 20 °C	11.5	V (DC)	max.
Leakage Current	I_{Leak}	2 min./ +20 °C	300	µA	max.
Dissipation Factor	DF	0.25 V/ 120 Hz/ +20 °C	8	%	max.
Ripple Current	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):

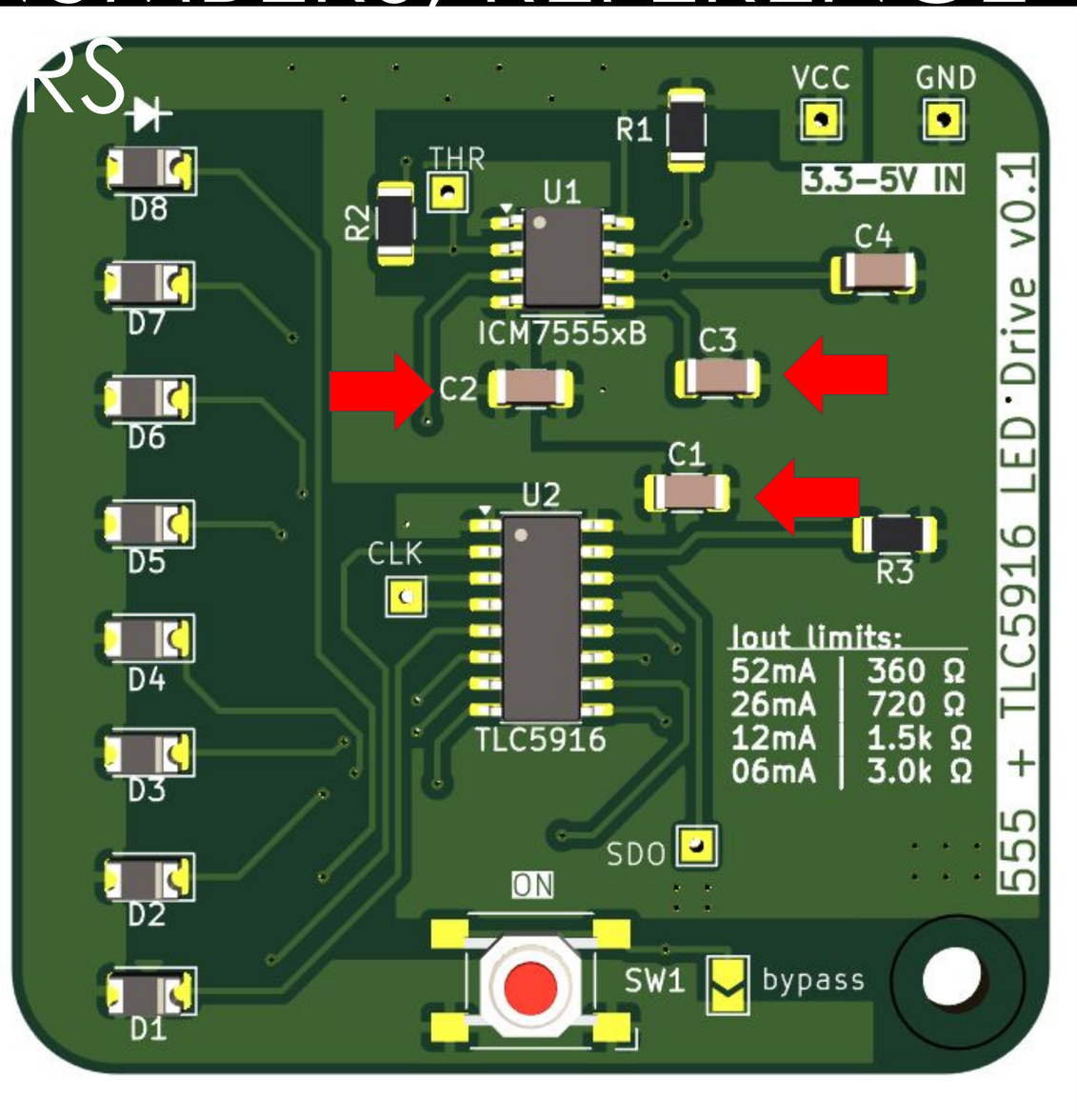
Properties	Volume mm^3 <350	Volume mm^3 350-2000	Volume mm^3 >2000
PB-Free Assembly I Package Thickness < 1.6 mm	260 °C	260 °C	260 °C
PB-Free Assembly I Package Thickness 1.6 mm - 2.5 mm	260 °C	250 °C	245 °C
PB-Free Assembly I Package Thickness > 2.5 mm	250 °C	245 °C	245 °C

refer to IPC/ JEDEC J-STD-020E

YOU can assemble these designs!

