Ticking Time Bombs

Replacing Electrolytic Capacitors

James Lewis

@baldengineer

bald.ee/**vcfmw2025**

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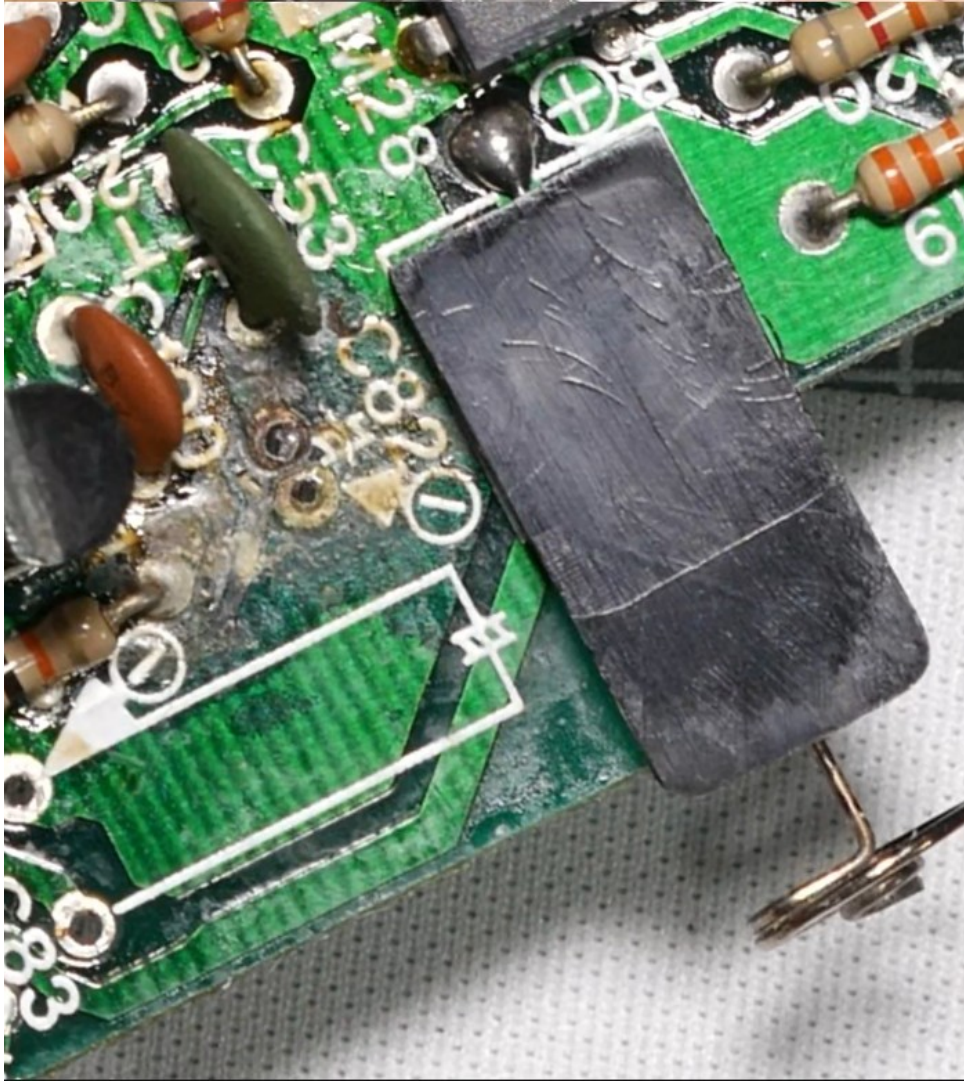
Do they need to be replaced?

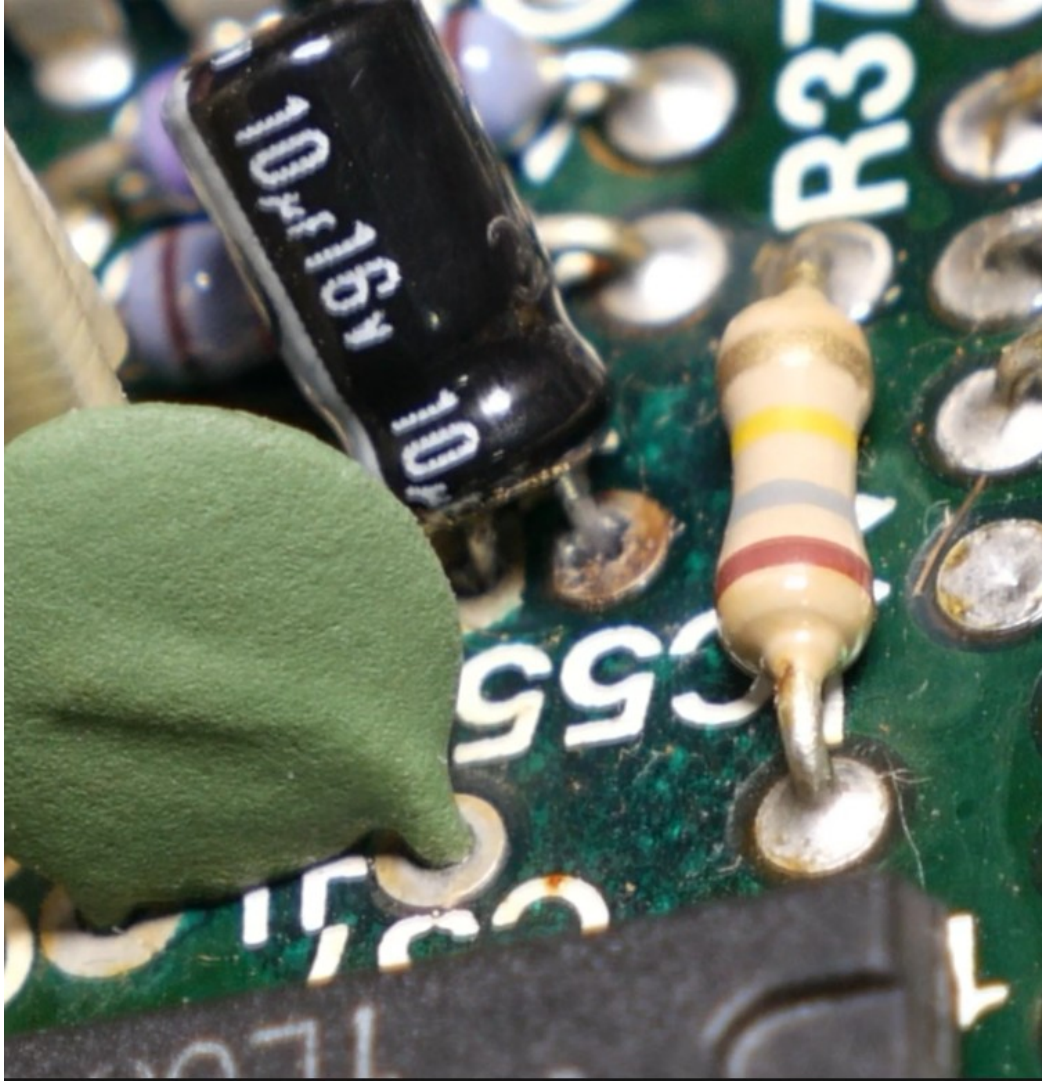
Uhhh...

Yes.



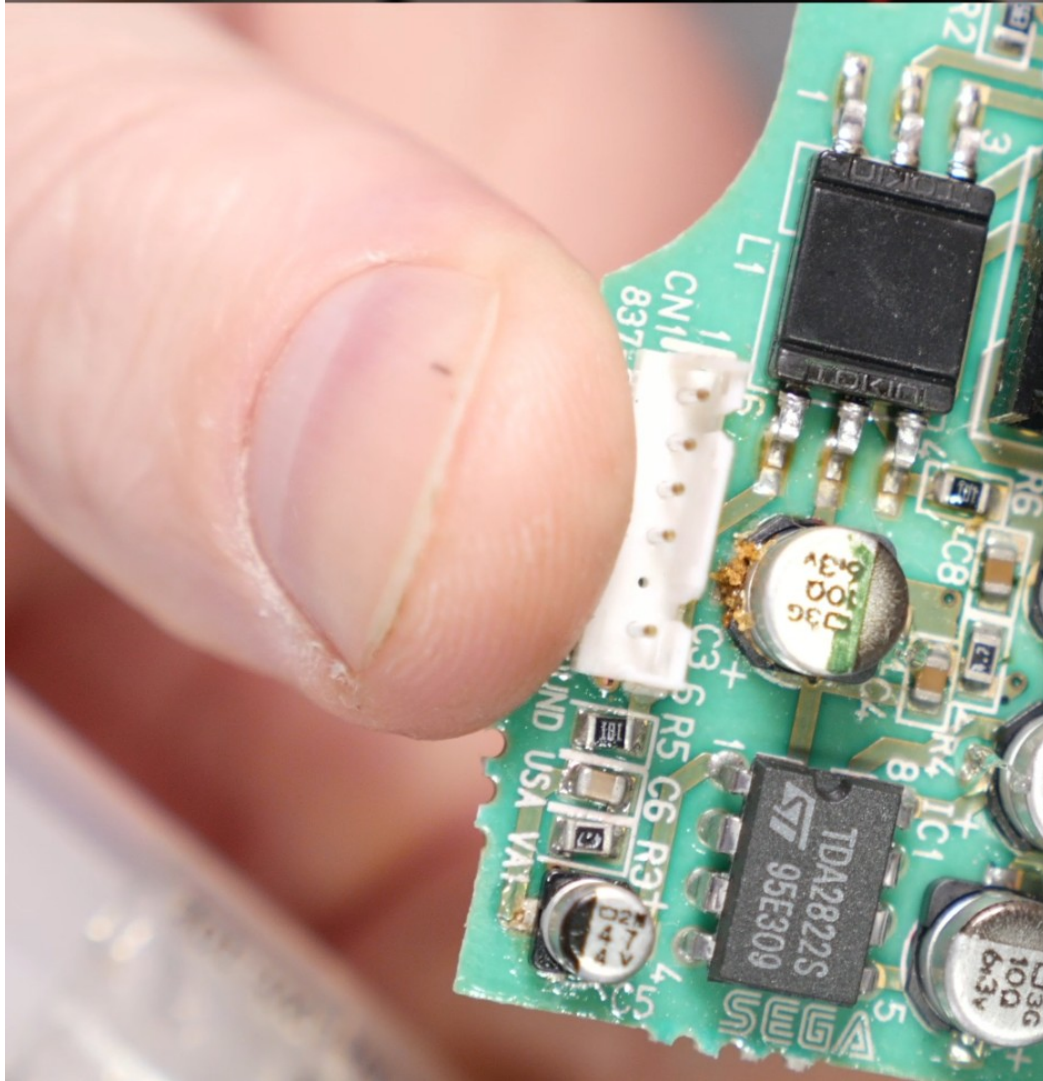
"My Caps Are Fine"

The damage can be hiding



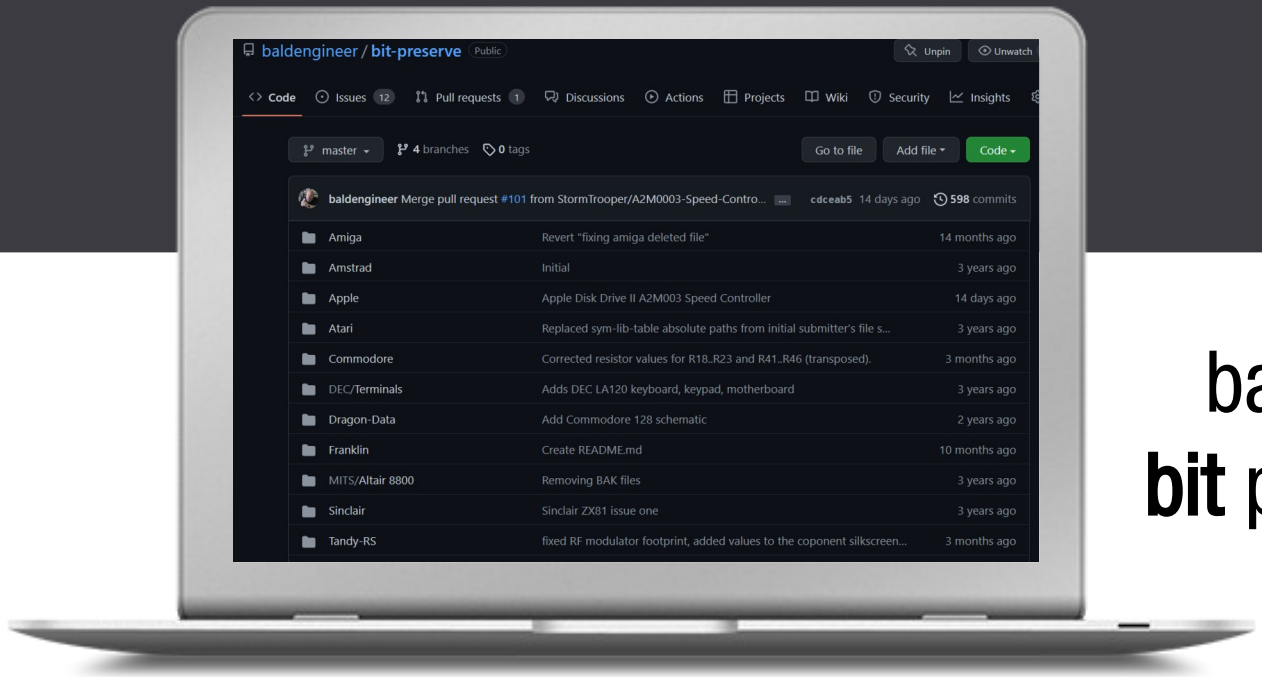
Sometimes

Bad caps can affect audio too.




