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Title: Updated Tandem Match, An
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Technical Correspondence

Conducted By Paul Pagel, N1FB
Associate Technical Editor

AN UPDATED TANDEM MATCH

◊ The Tandem Match[1] is a directional wattmeter as accurate as any commercial unit over the 1.8- to 54-MHz frequency range. It also provides a direct linear readout of SWR and power. Judging by the mail I've received since the original unit appeared, the unit continues to be a popular construction project despite the lack of a PC board. That lack exists no longer: A PC board is available from FAR Circuits.[2]

Several corrections to the original article appear in January 1988 *QST*. The project also appears in the 16th edition of the *ARRL Antenna Book*. The schematic in that book contains an error; there should be a 0.01-µF capacitor, not a wire, between the center pin of J1 and D6 and D7. The FAR Circuits PC board includes several minor modifications to the original circuit. An updated schematic is available from me or the ARRL Technical Department Secretary for a business-size SASE, and is provided by FAR Circuits with each PC board.

The primary revision to the original circuit is support of op amps other than the TLC27x4 family used originally. To use the circuit as it was originally designed (with the 9-V batteries and TLC27L4 or TLC27M4s), jumpers are connected at W1, W2 and W3. By omitting these jumpers, any quad FET-input op amp can be used in lieu of the TLC27x4s. Possible substitutes include the TL064, TL074, TL084, LF347, and LF444. These op amps probably won't work in the original circuit because of their higher current drain and their different input- and output-voltage ranges. Omitting W1, W2 and W3 disables the automatic turn-on circuit, and the circuitry associated with Q1, Q2 and Q3 need not be built. Instead, a +15- to +18-volt supply is connected to V+ and a –5- to –15-volt supply is connected to V–. If you want to use this unit to measure power levels greater than 1 kW, V+ must be 18 volts.[3] The V+ and V– supplies could be derived from an external ac-line-operated power supply or three 9-volt batteries.

The original circuit specified use of TLC27L4 or TLC27M4 op amps. I had a great deal of difficulty with circuit instability when I used a TLC27L4 at U1, especially when RF is applied to the input. The problem may be related to the very low supply current (10 µA) required by this op amp. I recommend building the circuit using TLC27M4s or TLC274s, which use a much higher supply current. This increases the overall current drain to 3.8 mA, or 17 mA, respectively.

Other circuit changes are minor. The feedback resistors around the 1N5711 diodes are now 100 kΩ instead of 180 kΩ and 1 MΩ. The feedback capacitors from the op-amp output to inverting input have been increased in value from 0.001 µF to 0.01 µF. Several additional 470-pF bypass capacitors have been added to the circuit. Please note: I don't recommend using plastic-case 2N2222/2N2907 transistors at Q1, Q2 or Q3. Their higher leakage current could cause false triggering of the automatic turn-on circuit.

Radio Shack no longer sells the 50-µA meter specified in the original article. They do, however, offer a 0- to 15-volt dc meter (#270-1754) which, in reality, is a 1-mA full-scale meter movement packaged with a 15-kΩ series resistor. This meter can be used in the circuit by reducing the value of the resistor in series with the meter from 100 kΩ to 5 kΩ. The 1N34 diodes are available at Radio Shack (#276-1123); 1N271s are almost identical and can also be used. Mount the 1N34 diodes slightly above the circuit board so that the heat from soldering does not cause a diode failure. (Use a clip-on heat sink [such as Radio Shack's #276-1567], a pair of pliers or a hemostat on the diode lead above the board to draw the heat from the diode body.—*Ed.*)

The Tandem Match PC board is double-sided with plated-through holes. The upper (component) side has mainly the chassis and circuit ground planes, although there are a few signal traces. Check the board carefully to ensure that none of the ground planes pass too close to a circuit lead. I found it necessary to scrape away a bit of foil from a few places around the IC holes; this is easy to do with an X-ACTO knife. All of the trimmer pots must be square multiturn units with top adjustment screws.

The PC board accepts ¼-watt resistors and radial-lead capacitors. Mount the ferrite beads so that they don't touch any PC board traces; the beads have sufficient leakage to cause problems in the high-impedance portions of this circuit. Before mounting the SO-239 connectors on the PC board, enlarge the location holes to ⅝" diameter. The components connected to the SO-239s are soldered directly between the center pin and the board traces. Be sure to follow the instructions in the original article (or the *ARRL Antenna Book*) as to the mounting of the four 200-Ω resistors that serve as a 50-Ω termination resistor, and the 1N5711 detector diodes. I soldered the ground end of the 200-Ω resistors directly to the chassis ground plane. Despite what the original article says, I've found that the detector diodes need *not* be a matched pair.

You must enclose the PC board within a metal cabinet. Otherwise, RF can get into the circuit and cause problems. These problems usually manifest themselves as an SWR reading of less than 1, or a negative voltage at TP3 or TP6. This problem can also occur if you have a large common-mode current on the coaxial cable (current flowing on the coax shield). A solid metal enclosure makes the circuit less susceptible to RFI.

Parts can be obtained through various distributors including Digi-Key, Surplus Sales of Nebraska, Active Components, and Newark Electronics (see the ARRL Parts Suppliers List in any recent *Handbook*). I wasn't able to find a single distributor that stocks all of the parts. So, I contacted a local distributor, Anchor Electronics,[4] owned and operated by John Burgoon, AB6JQ. John has agreed to stock the semiconductor parts used in the revised Tandem Match, including the TLC27M4CN, 1N5711, LM336-2.5 and CA3146E. Anchor also stocks the other parts, including the trimmer pots and diodes.—*John Grebenkemper, KI6WX, ARRL Technical Advisor, 19490 Miller Ct, Saratoga, CA 95070.*

[1] J. Grebenkemper, "The Tandem Match," *QST*, Jan 1987, pp 18-26. Also, see Feedback, *QST*, Jan 1988, p 49. The Tandem Match also appears in various editions of the *Handbook* and *The ARRL Antenna Book*.

[2] A PC board is available from FAR Circuits, 18 N 640 Field Court, Dundee, IL 60118; price, $19 plus $1.50 shipping. PC-board template packages are available from FAR Circuits.

[3] The amount of power you can measure is dependent on the common-mode range of the op amp. Let's assume the common mode is 3 volts below V_{CC}. This means we can have an input voltage of 15 volts, that is equivalent of 2.25 watts being fed into the detector (which is slightly more than the 2 watts dissipation of the 50-Ω termination resistor). With a 30-dB coupler, this corresponds to 2.25 kW through the wattmeter. If the supply voltage is 15, we're limited to measuring 1.4 kW with this same common-mode range.

[4] Anchor Electronics, 2040 Walsh Ave, Santa Clara, CA 95050, tel: 408-727-3693, fax: 408-727-4424. Minimum order: $20.

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Feedback

◊ Refer to "Sporadic-E Causes," *QST*, Technical Correspondence, April 1993, page 73. In the second paragraph, fourth sentence, insert the words "peaks and" between the words "whose" and "troughs" so that the partial sentence reads: "...over at least a decade and whose peaks and troughs were closely related...—*Neil Spokes, AB4YK*