

NOTES ON BUILDING A Z10050A 3-DB HYBRID SPLITTER/COMBINER

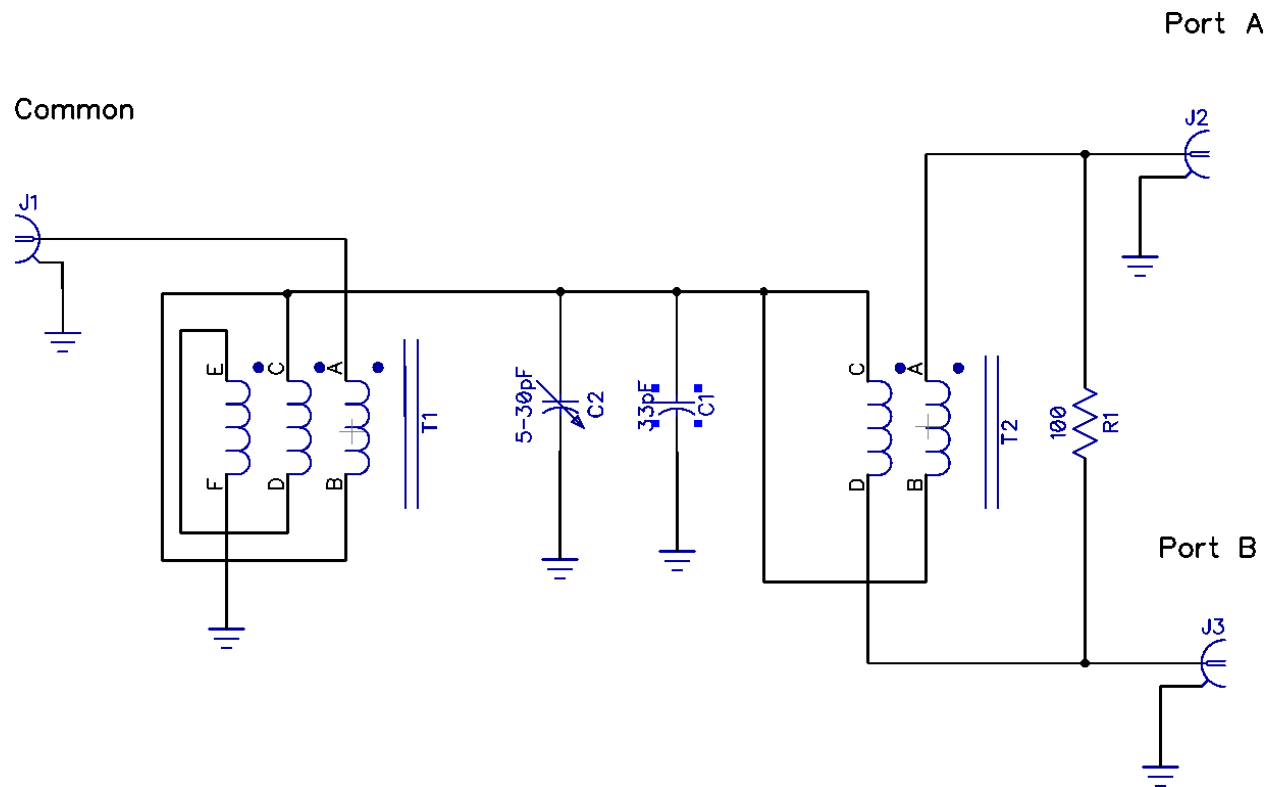
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The Z10050A is a wideband two-port hybrid splitter/combiner providing good port-to-port isolation and low intermodulation generation, suitable for use to 30 MHz and above. Although a simple printed circuit board was developed for this kit, it may easily be constructed using "open air" methods. In fact, the open air version performs slightly better than the printed circuit board model as it has reduced stray capacitance to ground.

The Z10050A may be used as a splitter, such as to drive two receivers from a common antenna, or as a combiner, such as to couple two signal generators together into a common output. In either case, the Z10050A provides at least 30 dB isolation between Ports A and B.