AddOhms
BALDENGINEER
FPGA
Emulation

Bit Preserve
Vintage Computer Schematics in KiCad



bald.ee/
bit preserve

Capacitance

Decades: 10, 100, 1000
E12 Series: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82

Rated Voltage

Dimensions

Length (Height) x Diameter (and Pitch)

Temperature

1000 Hours @ 85°C
85°C ▶ 105°C 105°C ▶ 125°C

Impedance

Impedance ↑ Ripple Current ↓

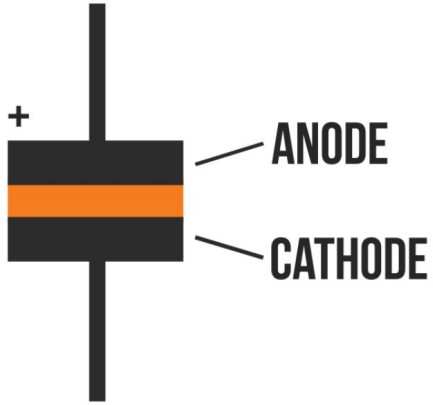
Cost

¯_(ツ)_/¯

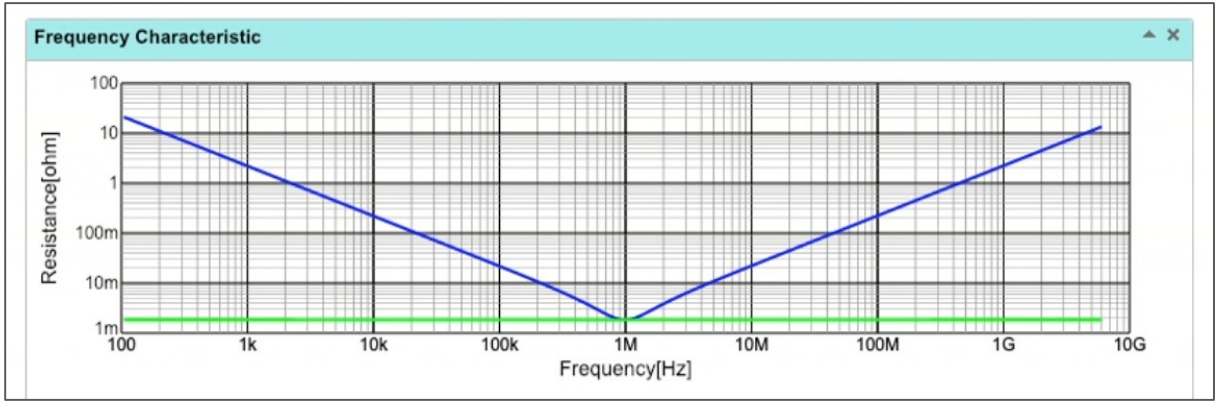
Capacitor Introduction

Capacitor Basics

DIELECTRIC



$$C = \frac{k\, e_o\, A}{d}$$

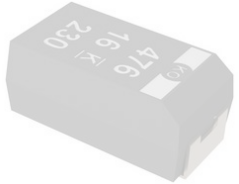


Five Major Capacitor Types

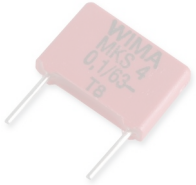
Ceramic

Aluminum Electrolytic

Tantalum



Film

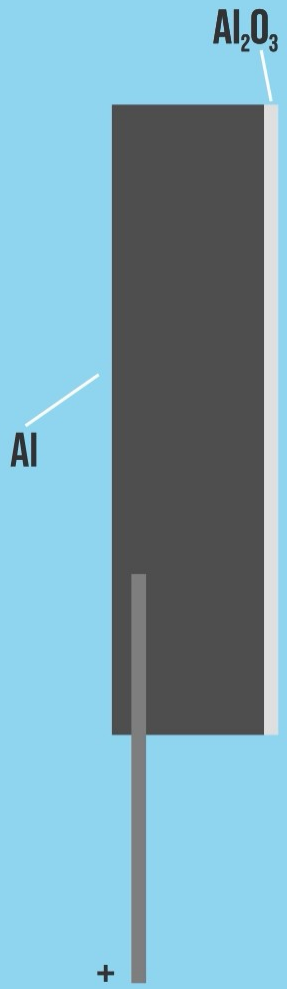


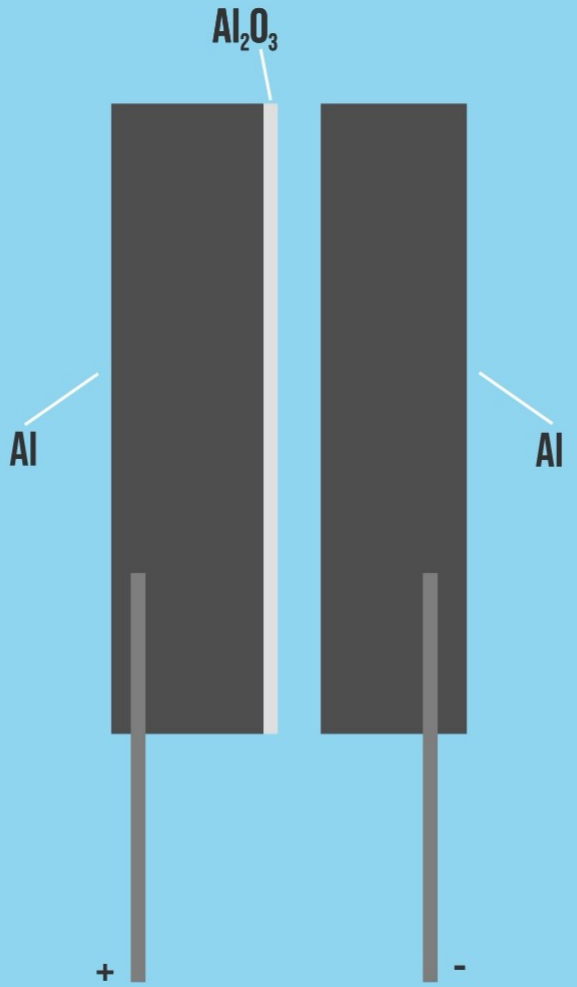
EDLC

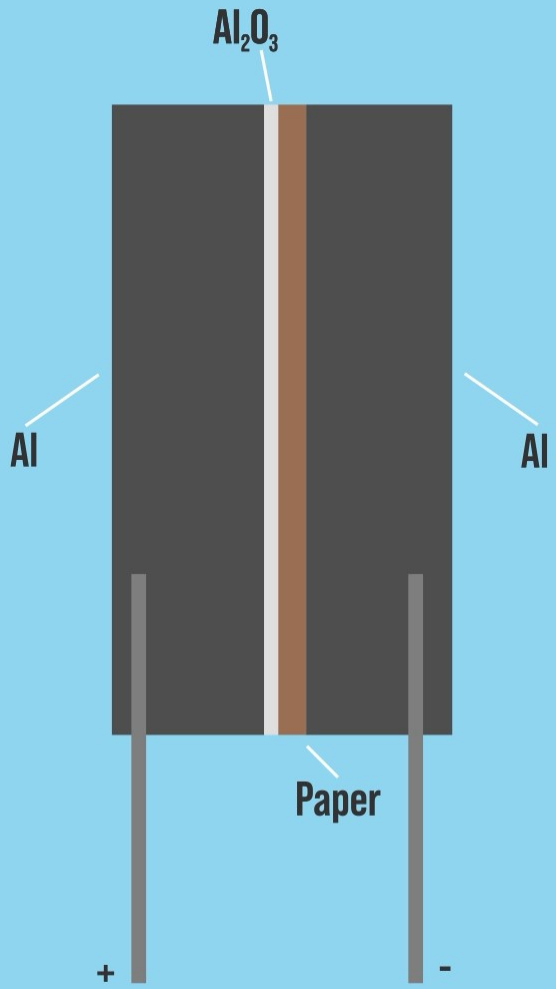
Aluminum Electrolytic

AI

AI


Al_2O_3
Al
+


Al_2O_3
Al
Al
+
-


Al_2O_3
Al
Al
Paper
+
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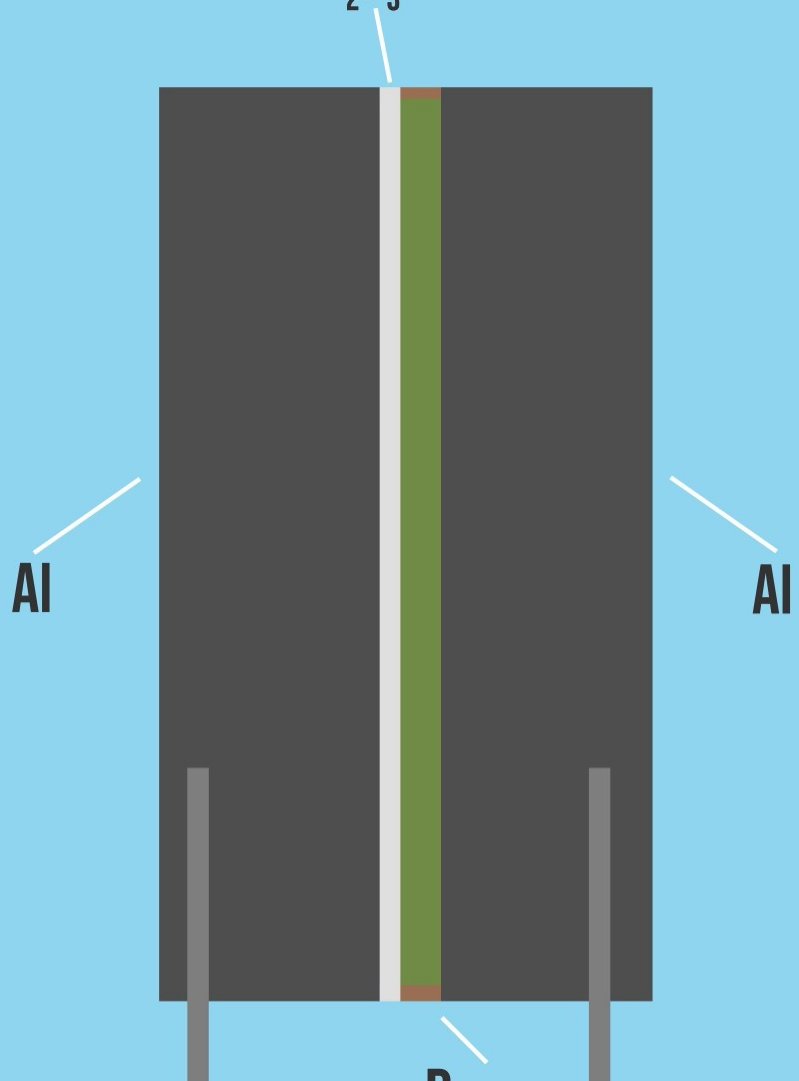
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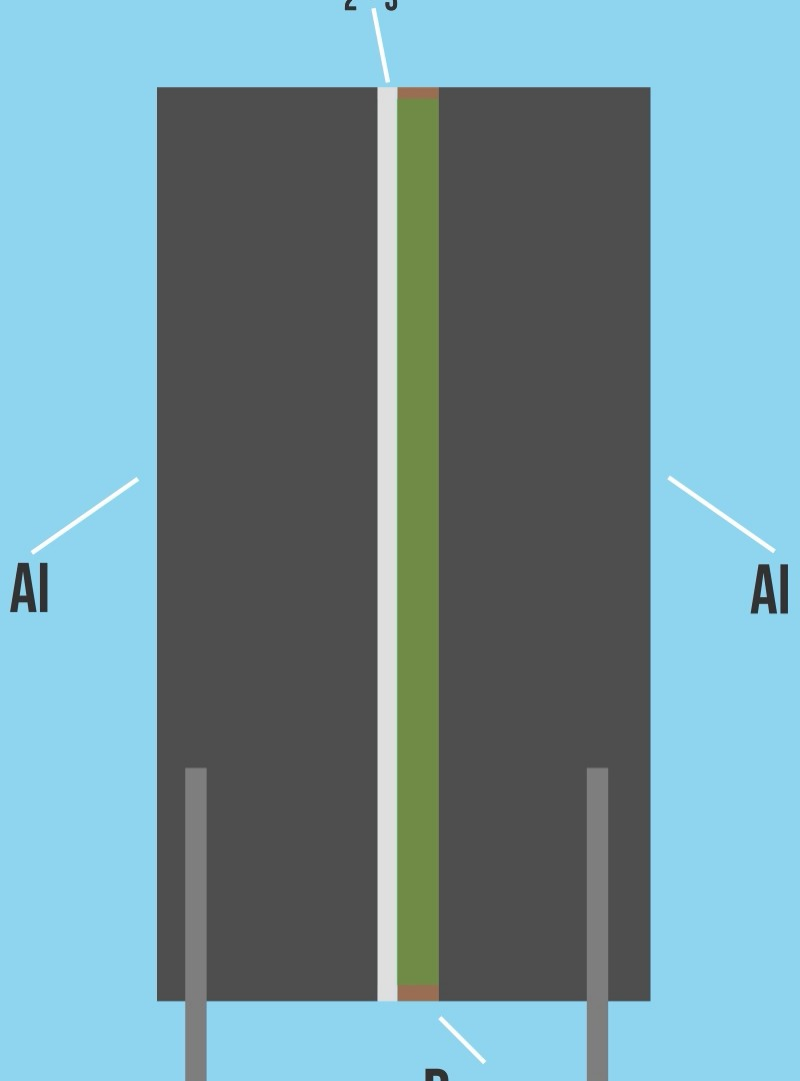
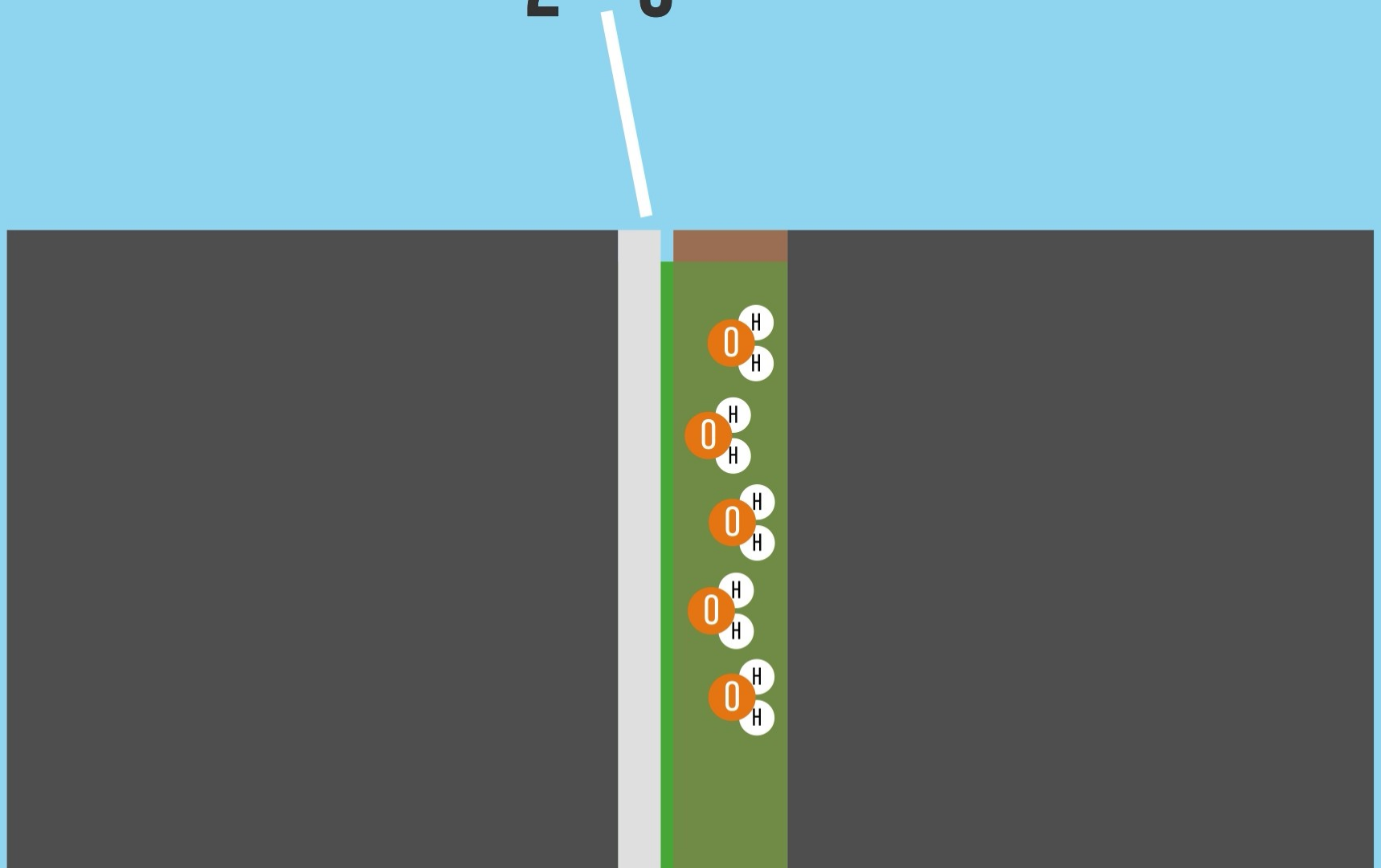
Al



