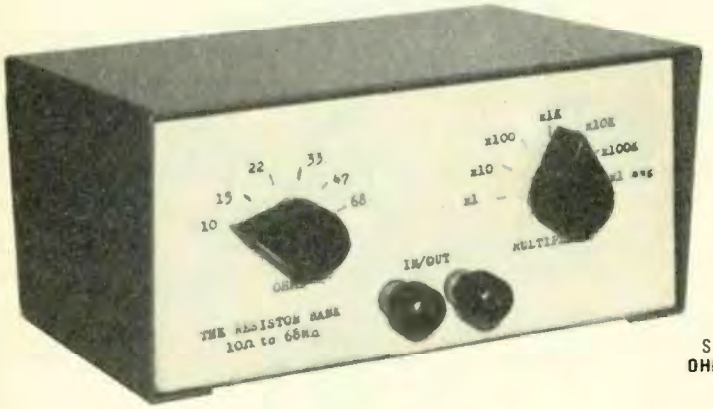
RESISTOR BANK



- **Pick the right resistance to complete the transistor bias network**
- **Find the replacement for a burned out, or otherwise illegible, resistor**
- **Select the frequency determining resistor for an R-C oscillator**
- **Determine a pot's paralleling resistance to trim to a selected value**
- **Check your ohmmeter's readings**

By C. B. Ohman

ONE OF THE MORE USEFUL TEST-BENCH INSTRUMENTS FOR the electronics experimenter is a resistance substitution box. The one described in this article—we call it the Resistor Bank—is unique in its convenience and ease of operation. What makes the device so useful? The Resistor Bank is useful in selecting the right resistance to complete a specialized-biasing network. It is useful for finding the right replacement for a burned-out, or otherwise illegible, resistor. It's ideal for selecting the frequency-determining resistor for an R-C oscillator. The Resistor Bank lets you check an ohmmeter for correct ohmic indication throughout the meter's many ranges. See how handy it is to determine the required paralleling resistance to trim another resistor to a desired value. Other opportunities for unusual applications for the device will suggest themselves once you make the unit and have it at the ready on your test bench

Had the Resistor Bank been a commercial unit, the engineering specification sheet would probably read something