SCHEMATIC



PARTS REQUIRED

Component ID	Quantity	Description	Source/Part Number
T1, T2 cores	2	Steward 35T0231-20P	Digi-Key 240-2585-ND
C1	1	33pF NPO/COG ceramic capacitor, such as Kemet C317C330J2G5TA	Digi-Key 399-4229-ND
C2	1	5.2-30 pF trimmer (green)	Digi-Key 490-1961-ND

Component ID	Quantity	Description	Source/Part Number
		Murata TZO3R300F169B00	
R1	1	100 ohm 1% 1/4w metal film, such as Yaeko MFR-25F169-100R	Digi-Key 100XBK-ND
J1, J2 & J3	3	Connectors of choice	
Wire	3 lengths	20 inches (0.5 M) #30 AWG (0.25mm diameter) magnet wire, red, green & gold	

TYPICAL CONSTRUCTION

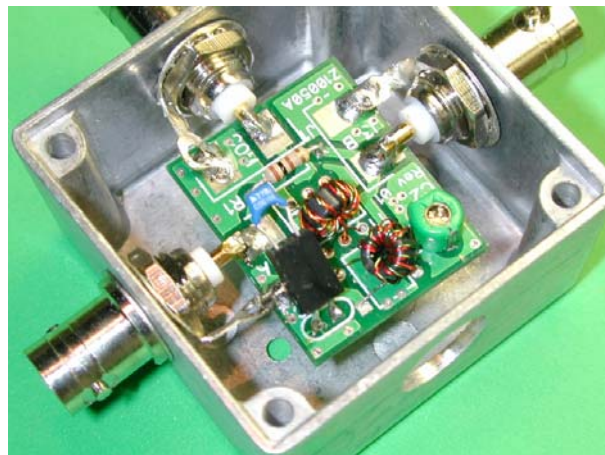
The photographs below show examples of how the Z10050A may be constructed. I've included photos of the printed circuit board version as well, although the PCB is not presently offered by Clifton Laboratories.

PCB in a Hammond box, 2"x2"x1" with BNC connectors.

Although difficult to see in the photograph, the two transformer cores have extended leads to place the cores about 1/16th inch (1.5 mm) above the PCB surface. This reduces stray capacitance from the windings to ground, improving isolation at higher frequencies.

The board is mounted by soldering to the BNC connector ground lugs. Once installed, it's difficult, at best, to remove.

The photo shows C1 in a socket to facilitate experimenting with different values during development. 33pF is a suitable value and a socket is not necessary.



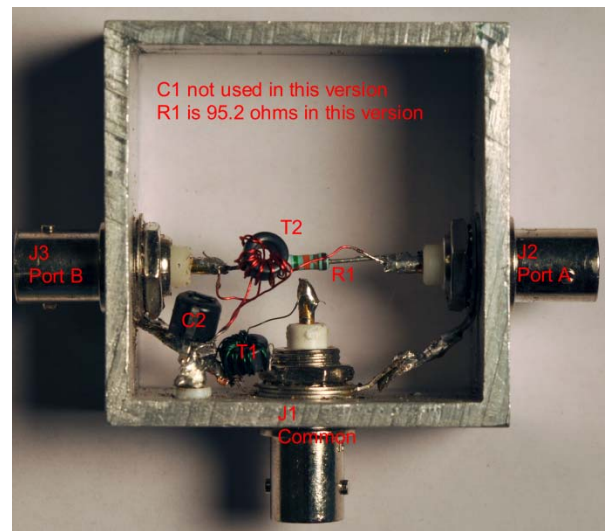
First prototype in a section of 2"x2" square aluminum tubing, with BNC connectors.

The prototype used a 95.3 ohm balance resistor instead of 100 ohms. Additionally, C2 is a 10-60 pF trimmer capacitor, so C1 is not required.

The construction is all "air mounted" with R1 being connected between J2 and J3 and T2's windings soldered to R1's leads.

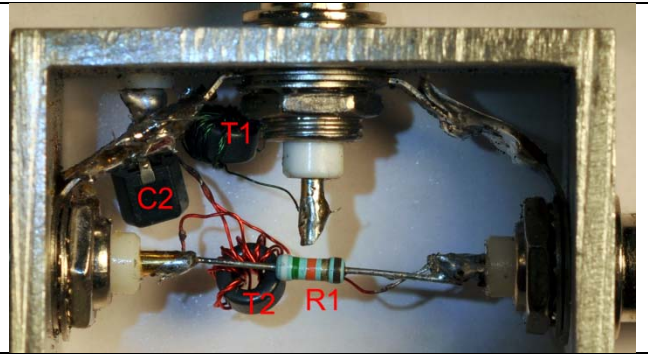
Likewise, the ground side of C2 is soldered to J1's ground lug and the other end hangs in air and serves as an anchor point for T1 and T2's leads. (The three ground lugs are soldered together.)