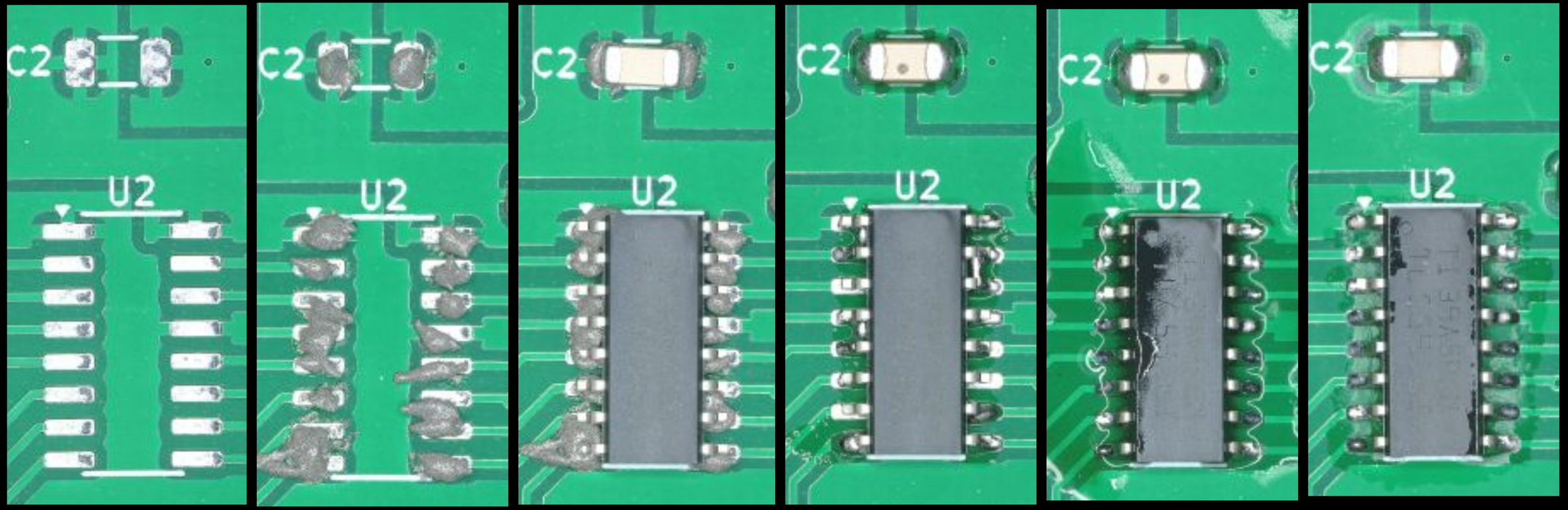
SMD PART NUMBERS, REFERENCE DESIGNATORS

Part Desc	CAP CER 0.1UF 50V X7R 1206
CREF	C1,C2,C3



YOU can assemble these designs!

Prep → Paste → SMD place → Reflow → Inspect/ Rework → Clean

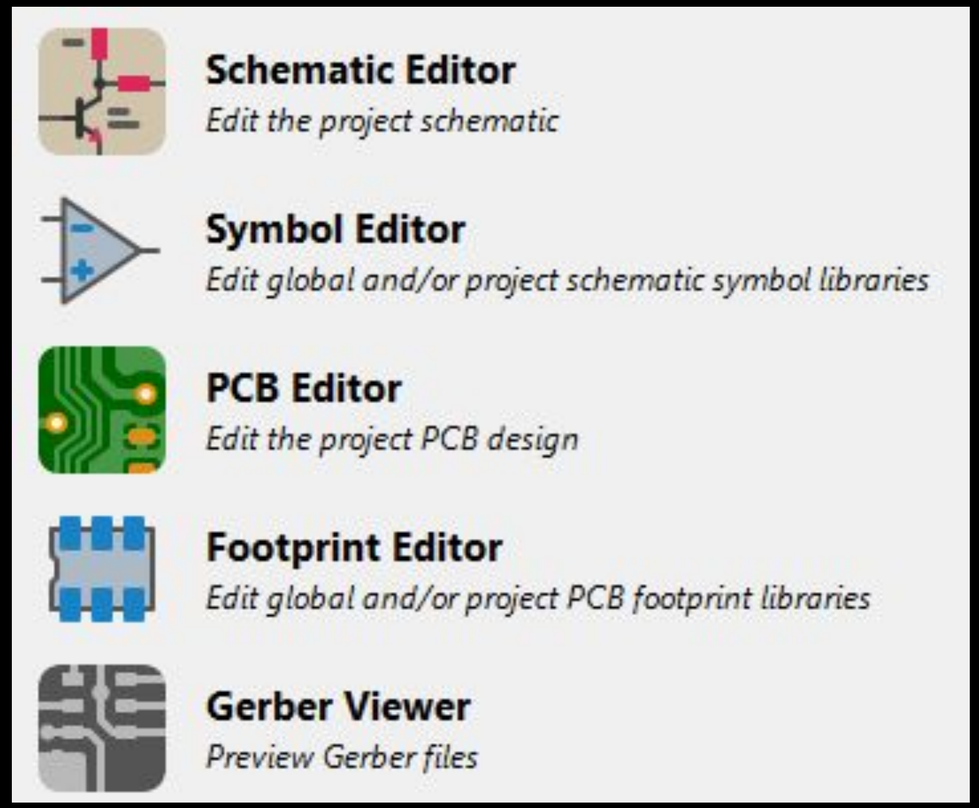


(SMD Reflow overview)

KiCAD

Now you know the lingo and the technology.