Ionic

Conductive

Acidic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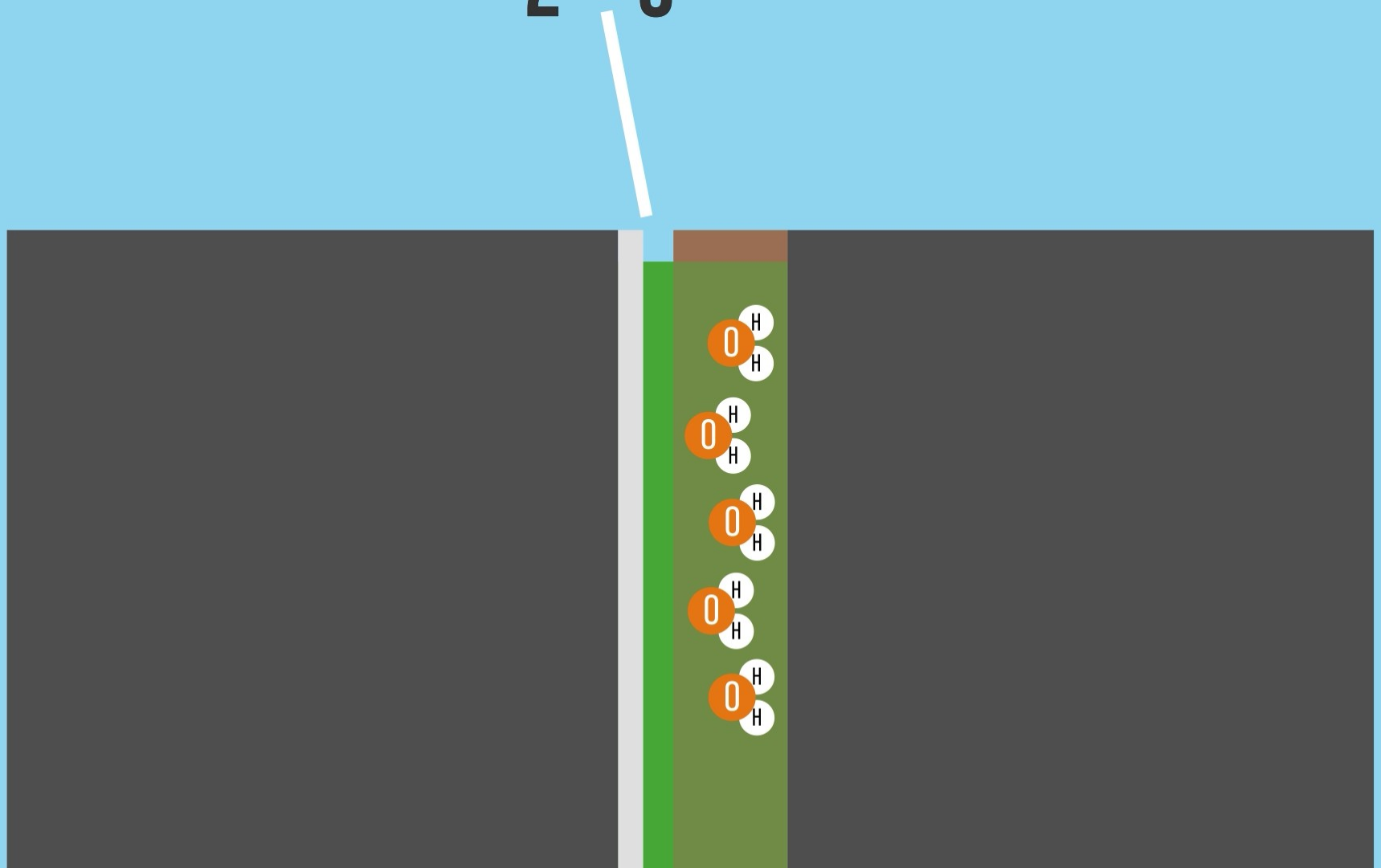
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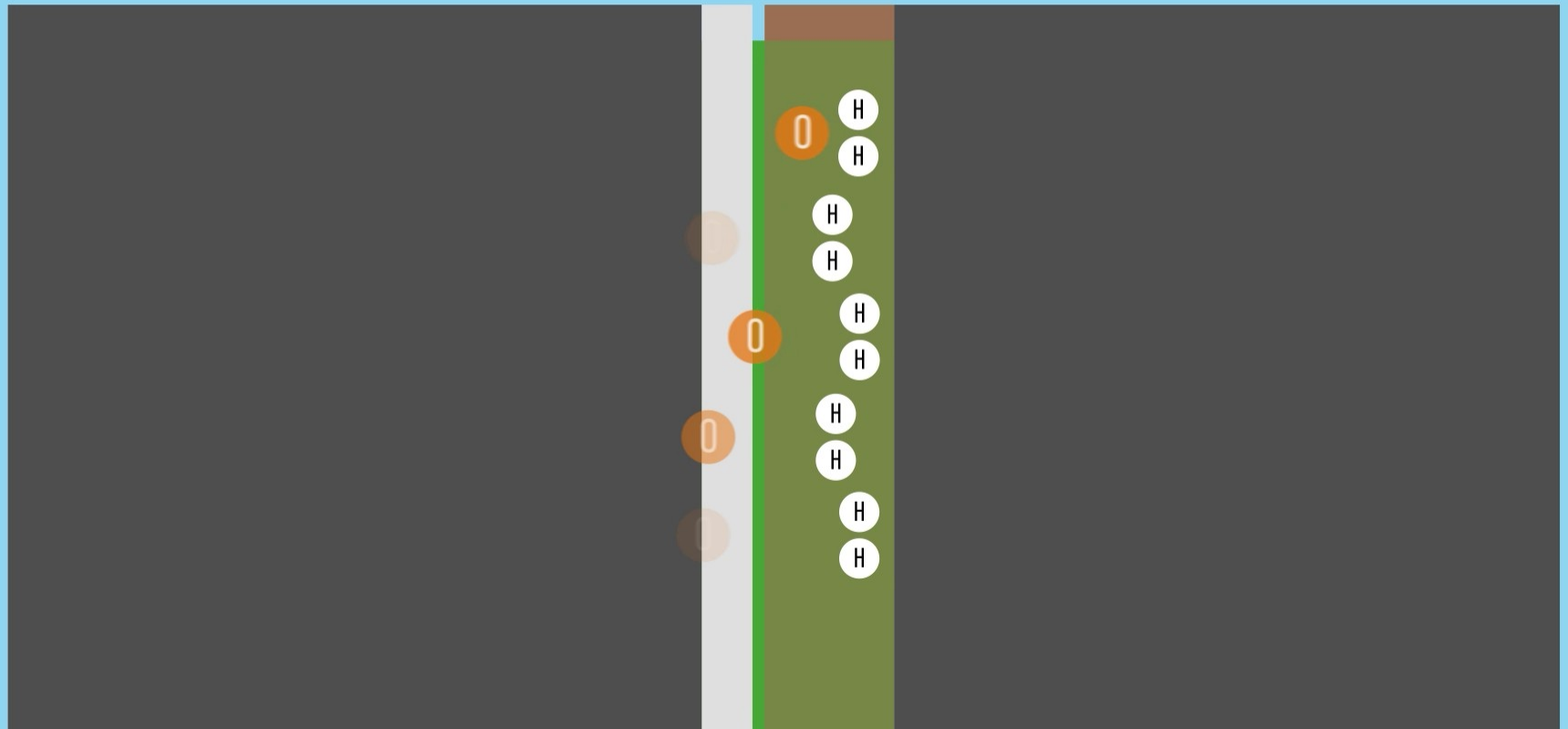
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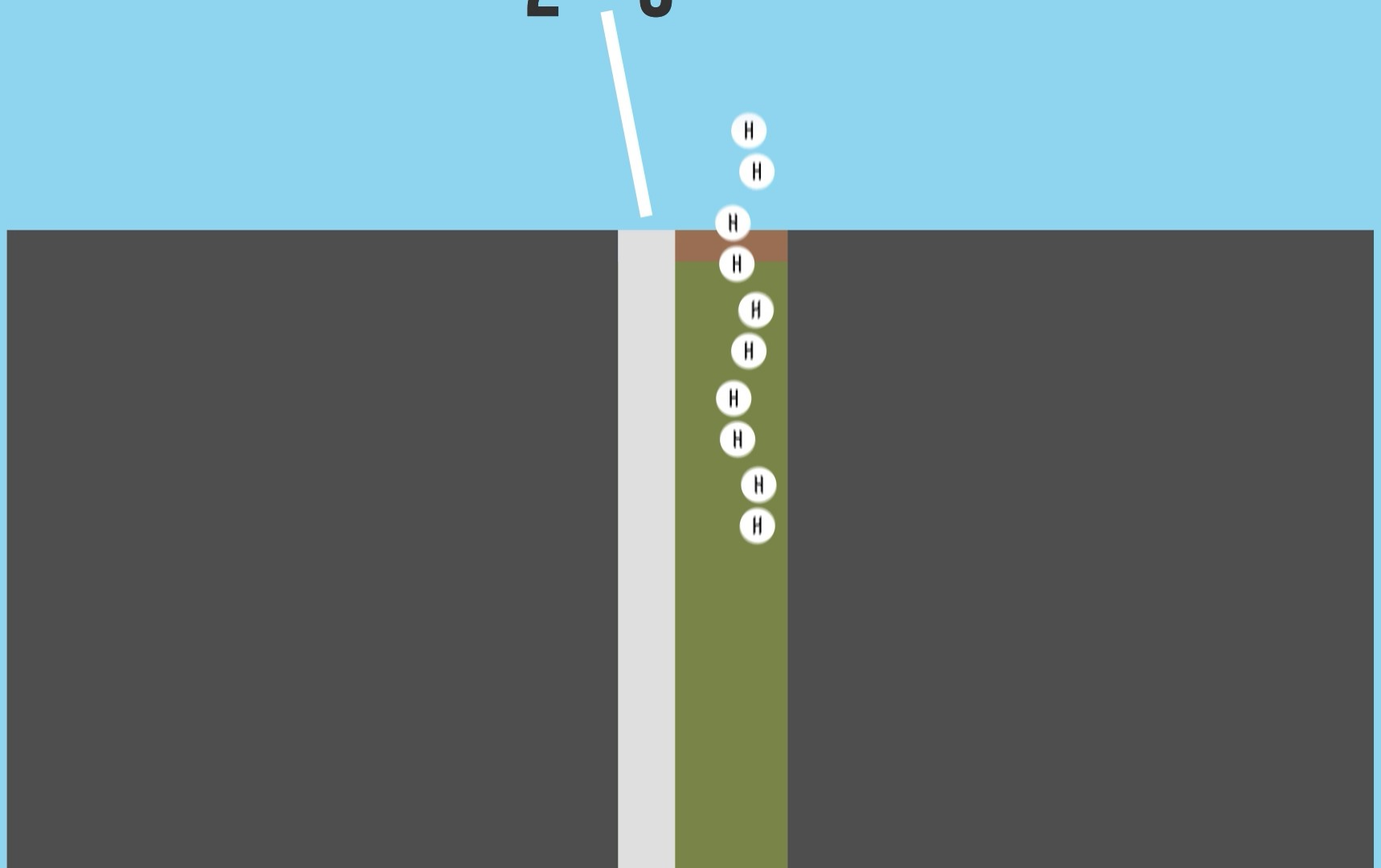
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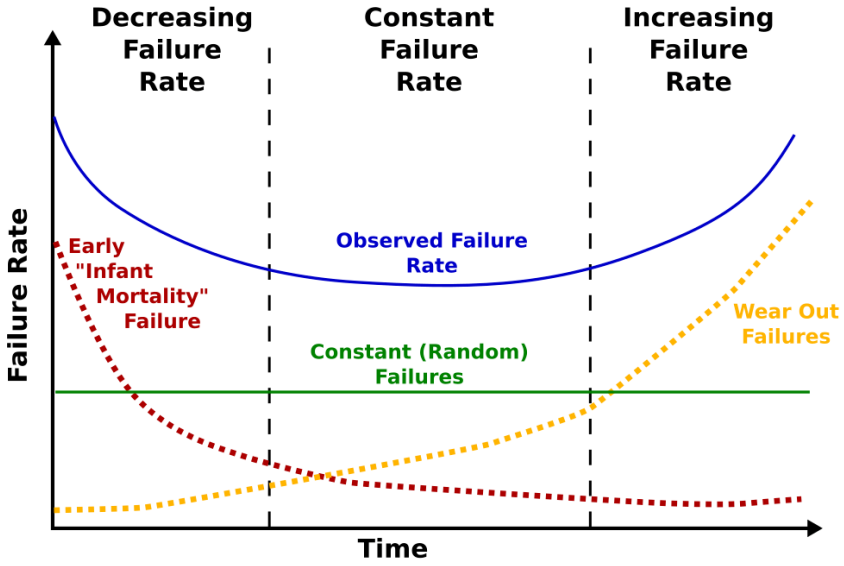
Courtesy of Derek Brodeur

Courtesy of Derek Brodeur

Courtesy of Derek Brodeur

Courtesy of Derek Brodeur

Everything Wears Out (Eventually)



- Electrolyte Dries (or Leaks)
- Parametric Failure
  - High ESR
  - High Dielectric Leakage
- Catastrophic Failure
  - Short between terminals (rare)
  - Explodes (Leakage)
  - High self-heating (ESR)

Picking Replacements

Traditional Al Electrolytic

Panasonic
INDUSTRY

⚠ Some part numbers are discontinued.

Aluminum Electrolytic Capacitors

Radial Lead Type

NHG-A series

■ Not available in Japan

- Endurance : 105 ℃ 1000 h to 2000 h
- to 2000 h
- AEC-Q200 compliant (6.3 V to 100 V)
- RoHS compliant

Specifications

Category temp. range	–55 ℃ to +105 ℃	–25 ℃ to +105 ℃
Rated voltage range	6.3 V to 100 V	160 V to 450 V
Capacitance range		
Capacitance tolerance		
Leakage current		
Dissipation factor (tan δ		
Endurance	After following life test with DC voltage and +105 ℃±2 ℃ ripple current value applied (The sum of DC and ripple peak voltage shall not exceed the rated working voltage) for 2000 h, when the capacitors are restored to 20 ℃, the capacitors shall meet the limits specified bellow. Duration 6.3 V to 100 V (ø5 to ø8) : 1000 h, (ø10 to ø18) : 2000 h 160 V to 450 V : 2000 h	
	Capacitance change	Within ±20 % of the initial value
	Dissipation factor (tan δ)	≦ 200 % of the initial limit
	DC leakage current	Within the initial limit
Shelf life	(With voltage treatment)	

Life Derating: 100 uF, 20 V, 105 C, 1000 Hours

10 °C decrease = 2X Life

(at rated voltage)

95 °C	2,000 Hours
85 °C	4,000 Hours
75 °C	8,000 Hours
65 °C	*16,000 Hours*
55 °C	*32,000 Hours*

Replacement Notes

TRS-80 Model 100 Caps

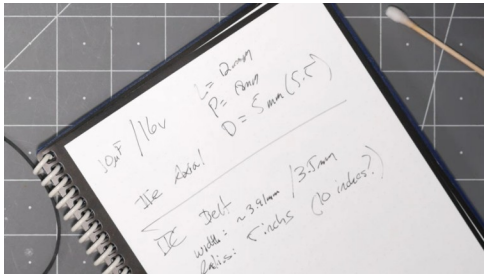
File Edit View Insert Format Data Tools Extensions Help

Share

Pitch is missing!

		Original				Modern Replacement				
	Designator	Cap	Voltage	Approx Size (DxL)	Notes	Cap	Voltage	Replace PN	Replace MFN	FFF Notes
x	C49	10uF	16v	4x7	85@2000 or 105@1000	10uF	35V	35ML10MEFC4X7		
x	C50	10uF	16v	4x7		10uF	35V	35ML10MEFC4X7		
x	C52	1uF	50v	5.5x11	NP	1uF	100V	MCNP100V105M5X11		
x	C54	10uF	16v	4x7		10uF	35V	35ML10MEFC4X7		
x	C55	10uF	16v	4x7	leaked	10uF	35V	35ML10MEFC4X7		
x	C75	47uF	16v	8x11.5	NP	47uF	35V	MCNP35V476M8X11.5		
x	C76	47uF	16v	8x11.5	NP	47uF	35V	MCNP35V476M8X11.5		
x	C77	47uF	16v	8x11.5	NP	47uF	35V	MCNP35V476M8X11.5		
x	C78	3.3uF	50v	*5.5x11.5*	(85 vs 105)	3.3uF	50V	50YXJ3R3M5X11		
	C82	4.7uF	25v	4x7	leaked	4.7uF	35V	MCUMR35V475M4X5		
	C83	470uF	10v	10x12	picture is wrong	470uF	25V	EEUFR1E471B		
x	C84	470uF	6.3v	10x12	same as above	470uF	25V	EEUFR1E471B		
x	C85	33uF	10v	5x8	leaked	33uF	16V	ECA1CAK330X		
x	C86	100uF	10v	6x12	no 6mm	100uF	16V	16ML100MEFC6.3X7		
x	C90	1uF	50v	4x7		1uF	50V	50ML1MEFC4X5		
x	C92	0.47uF	50v	5.5x11.5		0.47uF	63V	860020772004		
x	C103	220uF	10v	8x12		220uF	16V	860130374004		

