K4LED Engineering Notebook

A Precision DIY Stepped 50 Ohm Variable Bridged T Attenuator

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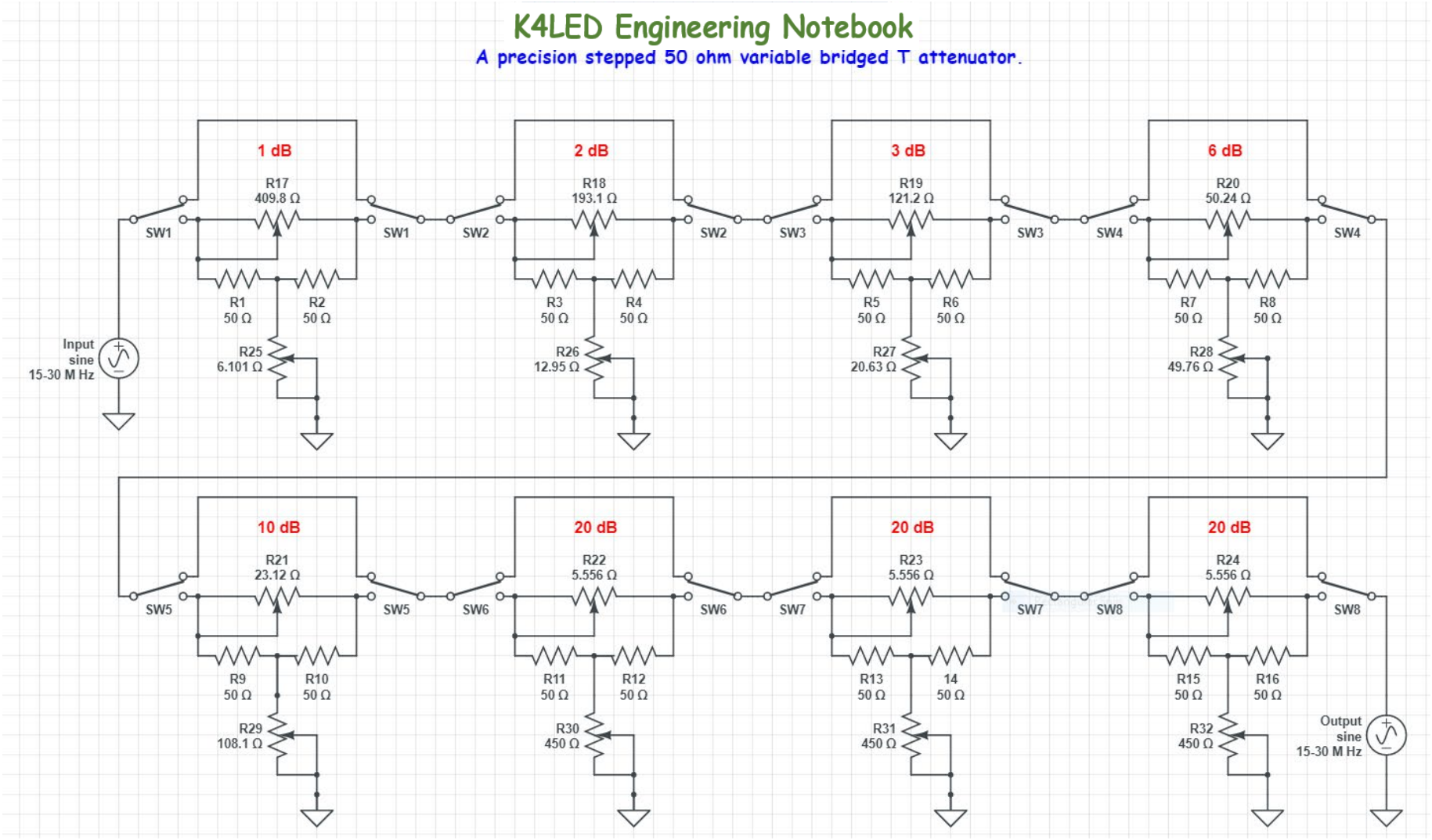
This DIY project describes a high precision 15 to 30 MHz stepped attenuator with each attenuator section adjustable to ± .01 dB accuracy or better. An inexpensive eBay Tronson attenuator (figure 1) is used for the base, case, and switches as an economical parts source for the attenuator. The original attenuator resistors are removed and discarded. It must be noted that the switches used are acceptable electrically, but mechanical failures were experienced. The purchase of two attenuators will provide an inexpensive source of switches in case there is a need to replace a switch. It is recommended that each switch be removed and reassembled out of the case. A brass ground buss bar (figure 2) is fabricated out of brass bar stock available from Amazon.com. Brass shim stock is used to form a ground shield between each switch (figure 3) then the new ground assembly is installed behind the switch bank (figure 4). The use of a Bridged T attenuator network (page 2) ensures that the input and output are held to 50-ohm impedance. The Cermet variable resistors provide precision calibration. The variable resistor values are calculated and adjusted with a Fluke 289 ohmmeter to .01 ohms accuracy. The resistor to ground is adjusted and installed and no further adjustments are made. The bridge resistors however