Let's talk about the software design toolset EDA (Electronic Design Automation)

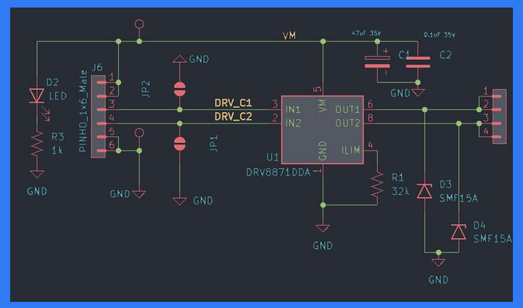


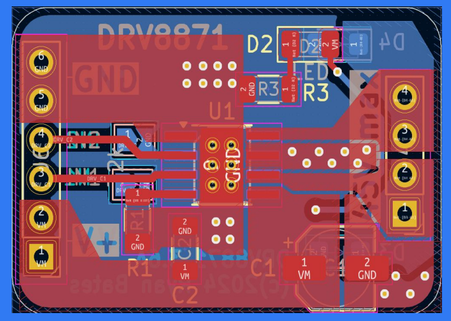
SURFACE MOUNT TECHNOLOGY (SMT)

Automated Manufacturing

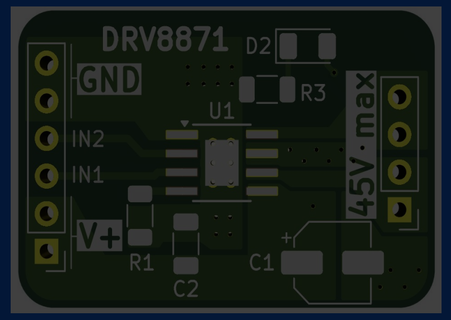
WE ARE HERE

Design

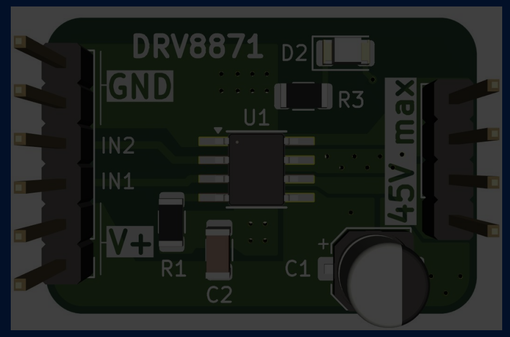