Original Caps | With Replacements | Sheet3



C506	3.9nF	??? - film capacitor?	
C702	4.7u	50v	
C704	2200u	16v	16mm x 26.5mm - 20 mOhm
c412	470u	16v	- 180mohm
c411	220u	16v	10mm x 13.5mm - 160mOhm
C404	330n	35v	4mm x 6.5mm - dipped ta, ?ohm
C406	4.7u	16v	4mm x 6.5mm - dipped Ta, 2.6ohm
c407	4.7u	16v	- 3.6ohm
c413	10u	35v	5mm x 11mm - 1ohm
c408	33u	16v	6.5mm x 11.5mm - 760m
c405	10u	35v	5mm x 11mm - 1ohm
C151	10u	63v	6mm x 11mm - 400 mOhm

bald.ee/model100-caps

Label the bags: Voltage, Cap, And Designator

Weird Types of Electrolytics

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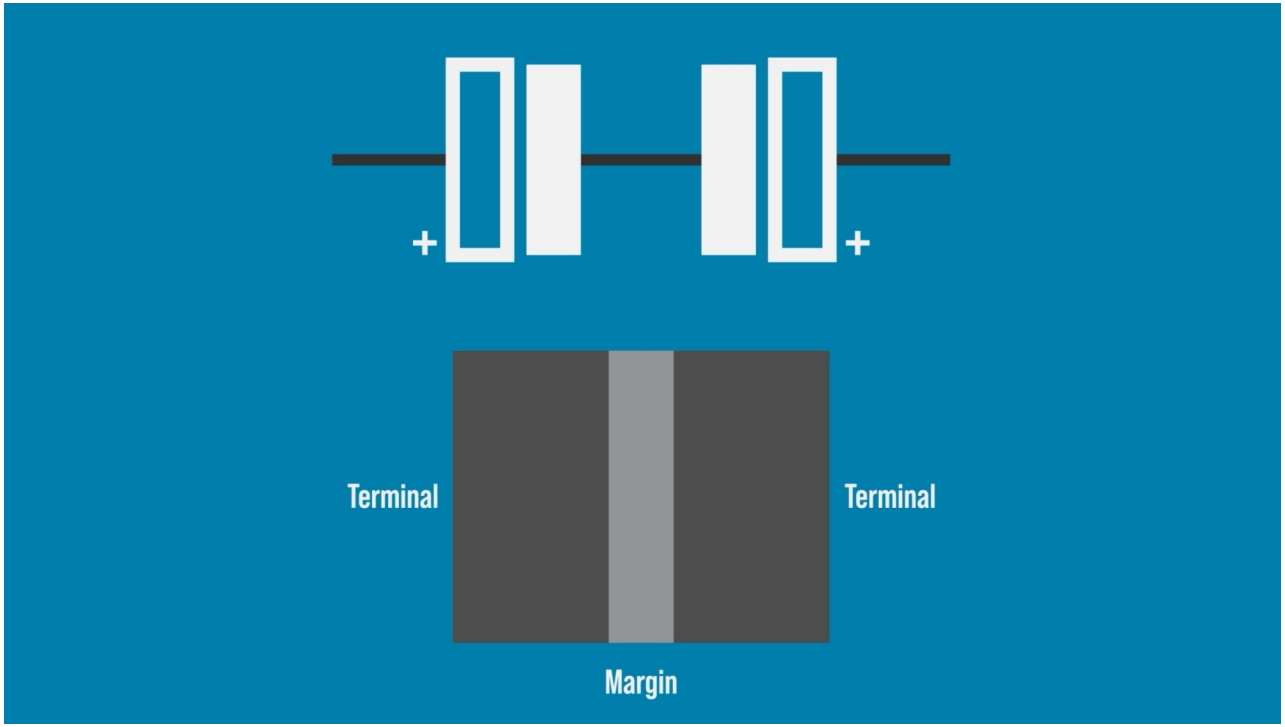
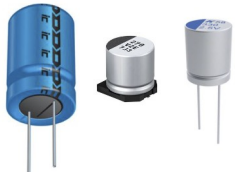
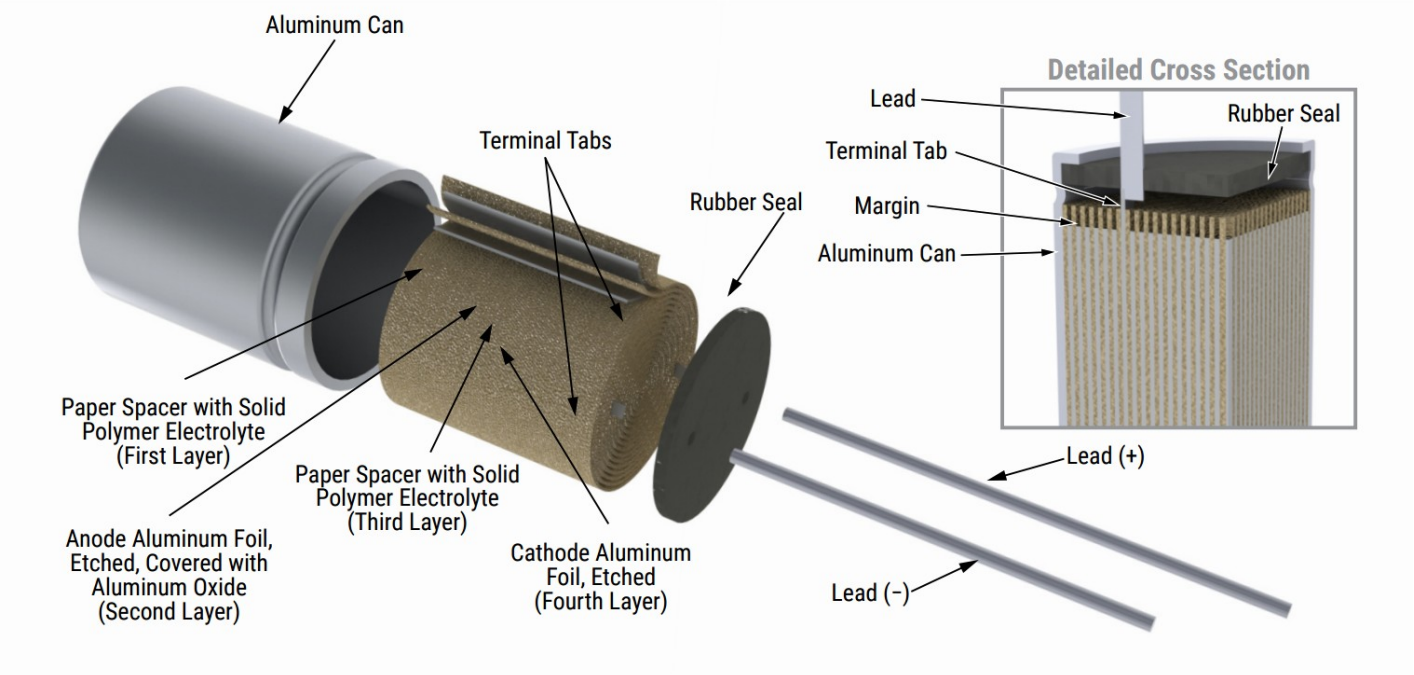
47 μF
16 V
JAPAN

Bipolar construction



Aluminium Electrolytic





Cross Section from KEMET A750 Series

Aluminum Polymer vs. Traditional

POLYMER

The actual product may differ from image shown

Add to compare

Electronic Components KEMET CHARGED

Manufacturer Part No:	A755KS107M1EAAE025
Newark Part No.:	97Y1055

See all Technical Docs

Product Information

Capacitance:	100µF
Voltage Rating:	25V
AE Capacitor Case:	Radial Leaded
Product Range:	A755 Series
ESR:	0.025ohm
Lifetime @ Temperature:	5000 hours @ 105°C
Operating Temperature Min:	-55°C
Operating Temperature Max:	105°C
RoHS Phthalates Compliant:	Yes

HIGH CONDUCTIVITY

ESR: 0.025ohm

ESR: 2.321ohm

TRADITIONAL

The actual product may differ from image shown

Add to compare

ILLINOIS CAPACITOR, INC.

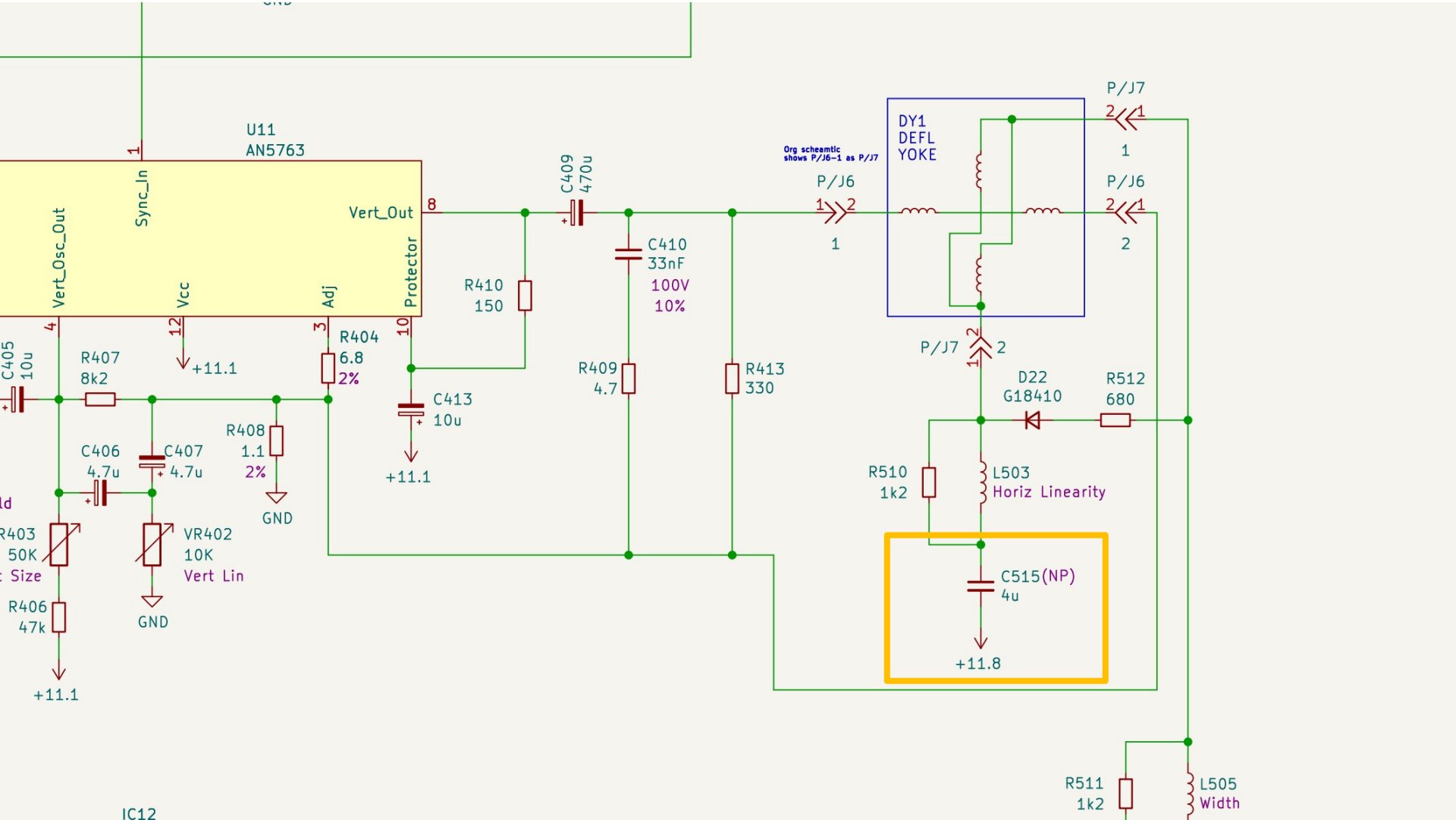
Manufacturer Part No:	107KXM025M
Newark Part No.:	69K8200