T1's input lead is soldered to J1, which also provides mechanical support to T1.



Opposite side view of the first prototype.

This prototype was built with single color wire. Separate colors for each winding simplify building and reduce the risk of error.

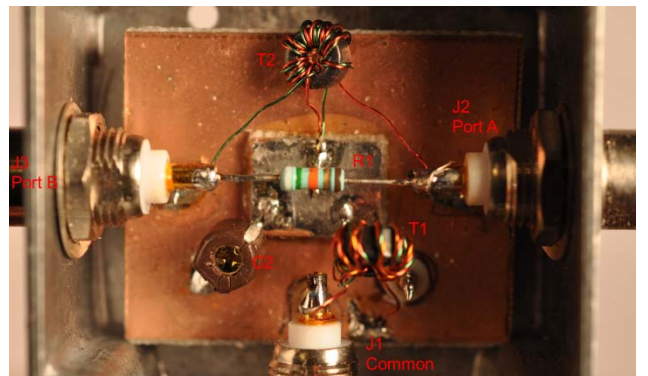


The second prototype is an evolutionary step towards a printed circuit board. The housing is a 2"x2"x1" (50mm x 50mm x 25mm) Hammond die cast enclosure.

There are two pieces of scrap printed circuit board stock. The large one is a ground surface and is supported by soldering it to the BNC connector ground lugs. In the center of the ground PCB is a smaller piece of PCB stock, glued with epoxy to the larger board. This rectangular piece of board is the common point to connect C2's non-ground lead, T1, pins C and B and T2, pin C.

Instead of gluing the pad, I could have cut away the copper to form a small island.

As with the first prototype, R1 is 95.3 ohms, not 100 ohms, C2 is a 10-60 pF trimmer and C1 is not used.



WINDING T1 AND T2

T1 is trifilar wound and T2 is bifilar wound. Trifilar means three wires and bifilar is two wires.

If wire of three different colors is available, building and verifying the build is easier. If only a single color wire is available, it will be necessary to identify the wires by a resistance check and mark them.

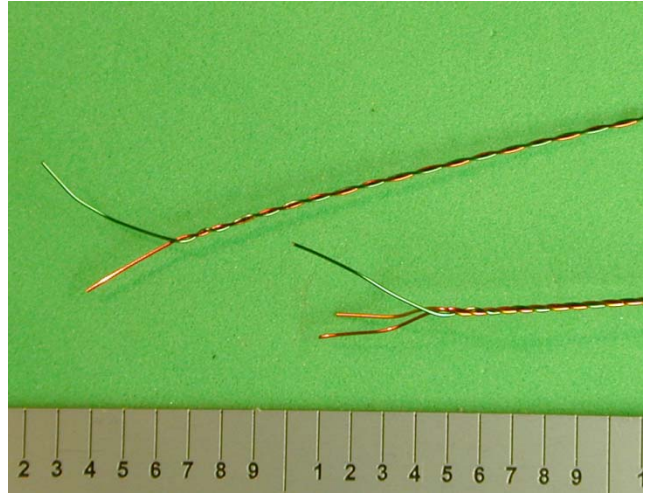
The wire lengths suggested below assume the coupler will be constructed compactly. If long leads will be required, you may wish to use longer lengths. If so, adjust the number of turns to maintain approximately 6 twists per inch (6 twists in 25 mm, or approx 4 mm per twist.)

Cut two lengths of red, two lengths of green and one length of gold #30 magnet wire 10 inches (25 cm) long.

Twist one red and one green wire to approximately 60 twists. Twist one red, one green and one gold wire to approximately 60 twists, as illustrated to the right.

Wind 12 turns of the bifilar wire on one core and 12 turns of the trifilar wire on the remaining core. Try to center the windings so that approximately equal lengths of the bifilar and trifilar leads emerge from either side.