PCB Fabrication



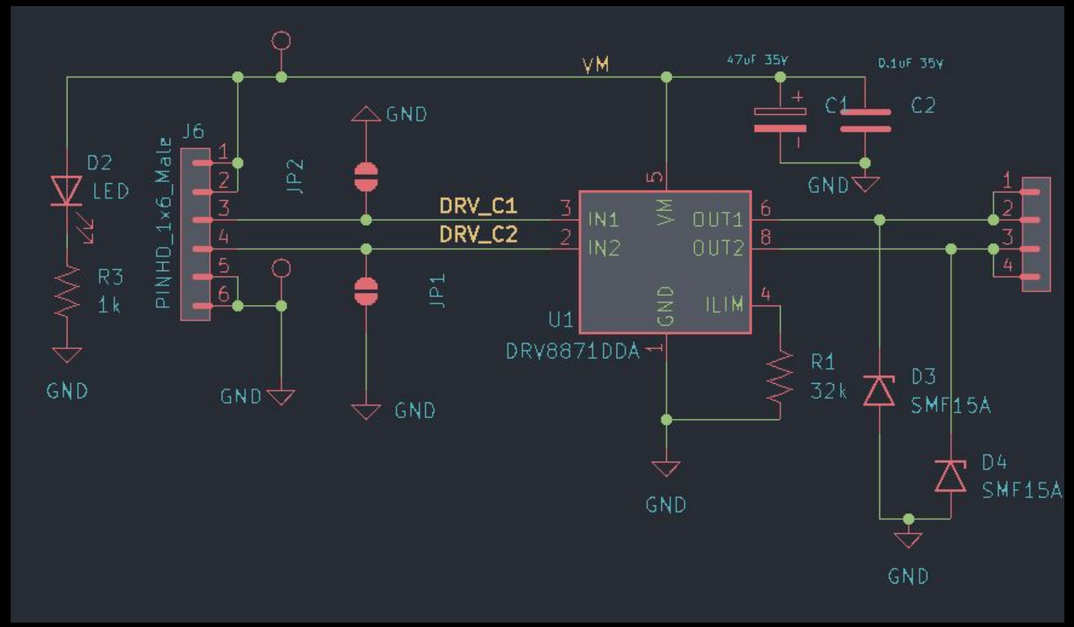
PCB Assembly



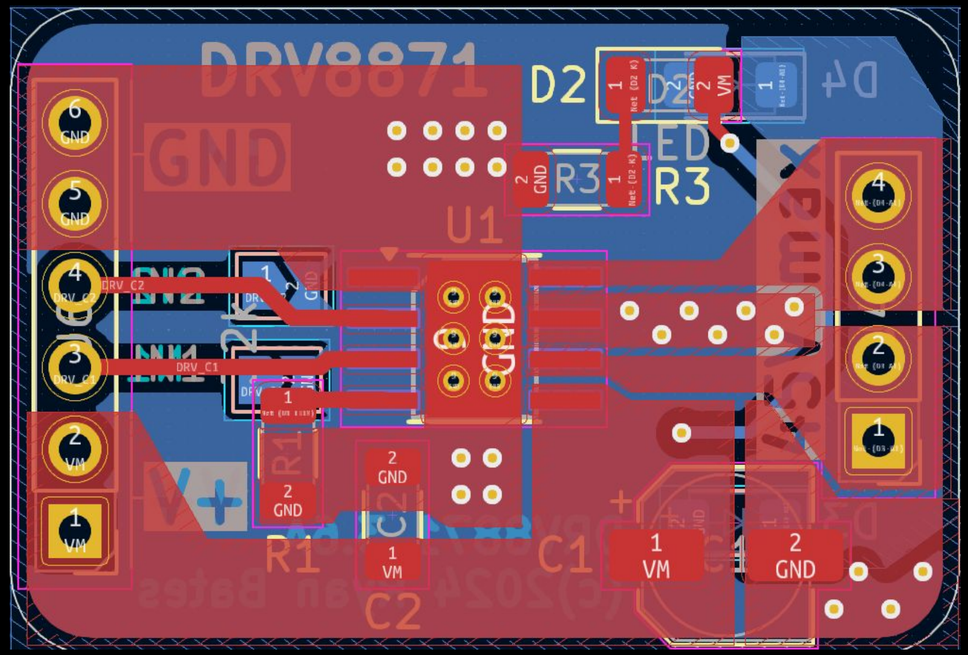
Kinda like plumbing but the pipes < 1mm.

WORKFLOW (HEADSPACE TALK FROM COACH)

Schematic



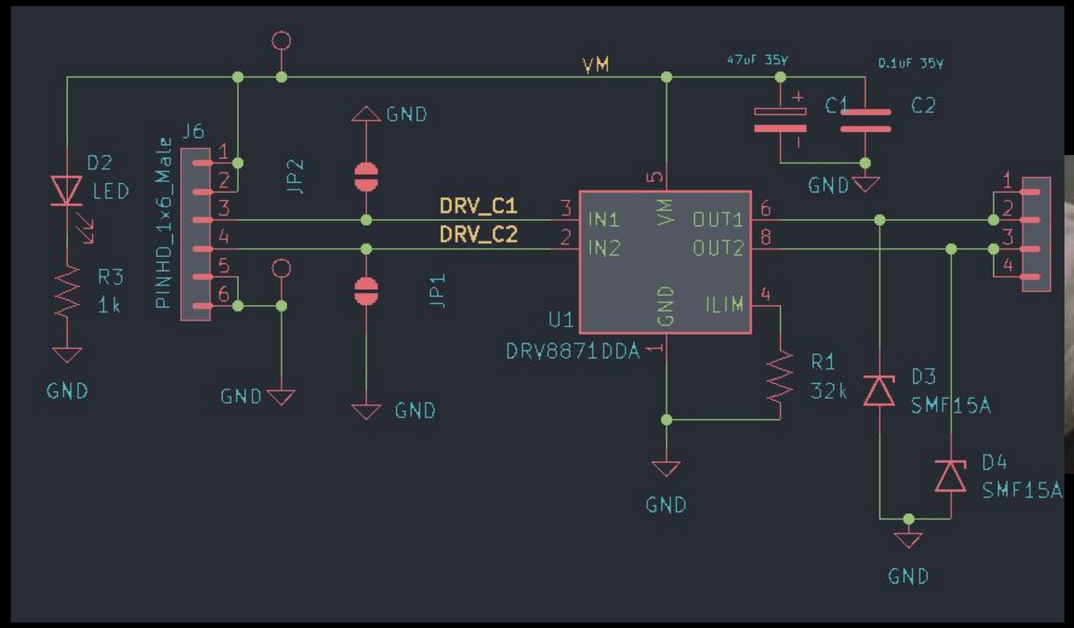
Layout



Routing is a puzzle.
It will develop into a skill *only with* practice.