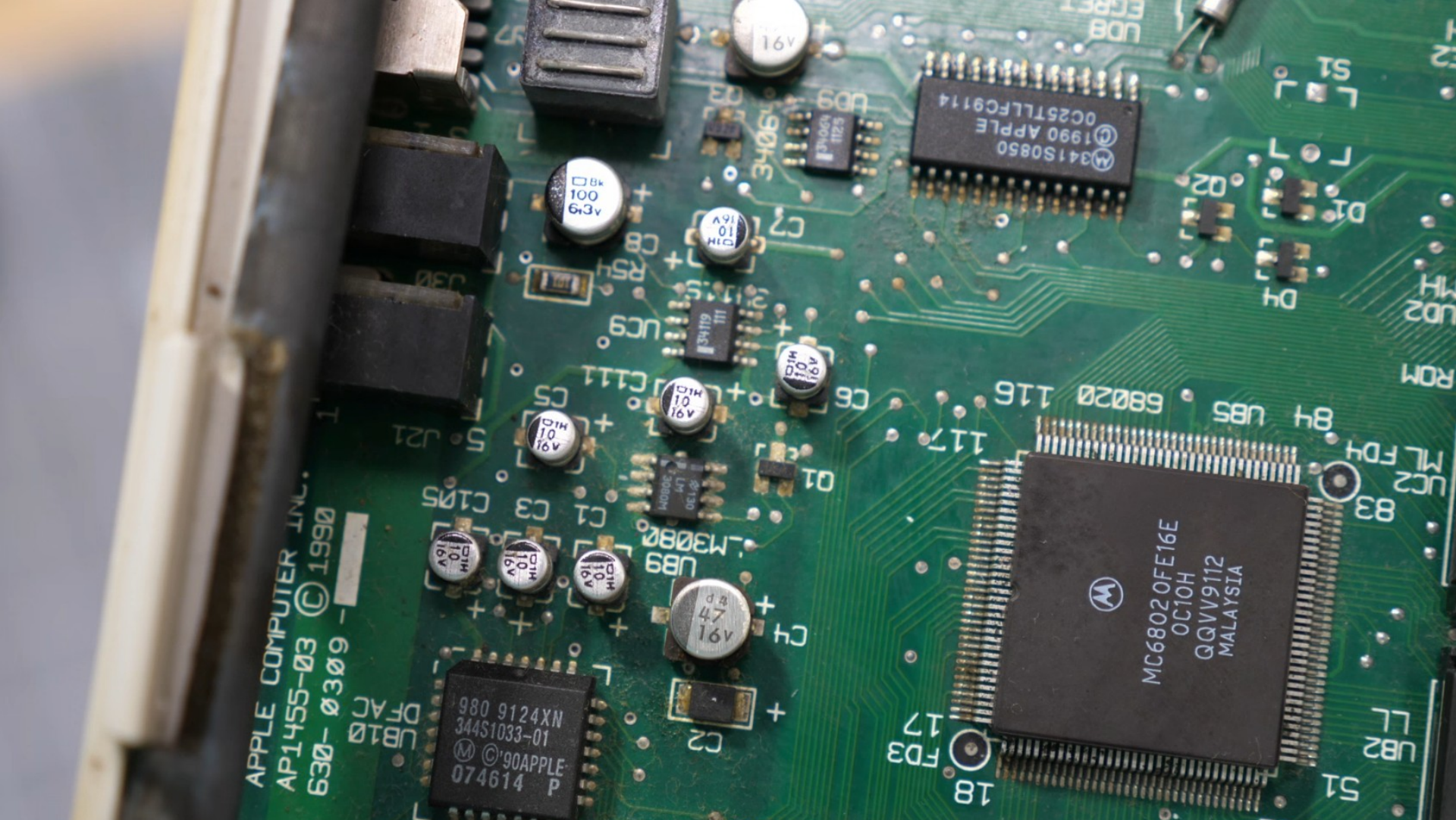
See all Technical Docs

Product Information

Capacitance:	100µF
Voltage Rating:	25V
Product Range:	KXM Series
Capacitance Tolerance:	± 20%
Capacitor Terminals:	Radial Leaded
Operating Temperature Min:	-55°C
Operating Temperature Max:	105°C
Lifetime @ Temperature:	2000 hours @ 105°C
ESR:	2.321ohm
RoHS Phthalates Compliant:	Yes

Examples


U11
AN5763
Sync_In
Vert_Out
Vert_Osc_Out
Vcc
Adj
Protector
C405
10u
R407
8k2
+11.1
R404
6.8
2%
R410
150
C409
470u
C410
33nF
100V
10%
C413
10u
+11.1
R408
1.1
2%
GND
C406
4.7u
C407
4.7u
R409
4.7
R413
330
R403
50K
Size
VR402
10K
Vert Lin
GND
R406
47k
+11.1
Org scheamtic
shows P/J6-1 as P/J7
P/J6
DY1
DEFL
YOKE
P/J7
P/J7
D22
G18410
R512
680
R510
1k2
L503
Horiz Linearity
C515(NP)
4u
+11.8
R511
1k2
L505
Width
IC12


APPLE COMPUTER INC.
AP1455-03 © 1990
630-0309-
980 9124XN
344S1033-01
©'90APPLE
074614 P
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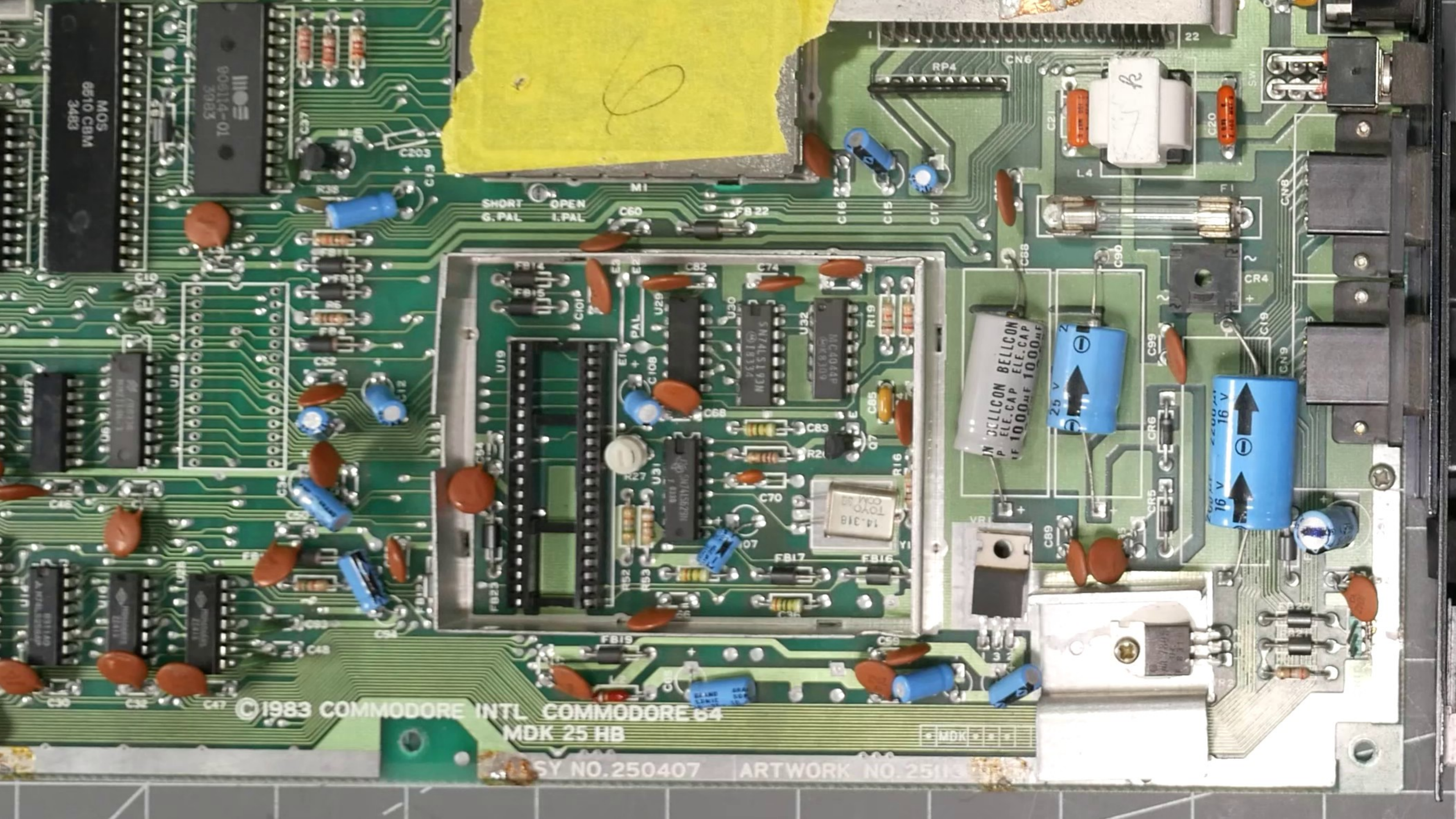
0C10H
QQVV9112
MALAYSIA
341S0850
©1990 APPLE
0C25TLLFC9114