A typical T1 is shown at the right. T2 will look similar, except that it will be wound with the bifilar wire.



The cores are small, as is the wire. I found it useful to use a

medium size sewing needle to thread the wire through the core.



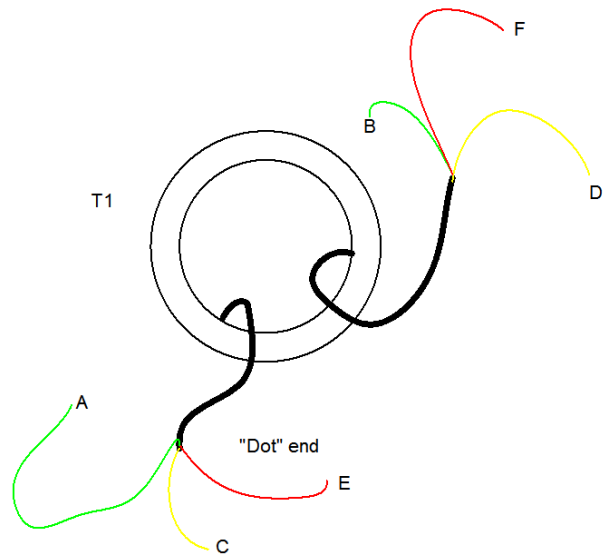
The eye should be large enough to take the trifilar wire. I cut the needle to a convenient length and also blunted the point with a grinding wheel.

If building a Z10050A with parts from Clifton Laboratories, the red and green wire is “solder strippable” meaning that the insulation will melt off when dipped in molten solder or rubbed on molten solder from the tip of a soldering

iron. The gold colored wire, however, is not solder strippable. The insulating coating must be removed, preferably by gently abrading it with fine sandpaper or emery paper.

THE "DOT" NOTATION

T1 and T2 have windings identified with a small black dot in the schematic. For our purposes, we can consider the dots as identifying one end of the bifilar or trifilar windings. The sketch at the right shows how T1's windings correspond to the letters in the schematic with green, red and gold color wires.



Other than having only red and green wires in the winding, T2 is the same.

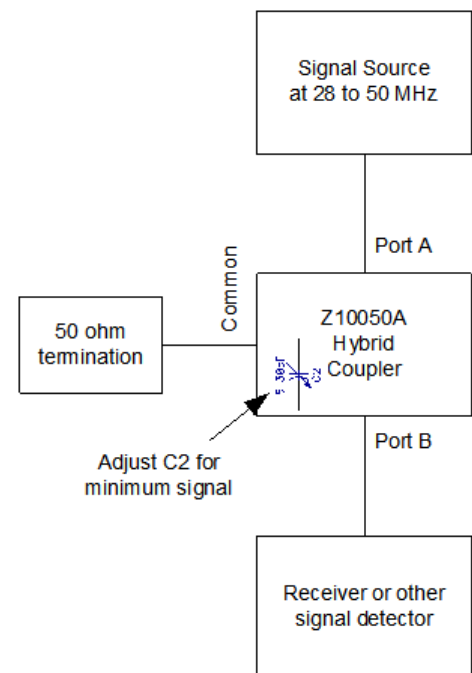
ADJUSTING C2

After assembly, C2 is adjusted to provide maximum port-to-port isolation at frequencies above 30 MHz. At Clifton Laboratories, this is done with an HP 8752B vector network analyzer. It may also be done with simpler tools, such as a signal generator and a receiver.

Test Equipment Required

- A signal source, such as a signal generator or other test oscillator capable of output at a frequency between 28 and 50 MHz.
- A way of detecting the test signal and measuring its strength. This may be a receiver with an S-meter. A broadband device, such as a sensitive power meter, is not recommended unless the signal source has a low harmonic level.
- A 50 ohm termination.

Connect the test equipment as indicated in the block diagram at the right. If the test equipment is capable of it, set the signal source and detector to 50 MHz and adjust C2 with an insulated tuning tool for minimum signal level. The difference between the applied test signal at Port A and the measured signal at Port B is the "isolation." Depending upon your quality of construction, 40 dB or more isolation should be possible at 50 MHz. I've measured > 50 dB isolation at 50 MHz on some of these, but achieving this level of isolation is not always achievable as it depends upon circuit strays cancelling each other.