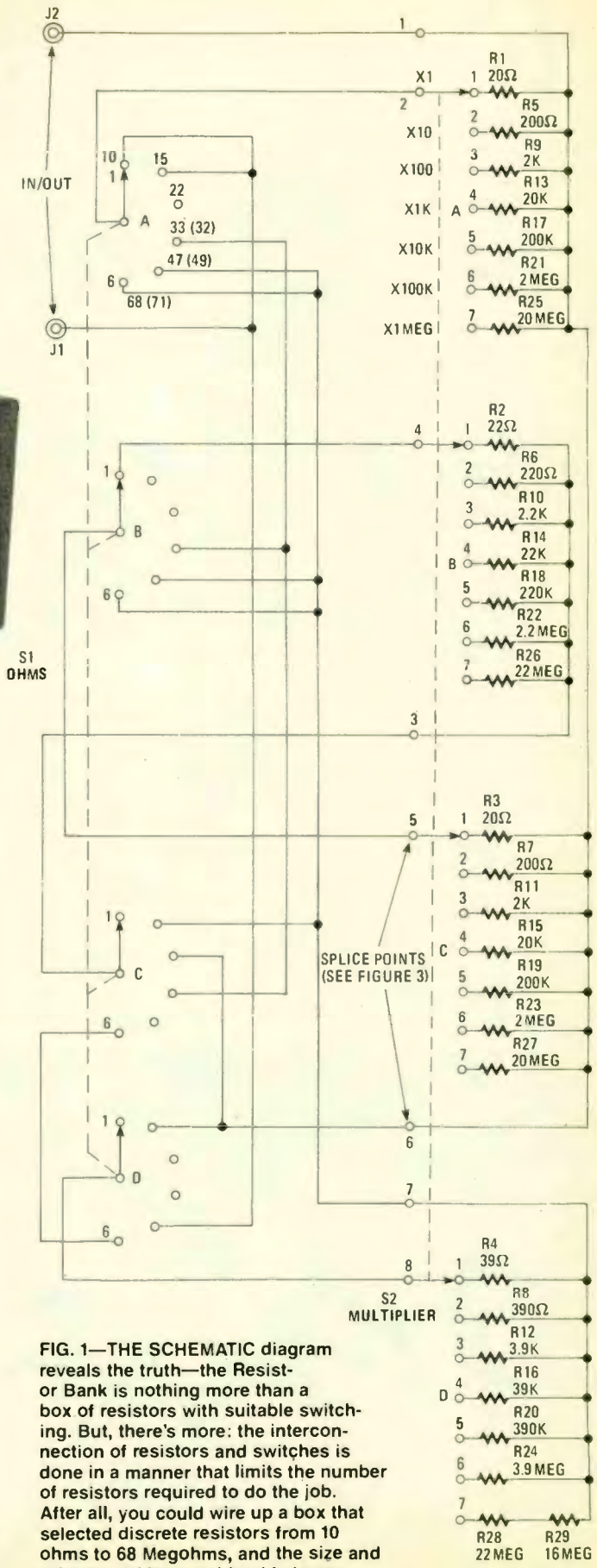
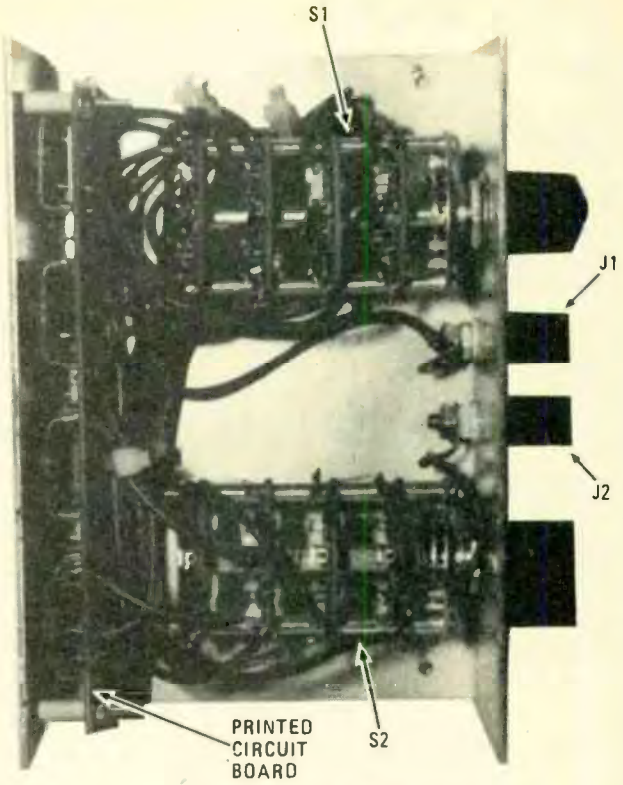


FIG. 1—THE SCHEMATIC diagram reveals the truth—the Resistor Bank is nothing more than a box of resistors with suitable switching. But, there's more: the interconnection of resistors and switches is done in a manner that limits the number of resistors required to do the job. After all, you could wire up a box that selected discrete resistors from 10 ohms to 68 Megohms, and the size and price would be considerably larger.

like this:

Specifications: *Ranges*: 7 decades (10-68 ohms, 100-680 ohms, 1K-6.8K, 10K-68K, 100K-68K, 1 Megohm-6.8 Megohm, 10 Megohms-68 Megohms). *Readings and Accuracy*: 6 selections per decade. ±5% resistors simulate a logarithmic progression (10, 15, 22, 32, 49, 71). Panel markings are to the nearest standard resistor values. *Internal Connections*: Series and/or paralleling to produce 42 outputs from 29 resistors. *Voltage Rating*: 500-volts AC or DC. Basically limited to 1-watt resistor heat dissipation, up to a maximum set by component ratings. Permissible voltage varies from 4.5-volts, as tabulated on instrument instruction plate. *Size*: Optional. Prototype is 6-in wide × 3-in. high × 4-in. deep. *Shipping Weight*: 1.5 pounds, approx.