WORKFLOW (Don’t break parity)

Schematic



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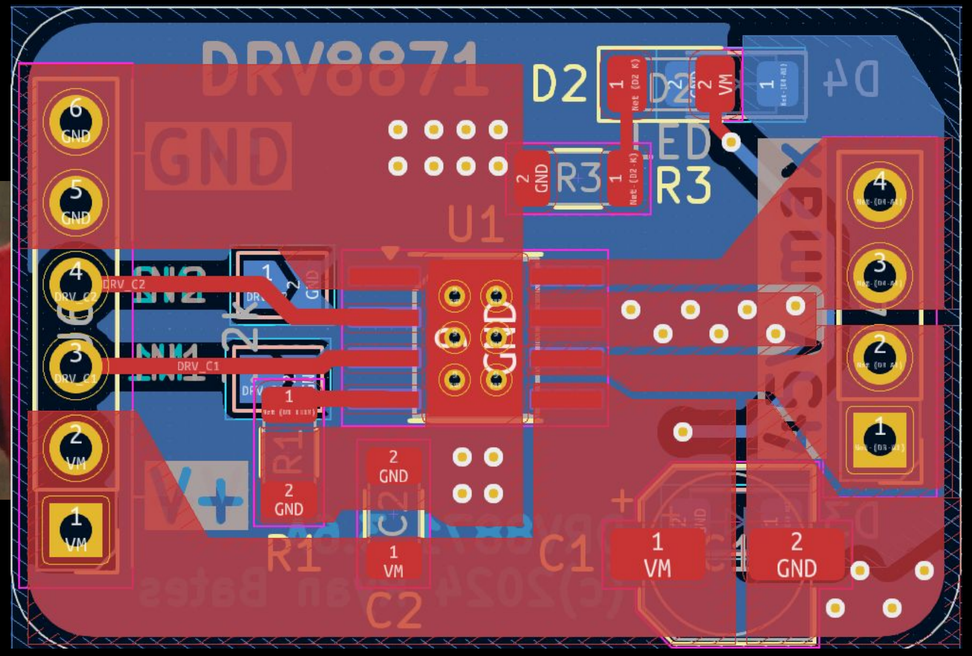
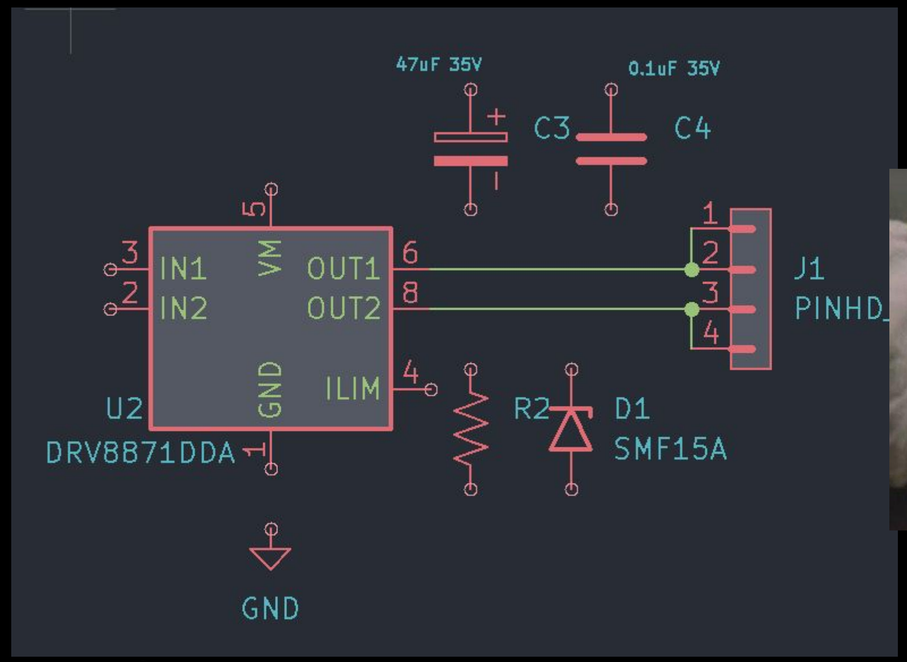
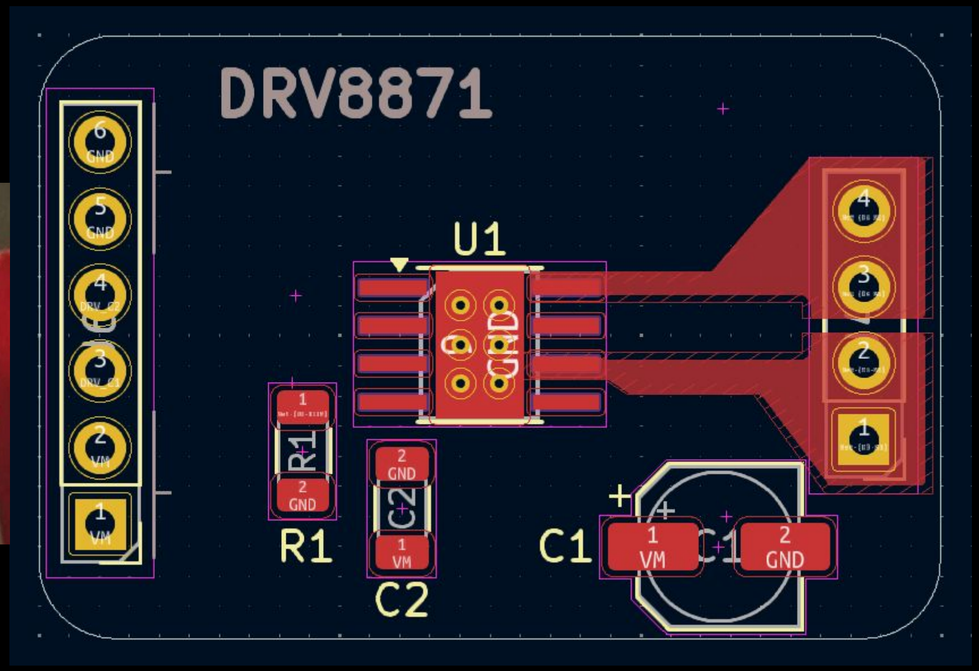


