For circuit design, debugging & servicing

Handy, low-cost R & C substitution boxes

Whether you are involved in servicing, circuit design at the professional or hobby level, or in testing electronic equipment, a set of resistance and capacitance substitution boxes is very useful. Put any or all of these four substitution boxes together and you may wonder how you ever managed without them.

by GERALD COHN

Resistor and capacitor substitution boxes are items that are often highly desirable, both in the workshop or in the field. Yet many of us still do without them, for the simple reason that the effort and time required to put one together just seems too high a price to pay for the convenience. But how often does one find that a perfectly good capacitor or resistor has to be thrown away because the pigtails have broken off in service through continued bending and flexing?

No doubt the reader can think of many instances when a substitution box would not only have saved him an otherwise good component, but also time and effort. Circuit design, for example, is one area where that last stage of debugging can be made so much simpler by the use of substitution boxes. To be able to select the exact value for a particular component by the mere flicking of a number of switches and all without unwanted hand capacitance effects is a decided advantage.

This article describes four simple, low-cost substitution boxes which have been designed especially for use in such instances. Included are three capacitor substitution boxes, and a decade resistance substitution box. We will consider the decade resistance box first.

RESISTANCE BOX

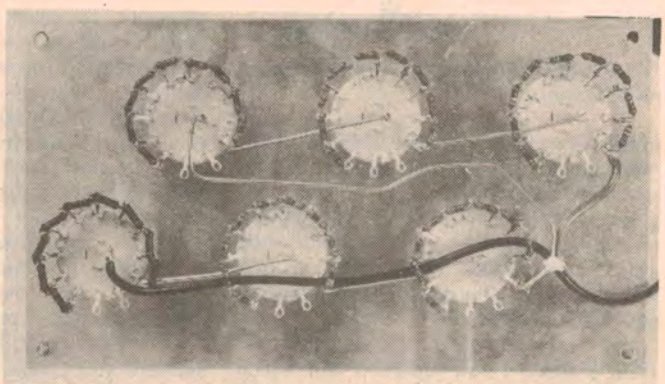
The resistance substitution box covers six decades of resistance values from 10 ohms to 10 megohms. Since there is more than one decade, it is called a "decade box". This name is derived from the arrangement used to select and switch in the desired component value.

As the circuit shows, each decade consists of a 10-position rotary switch, to which are connected nine identical resistors. Six of these switches are connected in series, the resistors on each having a value 10 times greater than those on the preceding switch. Any value between 10 ohms and 10 megohms, in increments of 10 ohms, may be selected.

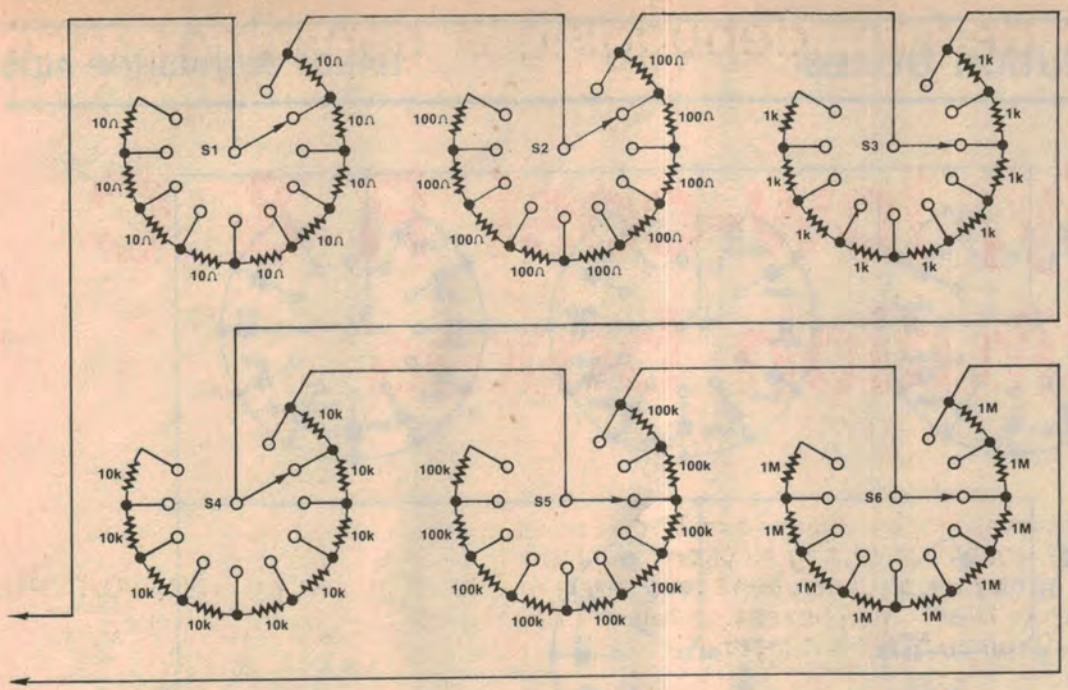
When we designed this unit, we elected to use 10 ohm increments instead of the 1 ohm increments often used on commercial substitution boxes. The reason for this is that switch contact resistance can considerably upset the accuracy of very low ohms settings. Commercial units get round this problem by employing high quality switches which, of necessity, are rather expensive.