There are seven groups of resistors, one for each resistance "multiplication" setting group. Refer to Figs. 1 and 2. Each group is made up of four resistors, two of different values and two of the same value. One group has five resistors, where two resistors simulate a single, unavailable resistance value. MULTIPLIER Switch S2 selects the group to be used, then (OHMS) switch S1 connects in series or parallel those resistors in the selected group. The resulting outputs conform to close approximation of the standard logarithmic progression. The 29 resistors provide a total of 42 outputs, from 10 ohms to 68 Megohms. Fig. 2 offers several simplified diagrams that indicate how resistors are selected and connected and the mathematics related to their summation.



HERE IS THE INSIDE VIEW of the author's Resistor Bank. The printed-circuit board is mounted off the rear surface of the chassis box on spacers. Switches were pre-wired before mounting and then soldered to the foil surface of the printed-circuit board which faces front. In truth, how you do it is your business, which in turn depends on the materials you have available and the intended use. You may want to build two units with one wired into your testbench top or panel for availability on all test and repair jobs. The other you can put in your portable test case.

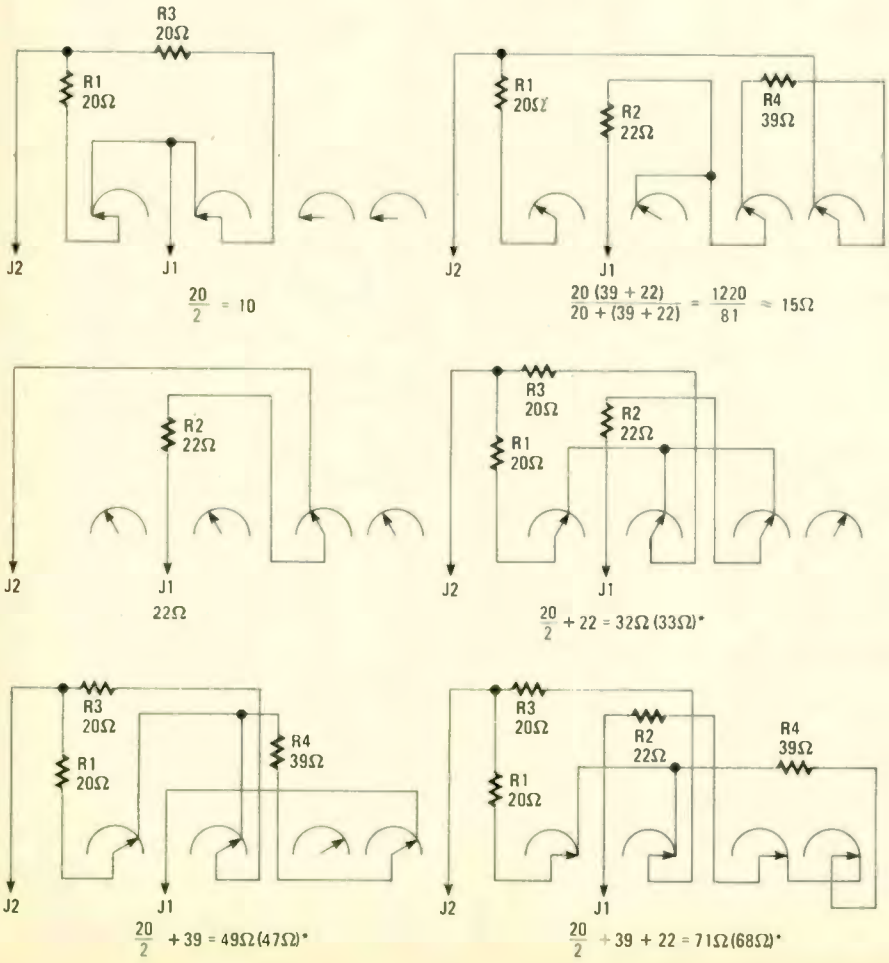


FIG. 2—SIX SIMPLIFIED diagrams illustrate with attending mathematics the techniques used to obtain six discrete resistance values. To obtain 10 ohms, two 20-ohm resistors are placed in parallel; 15 ohms, 20 ohms is paralleled with 22- and 39-ohms in series; 22, only one resistor is used; 33 ohms, approximated with the 10-ohm circuit in series with 22 ohms; 47 ohms, approximated with the 10-ohm circuit in series with 39 ohms; and, 68 ohms, approximated with the 10-ohm circuit in series with 39 and 22 ohms. Hand selecting a 39-ohm resistor that actually measures 37 ohms would bring the 47- and 68-ohm ranges right on the money and introduce a small unnoticeable −.4 percent error in the 15-ohm range compared to a previous +.4 percent error. In either case—peanuts!