WORKFLOW (THERE ARE RULES/ BEST PRACTICES/ ATTENTION TO DETAILS)

Schematic



Layout



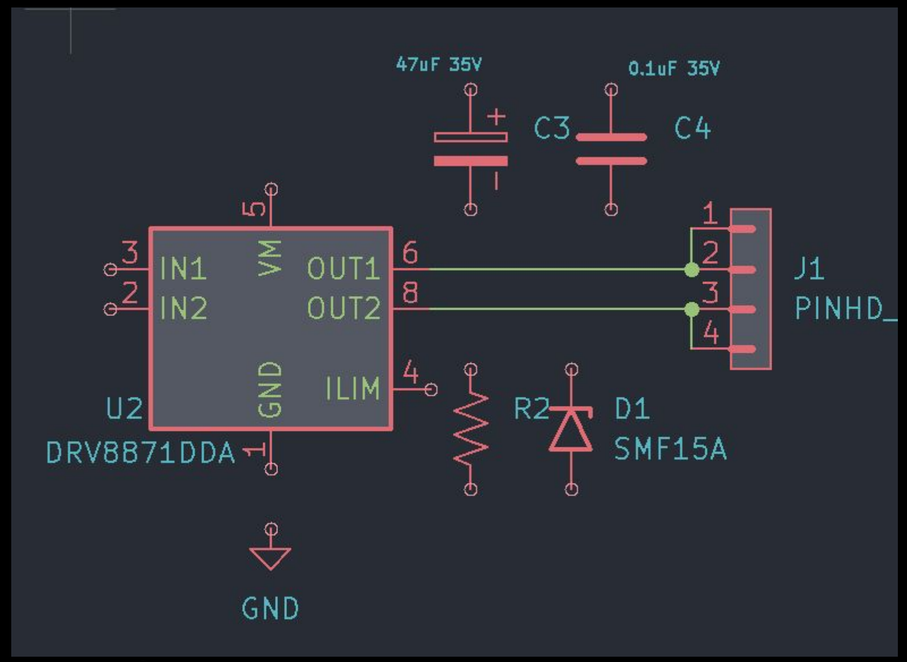
⚠ Electrical Rules

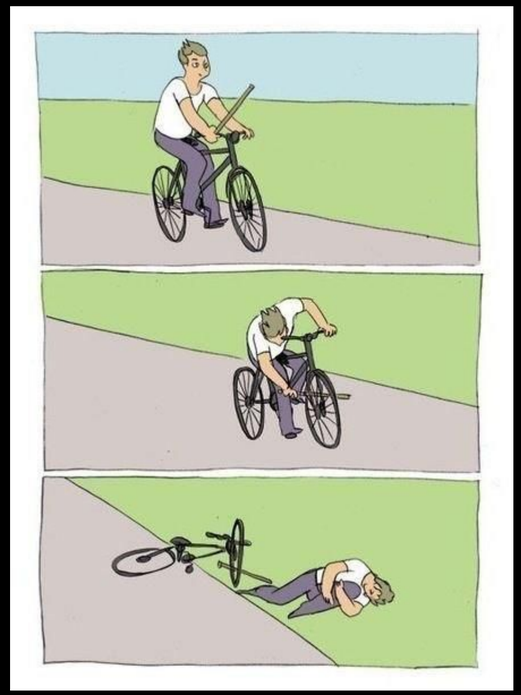
⚠ Design Rules

WORKFLOW (IF YOU BREAK RULES/ UNAWARE OF THEM)