If your test equipment will not make function at 50 MHz, the adjustment can be performed at a lower frequency, such as 28 MHz. However, the best results will be found if the adjustment can be made at 50 MHz.

TYPICAL PERFORMANCE

The vector network analyzer plot below illustrates the performance of a Z10050A prototype, built using the “air construction method.

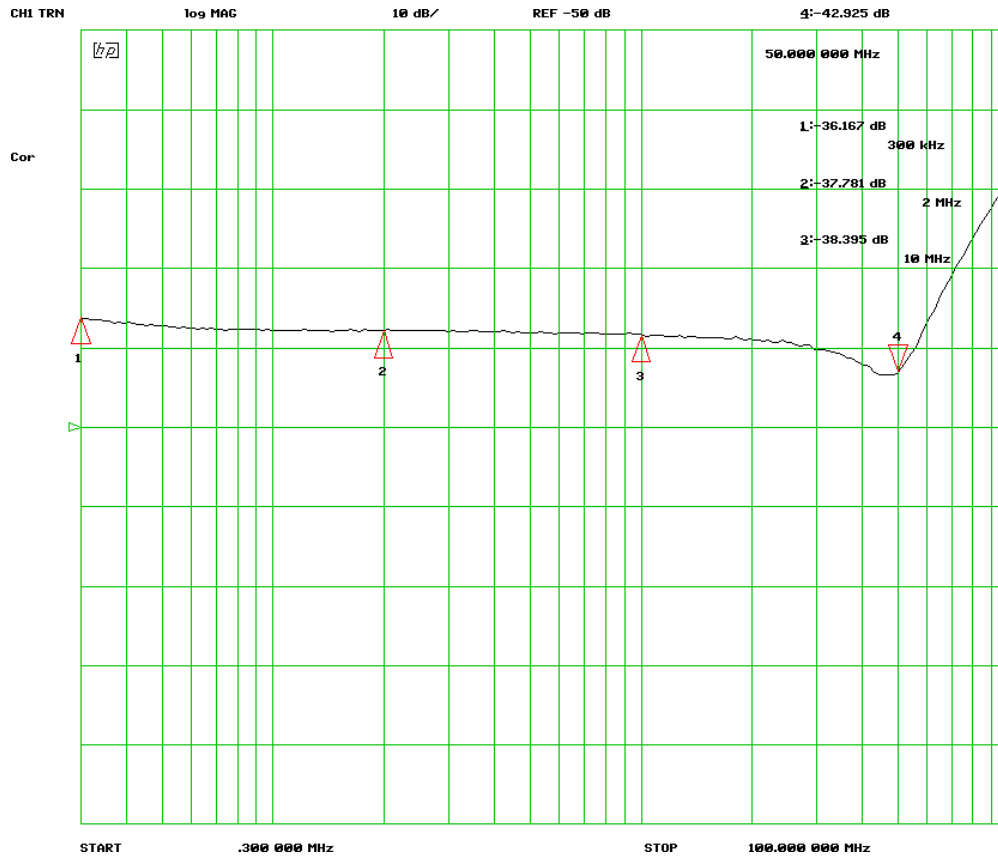
INTERMODULATION PERFORMANCE

Test signals applied at 3 and 4 MHz to Ports A and B, at a level to achieve 0 dBm output (for each test tone) at the common port. Intermodulation products observed are:

Frequency	Order	Level (dBm)	Intercept (dBm)
1 MHz	2nd	-85	OIP2: +85
2 MHz	3rd	-87	OIP3: +43
5 MHz	3rd	-94	OIP3: +47
7 MHz	2nd	-88	OIP2: +88

ISOLATION

Loss between ports A and B with common port terminated with a precision 50 ohm termination.



COUPLING LOSS

Since a coupler divides the output power from the common port into Ports A and B, a 3 dB loss (representing half power) is expected. Loss measured from the common to either Port A or Port B above 3 dB represents loss in the transformer windings, cores, C1 and C2, etc. Loss above the inherent 3 dB splitting loss is often called the “excess loss.”

The air constructed Z10050A measured below shows an excess loss of 0.35 dB at 30 MHz.