Construction

Parts used can be obtained from the junkbox if yours is well stocked. You will probably have to buy all or most of the ±5%, 1-watt resistors. You'll find them at an electronics parts supply house or in a mail-order catalog. Refer to the Parts List for a kit supplier.

A mail-order catalog is a good source for the rotary wafer-type switches, S1 and S2. Either shorting or non-shorting contacts (or a mixture) will do; but, if you are buying the switches, specify shorting-contacts for both switches to avoid presenting an open, or pulsed circuit to the external circuit.

Figure 3 diagrams the actual wiring. The Resistor Bank printed-circuit board can be composed of fiberglass, or the less expensive phenolic material. Resist circles, resist pen and etchant are the only other materials required for the printed-circuit fabrication. Wire used may be small gauge, say 24 AWG, since current-carrying capacity is not a factor; solid conductor is the easiest to handle.

You could generate a printed-circuit board for the Resistor Bank directly from Fig. 3. If you prefer, use perfboard and flea clips to simulate the same layout. Some builders may try to assemble the resistors directly to the switches, which is a *big mistake*. The heat of the soldering iron may damage the switch—that would be costly.

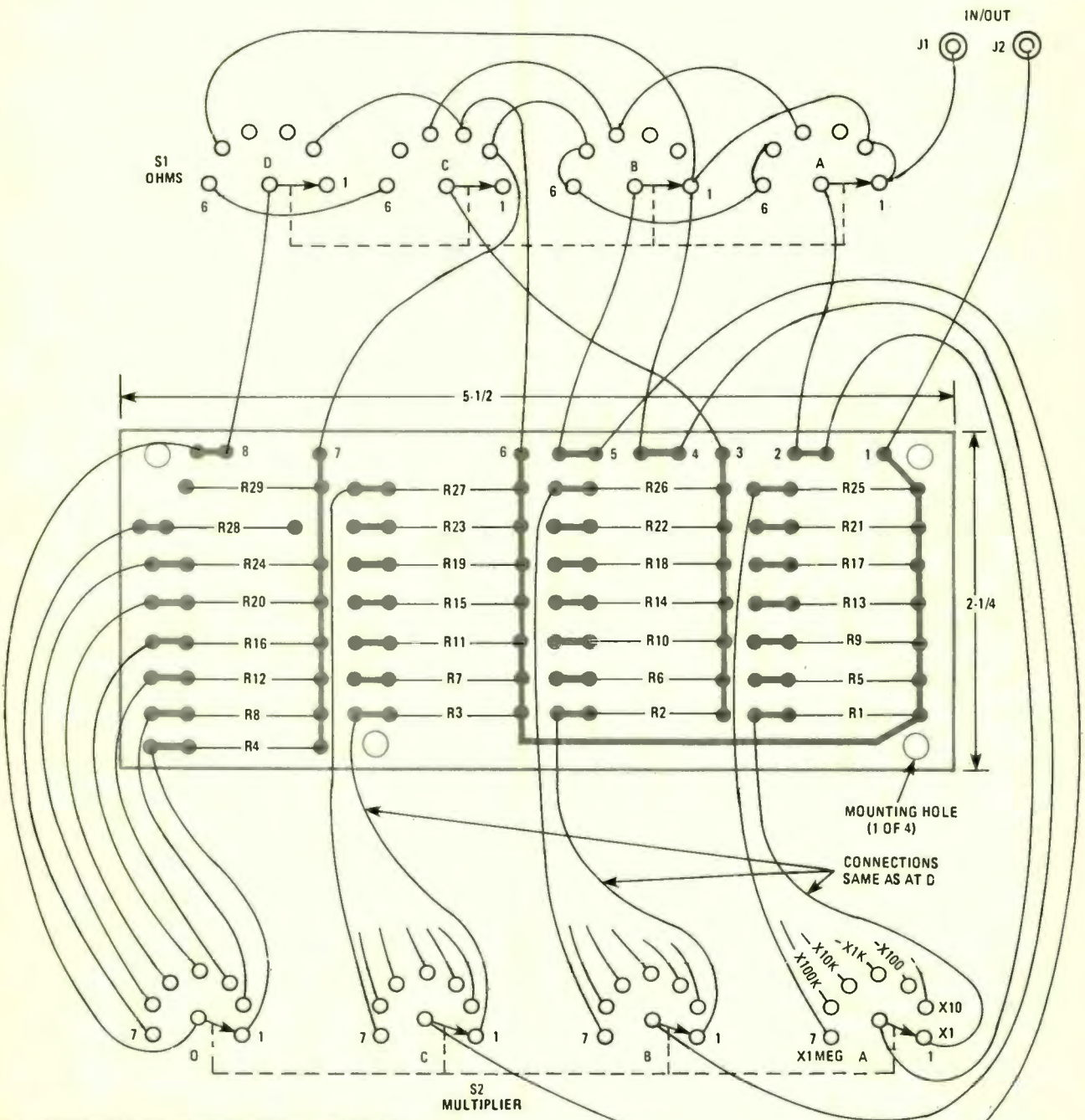


FIG. 3—THE PROJECTS's wiring diagram is shown here with the foil shown right-side up and full size. Switch terminals are shown as viewed from inside the box since that is where you will do the wiring. It would be a good idea to use colored ribbon cable. Wire the switch wafer closest to the printed-circuit board first, and then repeat procedure for each switch section duplicating that effort. Trace the printed-circuit foil pattern from the page to make your board and mount resistors on the non-foil side.

TWO VIEWS of the author's Resistor Bank. The front panel was suitably marked by typing switch settings on paper and cementing the paper to the panel. A typewriter eliminated the need for decals, but you may want to be a bit fancier. The rear panel presents some operating information gleaned from the text.