are adjusted carefully to ± .01 dB attenuation accuracy or better for each section. The 50-ohm resistors are Vishay .1% precision fixed resistors. A Rigol DG4102 signal generator is used to inject a 20 MHz zero dBm signal for adjusting the attenuator sections. The accuracy of each attenuator section is adjusted and checked with a NIST calibrated Tektronix MDO3022 (figure 5) and double-checked with a calibrated HP 437B Power Meter + 8484A sensor + 11708A reference + 12749A cable (figure 6). This ensures each attenuator section achieves an accuracy of ± .01 dB or better. If quality calibrated test equipment is not available, accuracy will then depend upon the accuracy of the test equipment used. The result is a precision calibrated stepped attenuator more accurate than anything you can reasonably purchase off-the-shelf with zero insertion loss at HF. It can easily be checked and re-calibrated as needed.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A precision stepped 50 ohm variable bridged T attenuator.
1 dB
R17
409.8 Ω
SW1
SW1
R1
50 Ω
R2
50 Ω
R25
6.101 Ω
Input
sine
15-30 M Hz
2 dB
R18
193.1 Ω
SW2
SW2
R3
50 Ω
R4
50 Ω
R26
12.95 Ω
3 dB
R19
121.2 Ω
SW3
SW3
R5
50 Ω
R6
50 Ω
R27
20.63 Ω
6 dB
R20
50.24 Ω
SW4
SW4
R7
50 Ω
R8
50 Ω
R28
49.76 Ω
10 dB
R21
23.12 Ω
SW5
SW5
R9
50 Ω
R10
50 Ω
R29
108.1 Ω
20 dB
R22
5.556 Ω
SW6
SW6
R11
50 Ω
R12
50 Ω
R30
450 Ω
20 dB
R23
5.556 Ω
SW7
SW7
R13
50 Ω
14
50 Ω
R31
450 Ω
20 dB
R24
5.556 Ω
SW8
SW8
R15
50 Ω
R16
50 Ω
R32
450 Ω
Output
sine
15-30 M Hz