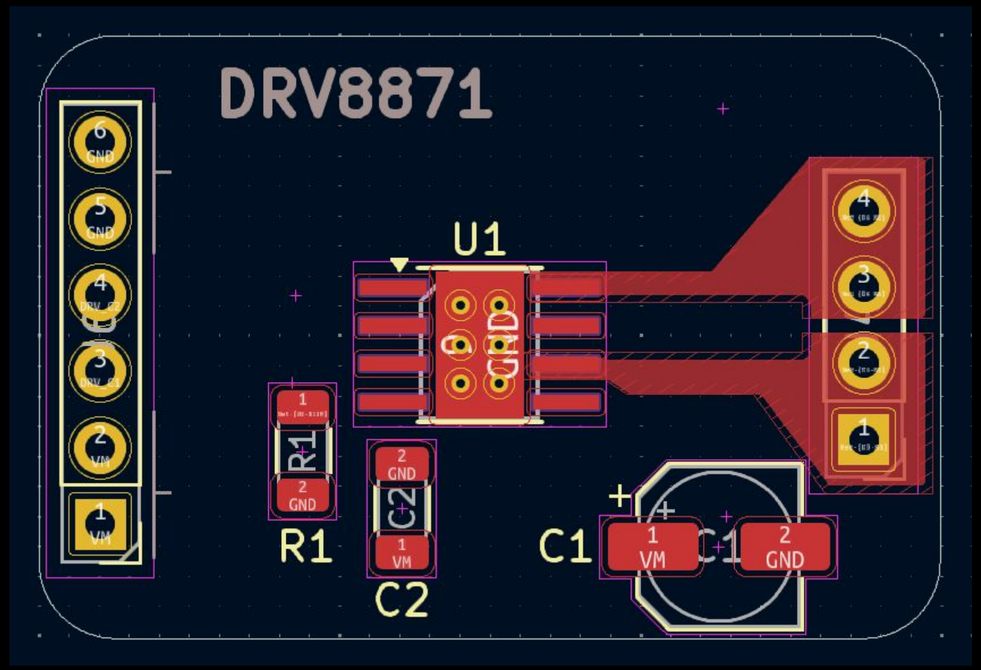
You will make mistakes. Embrace them.