The packaging of the project is up to you! You may prefer a home made box, a professional-styled cabinet, or no box at all. The author used an LMB-463 aluminum box. Panel treatment is optional. The faceplate on the prototype Resistive Bank shown in the photos was made by typing on paper. The layout was first drawn by hand, then the legends and wording were done on the typewriter. The finished product was cemented to the box's front panel. The faceplate was given several coats of spray from a can of clear lacquer. Rubber feet were added to the unit so that the front panel tilted up to the face of the technician using the instrument.

The use of the Resistor Bank requires only connection into the circuit via binding posts J1 and J2, then setting switches S1 and S2 to the desired resistance. The user selects the significant digits (OHMS), then sets the desired range (MULTIPLIER) from X1 to X1 MEG.

Protection against exceeding allowable resistor wattage (and the consequential danger of permanent resistor change) is assured by staying within the permissible voltages presented in Table 1. Those voltage limits should be included on an instruction plate attached to the rear or top of the Resistor Bank, so as to be a reminder. The same caution applies as for any resistance-substitution box: Do not to exceed the power rating of the internal resistors.

PARTS LIST FOR RESISTIVE BANK

RESISTORS

(All resistors are 5% tolerance, 1-watt, composition fixed types)

R1, R2—20-ohm
R2—22-ohm
R4—39-ohm
R5, R7—200-ohm
R6—220-ohm
R8—390-ohm
R9, R11—2000-ohm
R10—2200-ohm
R12—3900-ohm
R13, R15—20,000-ohm
R14—22,000-ohm
R16—39,000-ohm
R17, R19—200,000-ohm
R18—220,000-ohm
R20—390,000-ohm
R21,R23—2-Megohm
R22—2.2-Megohm
R24—3.9-Megohm
R25, R27—20-Megohm
R26, R28—22-Megohm
R29—16-Megohm

ADDITIONAL PARTS AND MATERIALS

J1, J2—Multi-way, black binding posts (Radio Shack 274-662, or equivalent)
S1, S2—4-pole, 11-position, 4-sections, shorting-contacts, rotary wafer switches (Centralab PA1014, or equivalent)
Printed-circuit materials to manufacture circuit board, two knobs, hardware, aluminum chassis box (see text), rubber feet, wire, solder, etc.