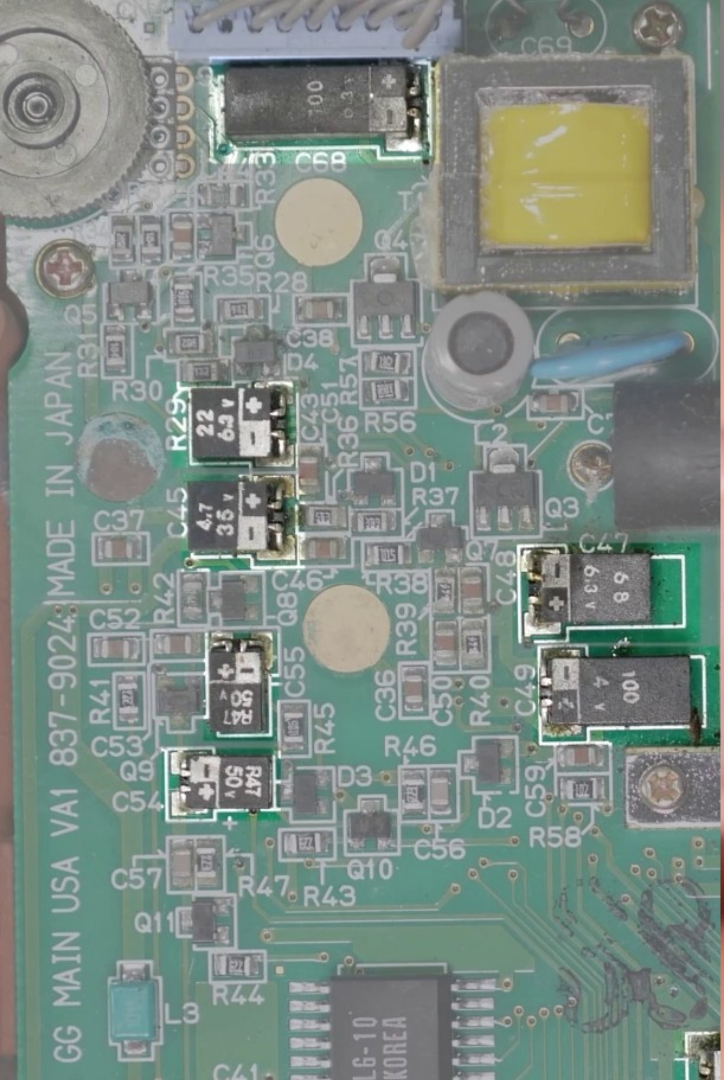


©1983 COMMODORE INTL. COMMODORE 64
MDK 25 HB
SHORT G.PAL
OPEN I.PAL
BELLCON ELE.CAP 1000μF

BAC

bald.ee/axial-bac


MADE IN JAPAN
IC BD GG MAIN USA VA1
SEGA
CAUTION
VORSICHT


GG MAIN USA VA1 837-9024 MADE IN JAPAN
C69
C68
R33
Q6
R35
R28
Q4
Q5
R31
R30
C38
D4
R57
R56
R29
C43
C51
R36
C45
C37
D1
R37
Q3
Q7
C47
C46
C48
R42
Q8
R38
R39
C52
C55
C36
C50
R40
C49
R41
C53
R45
R46
Q9
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C56
C57
R47
R43
Q10
Q11
R44