Schematic





Layout

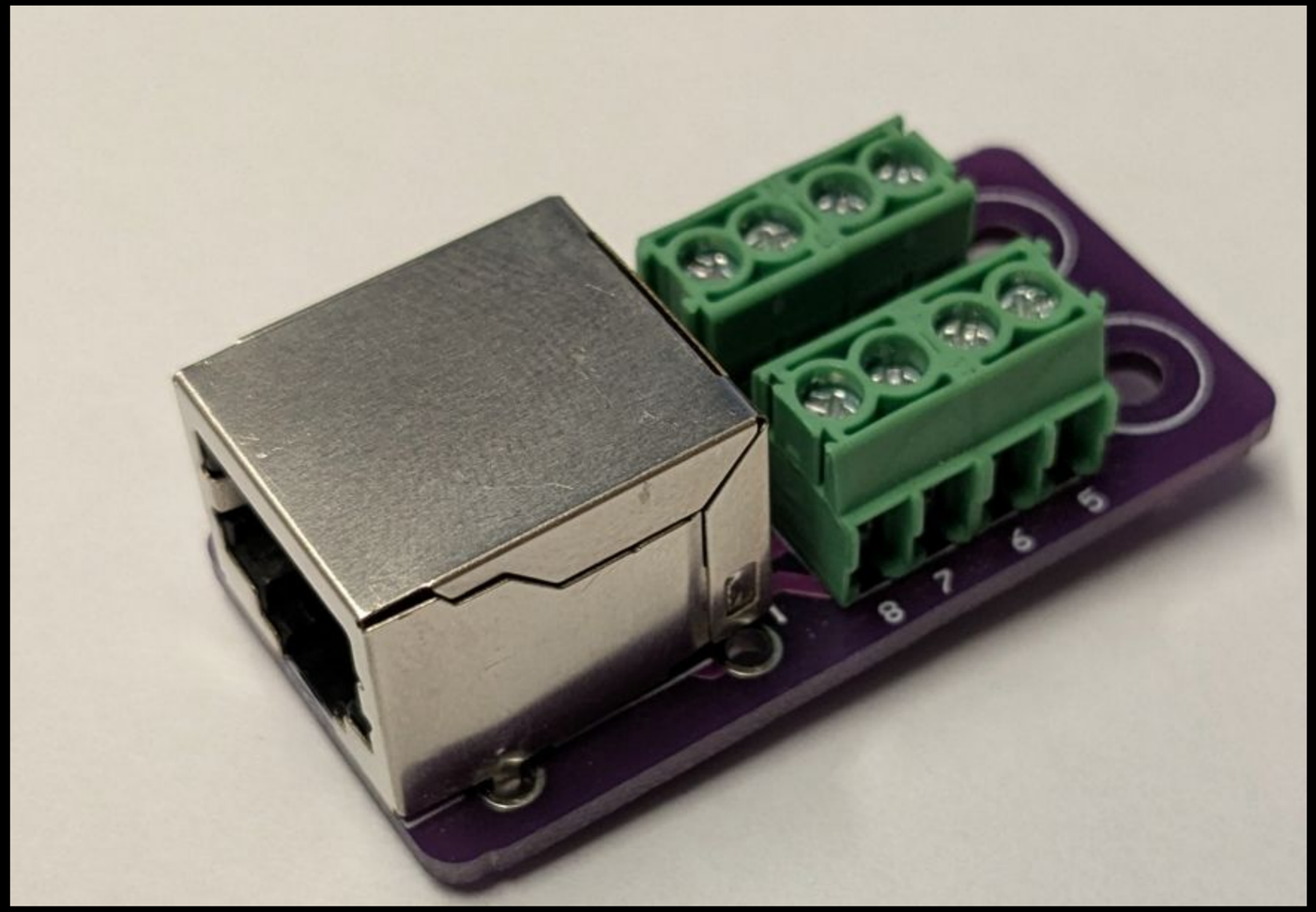


⚠ Electrical Rules

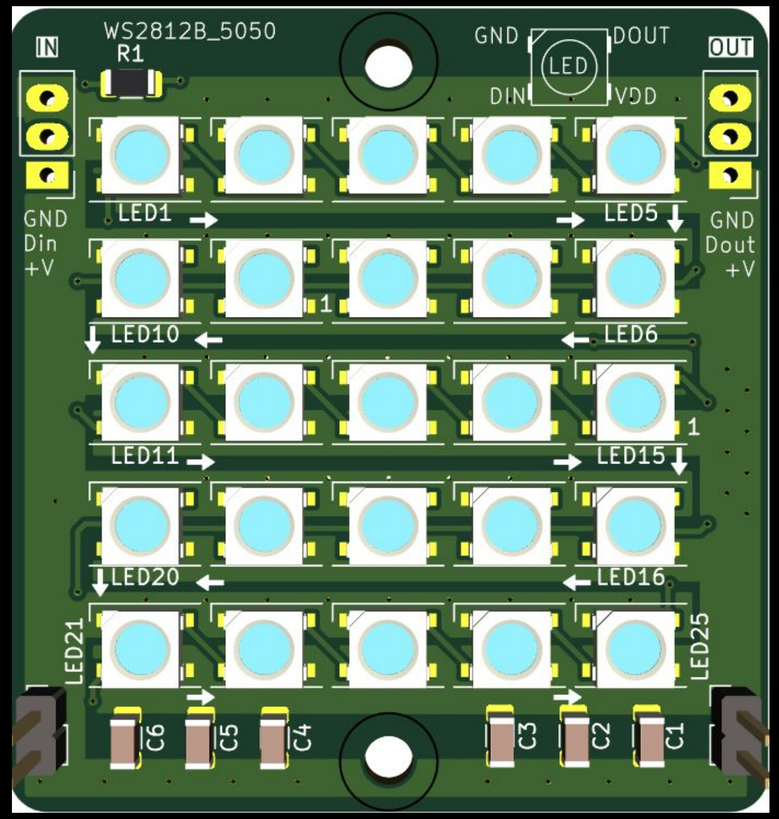
⚠ Design Rules

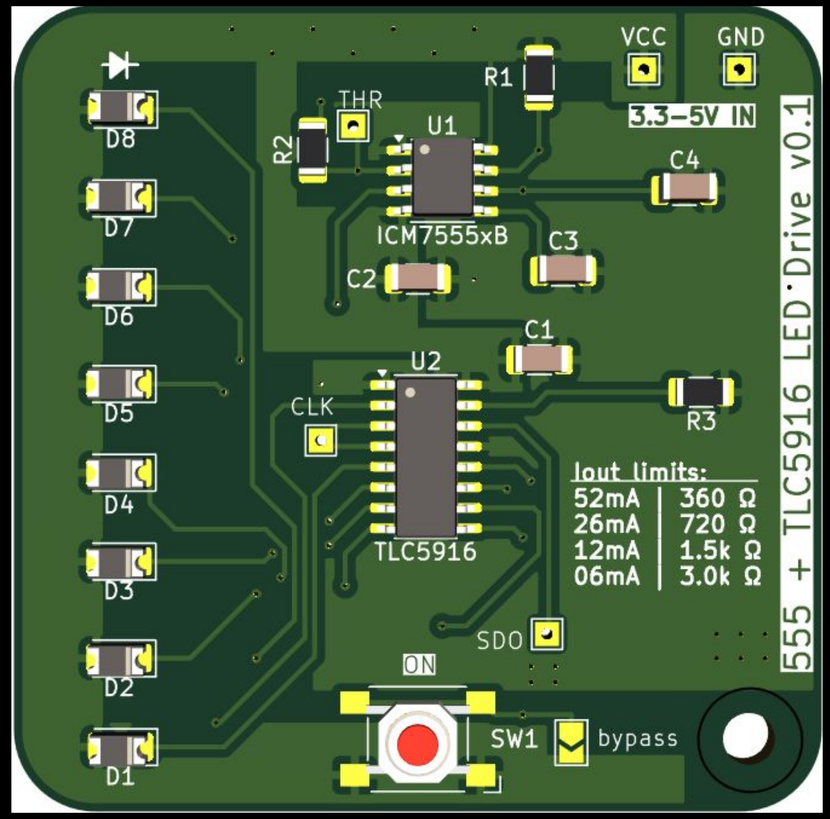
PROJECT #1 !

- RJ-45 (ethernet) breakout PCB
- Use network cables as whatever you want 8-conductor power, data, signal cables



…Example #2 and #3





Open KiCAD.

Layout time!

EXERCISE 3: WHAT IS IT?

Turn on lights (LEDs)

without a microcontroller.