WHERE TO BUY

A kit of working parts (consisting of all resistors, switches, solder-plated, pre-drilled, fiberglass, printed-circuit board, and wire) is available from C. B. Ohman, 3695 Alcott Street, San Diego, CA 92106. Cost: $33.00 plus #3.00 for shipping and handling.California residents add $1.98 sales tax. Allow for 6 to 8 weeks for delivery.

TABLE 1
MAXIMUM VOLTAGE PER RANGE

Resistance Range (Ohms)	Permissible Voltage (VAC/VDC)*
10-68	4.5 (3.2)
100-600	14.0 (10.0)
1000-6.8K	45.0 (32.0)
B 10K-68K	140.0 (100.0)
100K-680K	450.0 (320.0)
1 Meg-6.8 Meg	500.0 (500.0)
10 Meg-68 Meg	500.0 (500.0)

Evaluation

The accuracy of the resistance value selected is independent of the number of resistors involved, or their interconnection. The overall accuracy of the instrument is therefore ±5%, the same as that of the individual resistors used. That accuracy is for the actual 10-15-22-32-49-71 progression, not for the 10-15-22-33-47-68 panel markings.

The listings in Table 2 shows actual selected resistance for the Resistor Bank as measured with a digital multimeter whose accuracy is ±0.2% of reading on the resistance set-

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RESISTOR BANK

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ting. The resistors used for the Resistor Bank are *5-percenter's* used just as they came from the store. None were *Hand-selected* by resistance measurement.

TABLE 2
ACTUAL PROTOTYPE RESISTANCE VALUES

Resistance (ohms)		±5% Limits (ohms)		Read on Ohmmeter (ohms)
Marking	Actual	Low	High	
10	10	9.5	10.5	10.5 (=11.1 − 0.6)
15	15	14.2	15.8	15.5 (=16.1 − 0.6)
22	22	20.9	23.1	23.9 (=24.5 − 0.6)
33	32	30.4	33.6	34.0 (=34.6 − 0.6)
47	49	46.6	51.4	49.3 (=49.9 − 0.6)
68	71	67.4	74.6	72.8 (=73.4 − 0.6)
1K	1K	0.95K	1.05K	0.99K
1.5K	1.5K	1.42K	1.58K	1.51K
2.2K	2.2K	2.09K	2.31K	2.26K
3.3K	3.2K	3.04K	3.36K	3.25K
4.7K	4.9K	4.66K	5.14K	5.07K
6.8K	7.1K	6.74K	7.46K	7.33K
100K	100K	95K	105K	102K
150K	150K	142K	158K	154K
220K	220K	209K	231K	225K
330K	320K	304K	336K	328K
470K	490K	466K	514K	497K
680K	710K	674K	746K	722K

Customizing

A final word. Now that you have read this article and understand the switching circuit, you may wish to tailor it to your special needs. Here are some tips for your consideration.

You may have no need for the 10-Megohm to 68-Megohm range. Just eliminate the ×1 Megohm multiplier section entirely from your Resistor Bank.

You could use 2-watt resistors for heavier current applications. However, you'll soon discover that these specialized ranges are limited so that not all the resistors need be 2-watt units. Also, think of providing ventilation holes in the unit's chassis box.

Smaller-tolerance resistors may be desirable for greater accuracy. That could be done on any particular range, or all of them. You could either resort to 1% tolerances, or hand-select specific values.

Any of those modifications, as well as others you can dream up, can be done without affecting the basic switching connections detailed in the Resistor Bank construction. ■

Note: The measured values in the 10- to 66-ohm range have been *improved* by subtracting the lead and contact resistance. The good readings of the other ranges show the value of starting out with accurately-marked, within-tolerance resistors. That won't always happen unless you make it so by screening the resistors first. Remember, you could go out of tolerance permanently by soldering the resistors in place that have been exposed to a series of high-humidity days.