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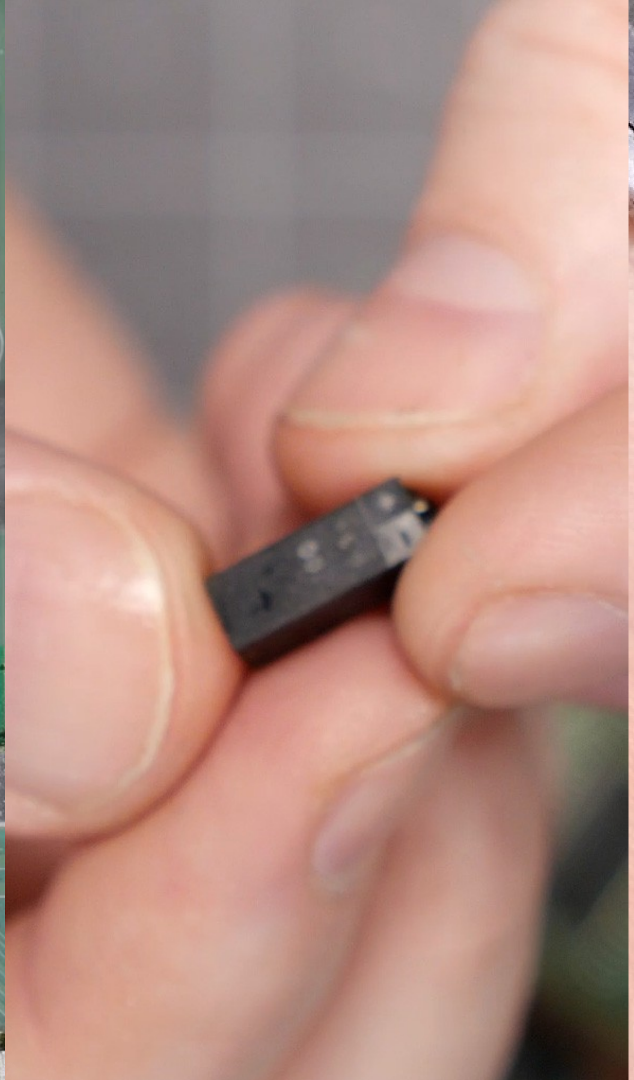
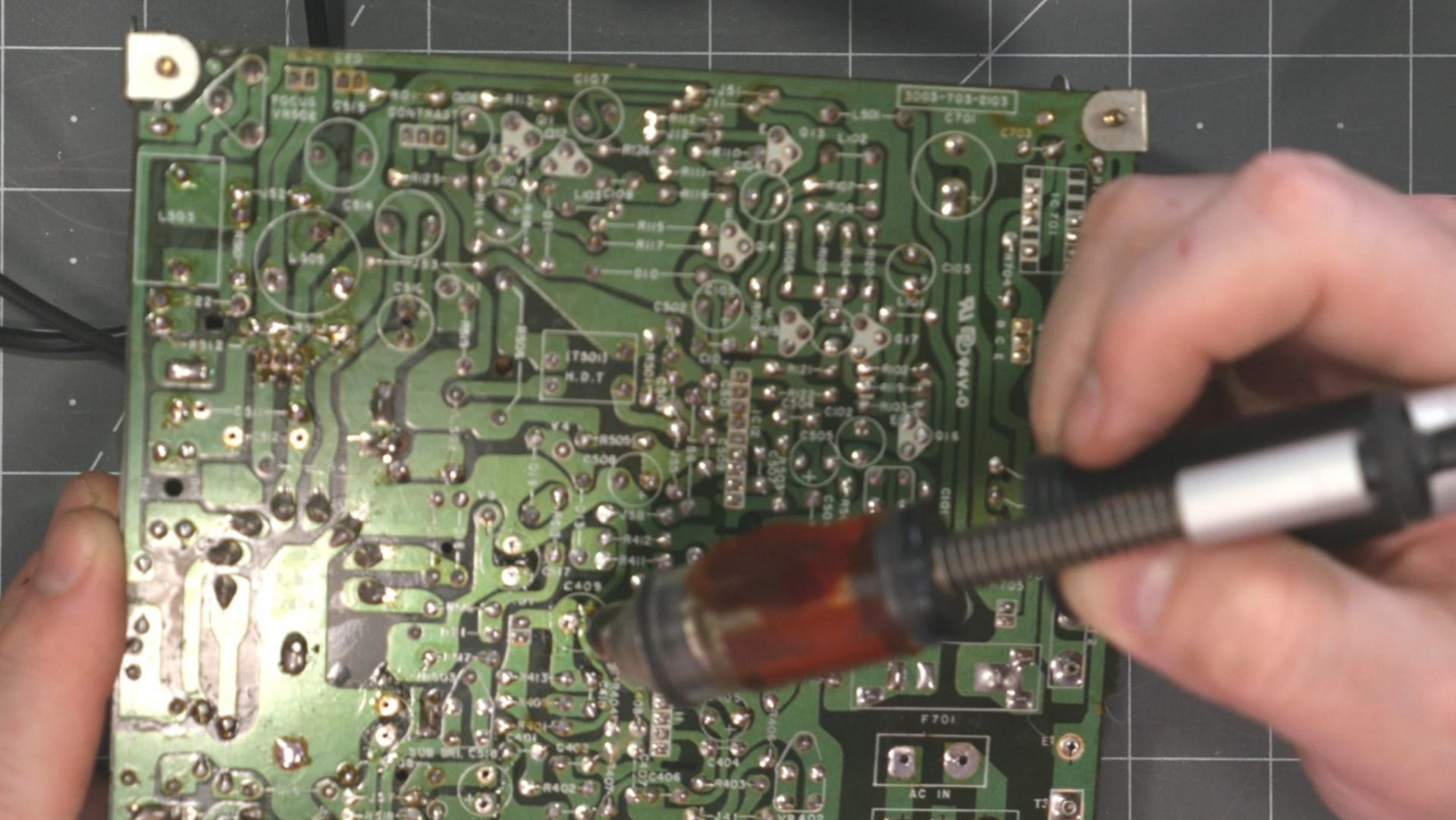
C41



Tools

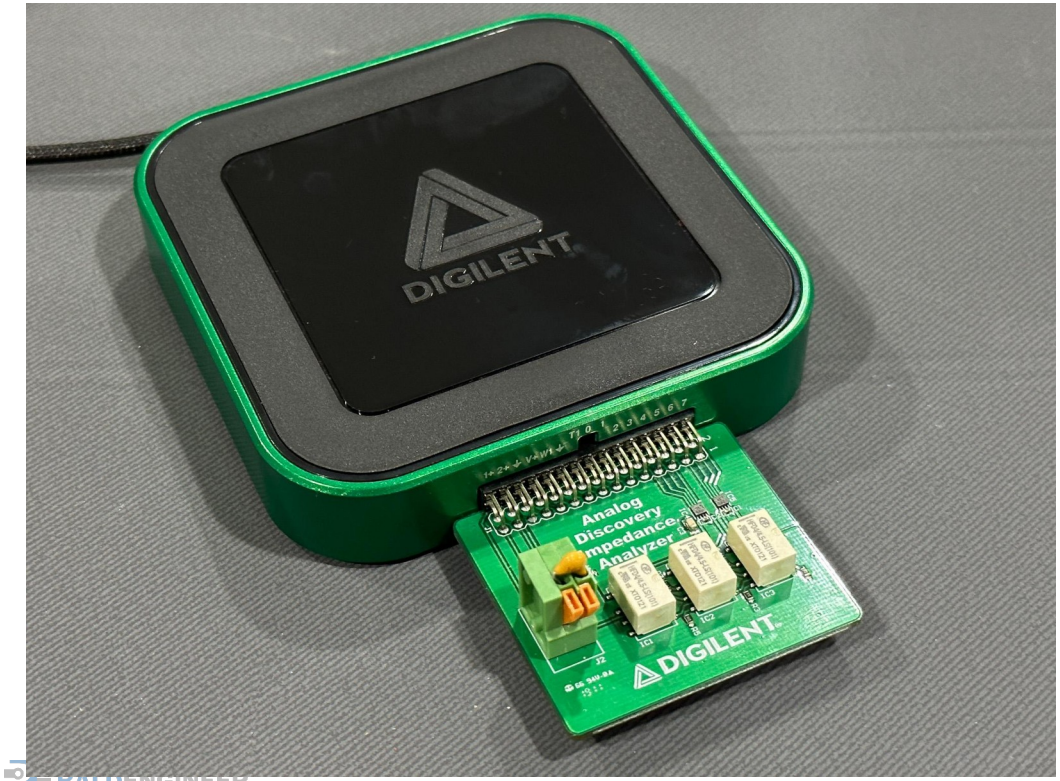

F701
AC IN

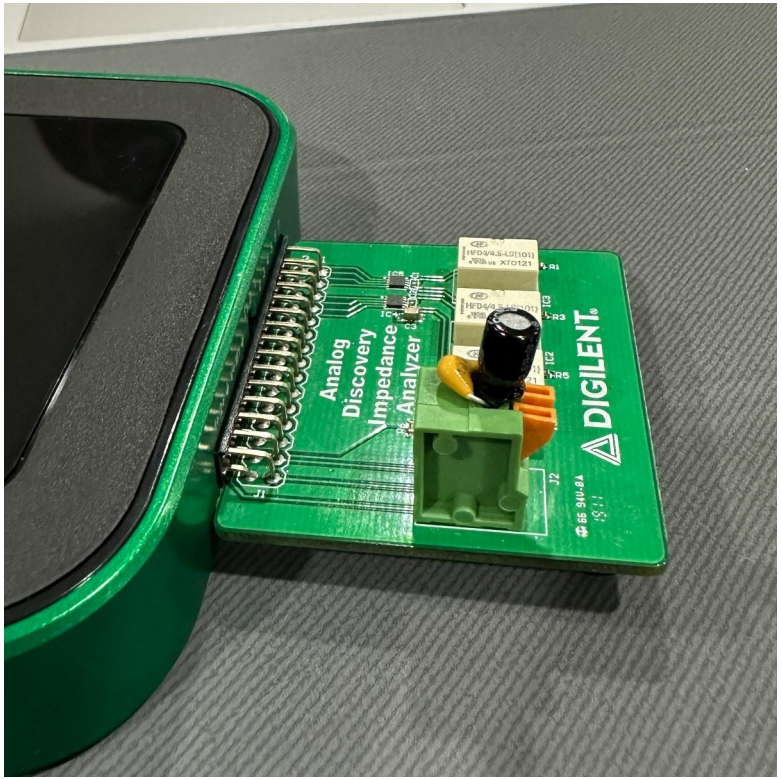
ENGINEER SS-02

Leakage / Reforming

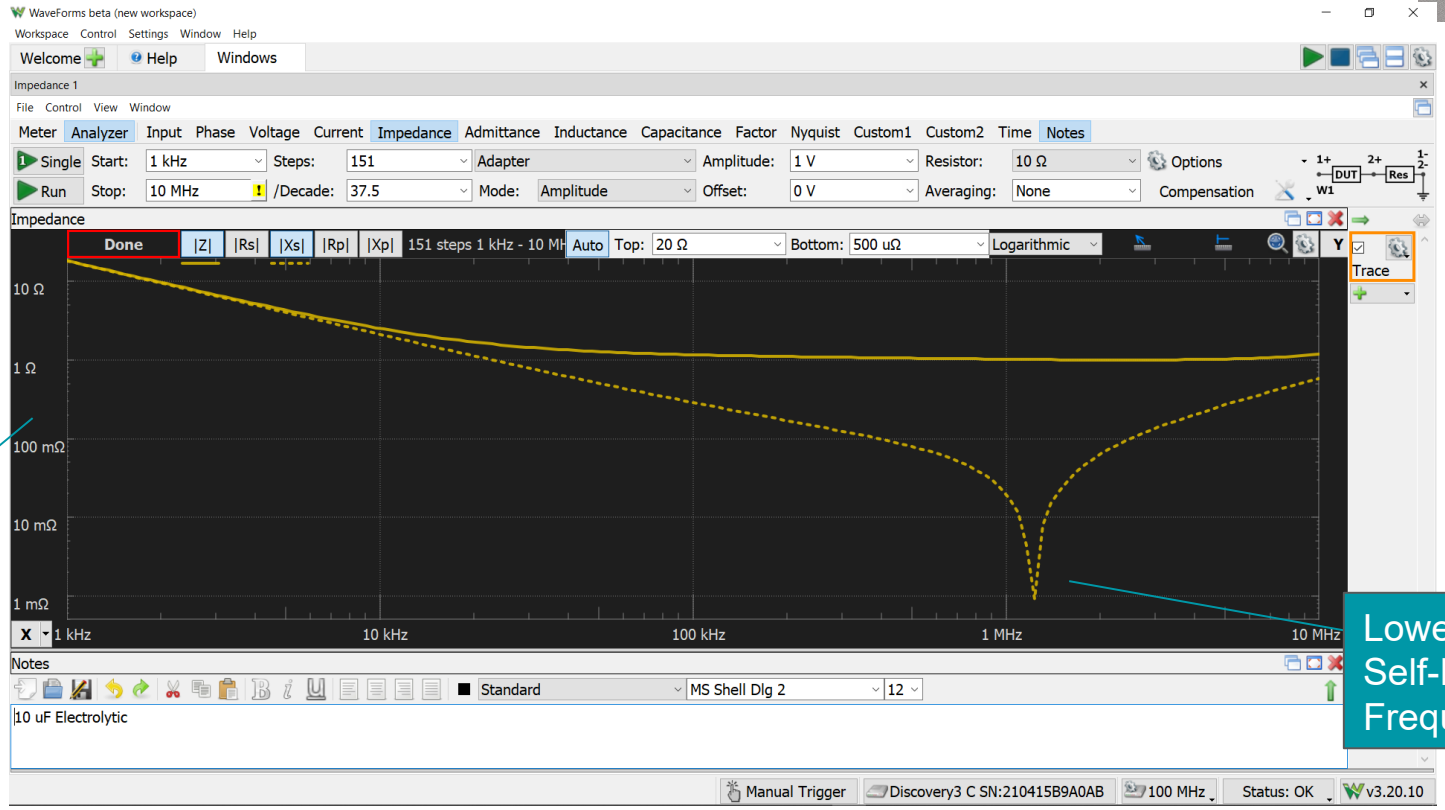

atlas ESR+
model ESR70
PEAK
electronic
design ltd
Cap = 4512µF
ESR = 0.05Ω
on - test
off
ESR, low resistance
and capacitance meter
+ Audible Alerts
with automatic
discharge function
P1
P2
UAB3
R4
R5
R6
Q1
Q3
Q4
RIO
FB3
FB4
CONN.
T
TL