Figures

Figure 1. Tronson Step Attenuator

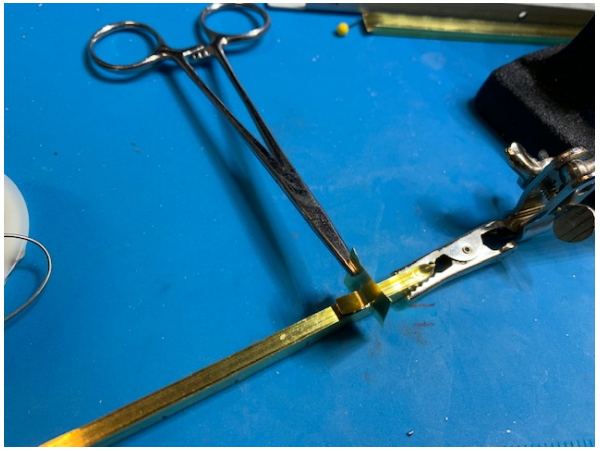


Figure 2. Brass Buss Bar with one shield

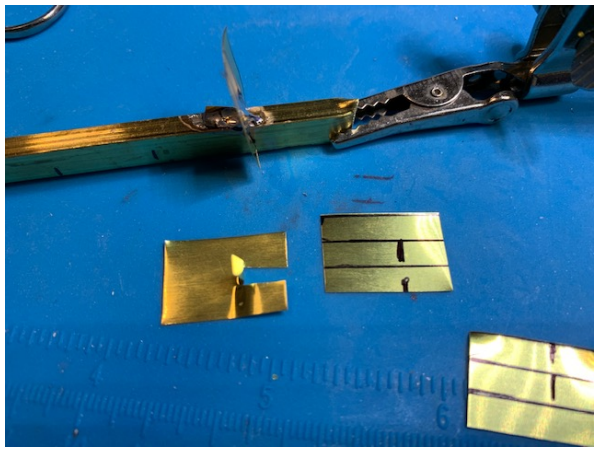


Figure 3. Brass Shim Shielding Construction

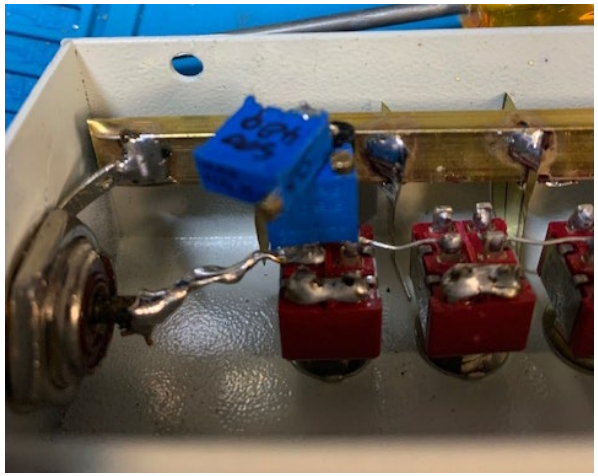


Figure 4. Brass Buss Bar behind the switches

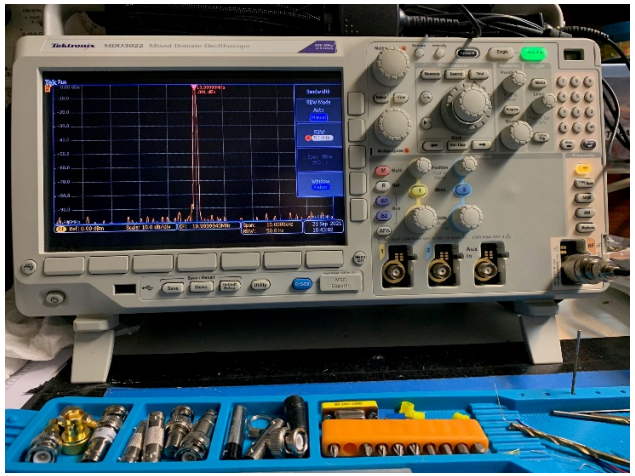


Figure 5. Tektronix MDO3022

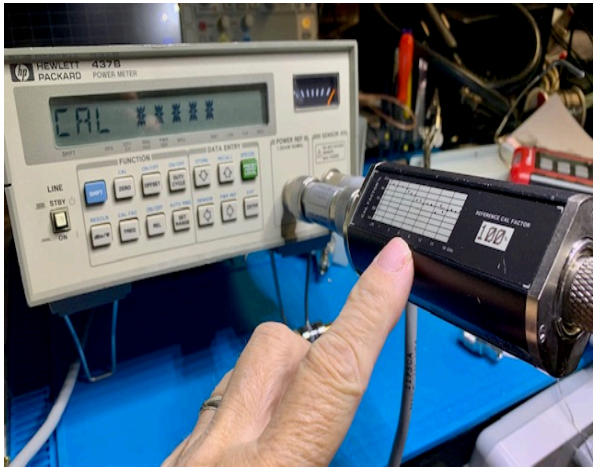
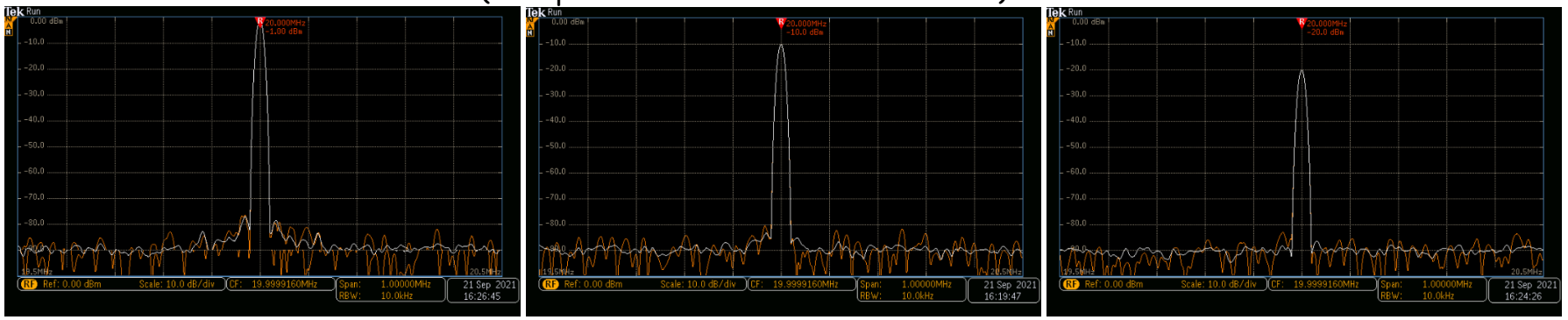