Digilent Analog Discovery 3 with Impedance Adapter





10 uF Electrolytic: Low-Frequency (DC)



Low Z at low frequency

Lower Self-Resonant Frequency

Resources

bald.ee/**teardown2024**

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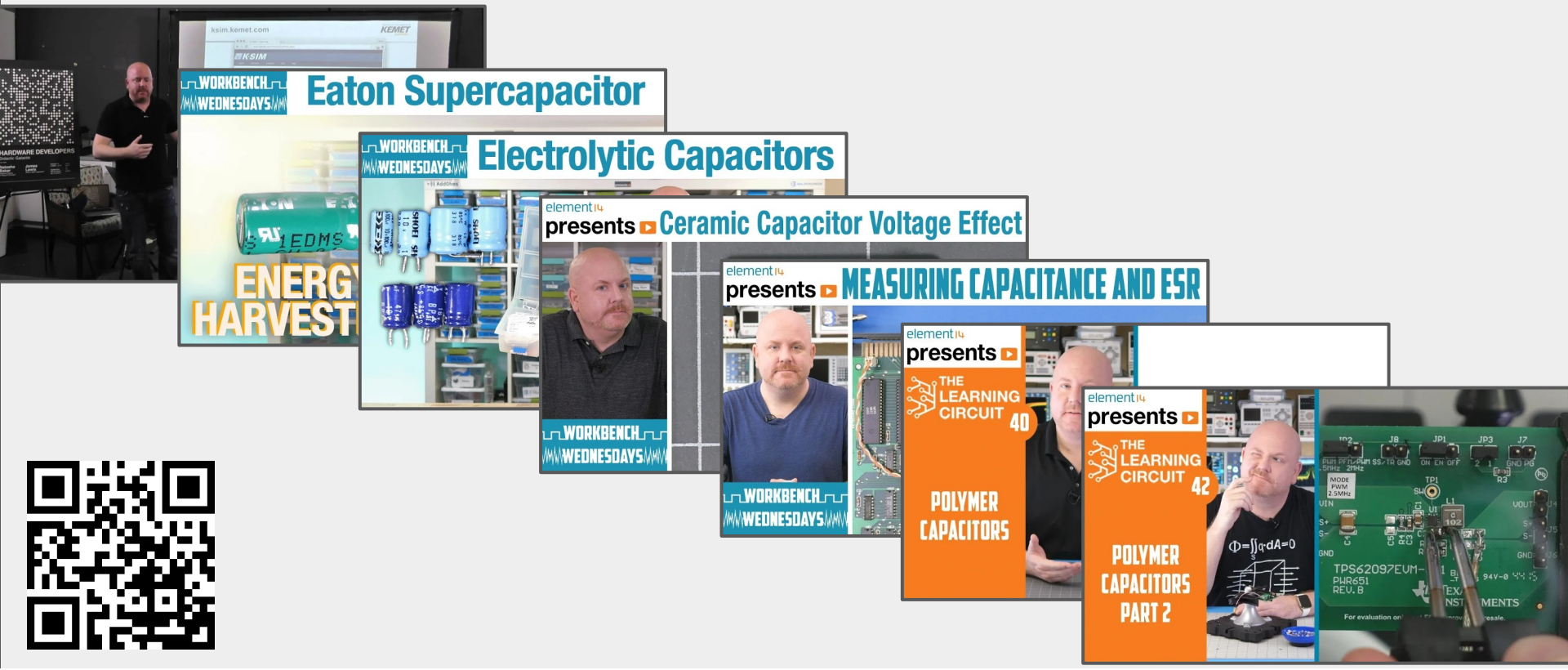
Capacitor Video Playlist



bald.ee/**capvids**

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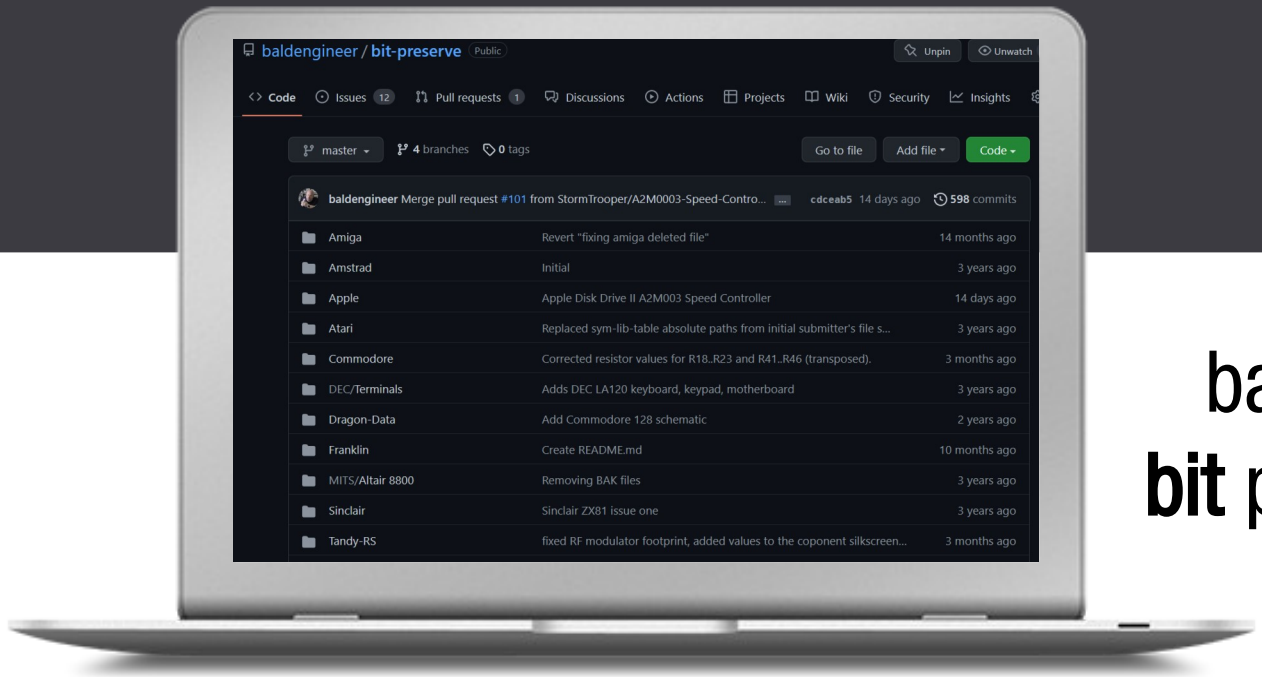
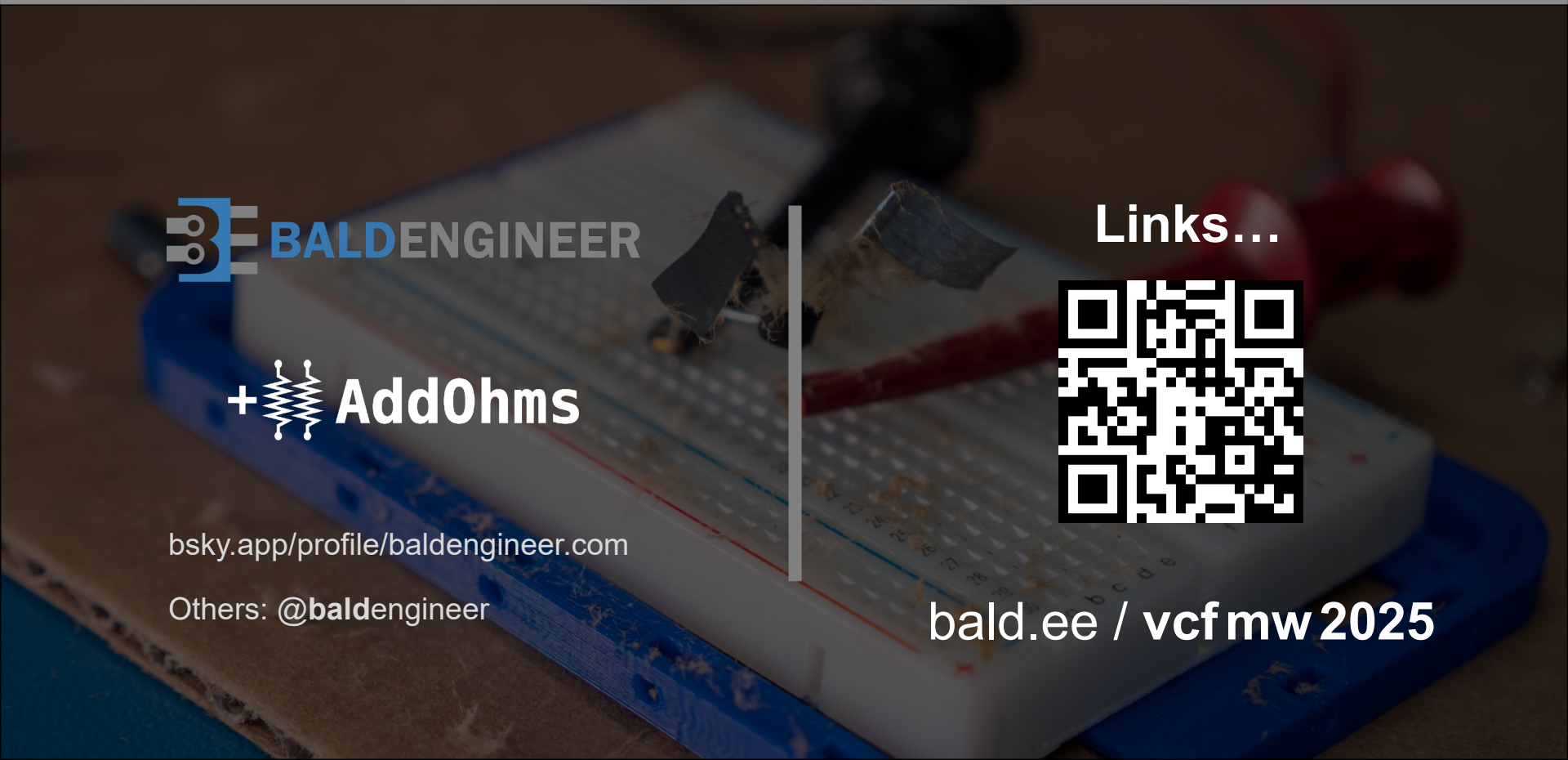
Bit Preserve
Vintage Computer Schematics in KiCad



bald.ee/
bit preserve

Thank You



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+AddOhms

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Others: @**bald**engineer

Links…

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