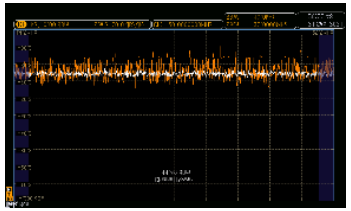
Figure 6. HP 437B Power Meter with Calibrator

Testing/References

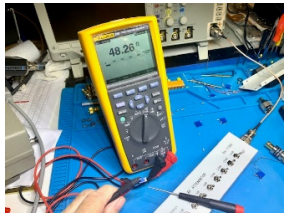
Tektronix MDO3022 (multiple test devices in one instrument) calibrated to NIST standards



Attenuator readings on a Tektronix MDO3022 Spectrum Analyzer. Rigol DG4102 > Attenuator >Tek MDO3022 SA



Spectrum is flat across the 15 to 30 MHz span.



Fluke 289 Multimeter.

References:

1. Attenuator Design Considerations; Resistive Attenuator Pads: Pi & T Circuit Design » Electronics Notes (electronics-notes.com) https://www.electronics-notes.com/articles/radio/rf-attenuators/pi-t-resistive-attenuator-pad-circuit-design-formula.php
2. Bridged T Equations: Bridged-Tee Attenuator Calculator - Electrical Engineering & Electronics Tools (allaboutcircuits.com)
3. Briged T Attenuator Calculator; Bridged Tee Attenuator Calculator (pasternack.com) Bridged Tee Attenuator Calculator (pasternack.com)
4. Bourns Variable Cermet Resistors; https://www.arrow.com/en/manufacturers/bourns/resistors/variable-resistors

Note: Cermet (ceramic based) variable resistors exhibit virtually zero inductance at HF frequencies.

Bill Of Materials

ID	QTY	VALUE	DESCRIPTION	PART #	SOURCE	COST	TOTAL
R1-16	16	50 OHMS	Vishay .1% metal film res.	71-PTF6550R000BYEK	Mouser.com	$3.60	$57.60
R22, R23. R24, R25, R26, R27	6	20 OHMS	Cermet Variable Resistor	PV37W200c01B00	Digikey.com	$3.53	$21.18
R20, R21, R28	3	50 OHMS	Cermet Variable Resistor	3266W-1-500LF	Digikey.com	$4.16	$12.48
R20, R28	2	100 OHMS	Cermet Variable Resistor	3266W-1-101LF	Digikey.com	$4.16	$8.32
R18, R19, R29	3	200 OHMS	Cermet Variable Resistor	3266W-201LF	Digikey.com	$4.16	$12.48
R17, R30, R31, R32	4	500 OHMS	Cermet Variable Resistor	3296W-1-501LF	Digikey.com	$4.16	$16.64
K&S Precision Metals 8240 Brass	1	N/A	BRASS BAR STOCK	.032"x 1/4" x 12"	AMAZON.COM	$1.39	$1.39
K&S Precision Metals 16053 Brass	1	N/A	BRASS SHIM SHEET	.008", 6" x 12"	AMAZON.COM	$8.62	$8.62
UHF male to BNC female	2	N/A	Adaptor	Price for 2	AMAZON.COM	$7.20	$14.40
Calibrator	1	N/A	Tronson Calibrator	Tronson RA-1728A	eBay	$27.00	$27.00
						TOTAL =	$180.11

Note: Lower cost components could be substituted but accuracy and performance may be reduced.
Video: Test results of the upgraded Tronson attenuator. https://youtu.be/0E6_p4Cn8cQ