While 5% tolerance resistors will be adequate for the majority of applications, there may be some situations where greater accuracy is required. We used 2% resistors throughout, although there is nothing to stop you from using even 1% resistors if your pocket stretches that far. The resistors we used came from Radio Despatch Service, (869 George St, Sydney), although other parts suppliers should also have close tolerance

A view of the completed resistance unit.



This photograph shows the internal layout and construction of the decade resistance box. Note the tinned copper wire for interswitch connections.



The circuit of the resistance box showing the series connection of the resistors. The switches are also connected in series, giving a maximum possible resistance of 9,999,990 ohms in increments of 10 ohms.

DECADE RESISTANCE SUBSTITUTION BOX

7/MS/-

resistors available.

Be warned, though, that 1% and 2% resistors are considerably more expensive than 5% types.

CAPACITANCE BOXES

The three capacitance substitution boxes cover a wide range of values from 100pF to 100uF. The smallest of the three covers the values often encountered in RF work — 100pF to 1000pF — while the second unit offers a much larger selection of values ranging from 100pF to 10uF, and can be considered as a general purpose unit.

The third box substitutes for most of the commonly encountered tantalum electrolytic values, from 0.1uF to 100uF.

To avoid confusion we've referred to the smallest unit as the capacitance substitution box, the 2nd unit covering 100pF to 10uF as the decade capacitance substitution box, and the 3rd unit as the tantalum capacitor substitution box. Let's consider the capacitance substitution box first.

As already mentioned, it has values ranging from 100pf to 1000pF — an entire decade. There are actually 13 preferred values available in this decade but, as there are only 12 positions available on the switch, we had to leave one out. We chose to leave out the 120pF value, as it is the least likely to be missed.

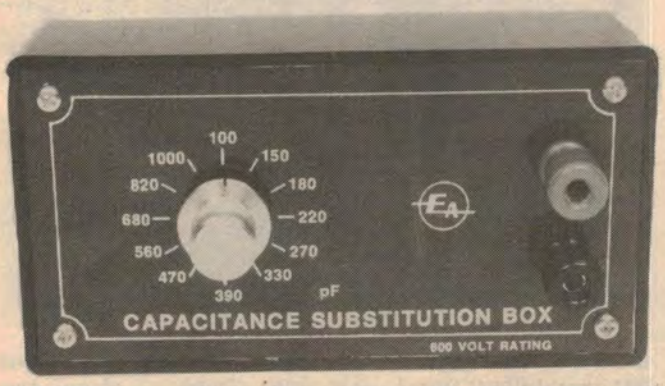
The obvious question at this point is "what type of capacitor should be used here?" Well, there are several different types that will do the job: these include mica and polystyrene types. However, we used miniature-plate ceramic capacitors, which are available in 2% tolerance from Philips.

Normally, ceramic capacitors would not be suitable because their usual tolerance range is too wide. If you cannot get the Philips type, we suggest that you use mica or polystyrene capacitors rated at 600V or higher.

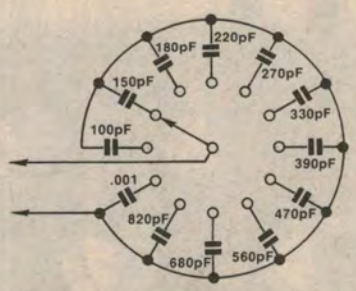
The second capacitance substitution box — 100pF to 10uF — has five rotary switches to provide five decades of capacitor values. Mica, polystyrene or Philips miniature-plate ceramic capacitors are used for values up to 820pF, while metallised polyester types are used for the remaining values up to 10uF. The tolerance rating of this box is ±10% (the tolerance of the polyester capacitors), while the voltage rating is 100V.

Finally, the tantalum substitution box has two rotary switches and a total of 18 preferred values between 0.1uF and 100uF. It has a voltage rating of 6V.

A glance at the circuit diagram will show that the 100uF value has been made up by connecting two 47uF capacitors in parallel. This was done because, at the time, we did not have a single 100uF 6V unit available. Similarly, the 68uF value can be made up of two parallel connected 33uF capacitors if you are unable to purchase a single 6V unit.



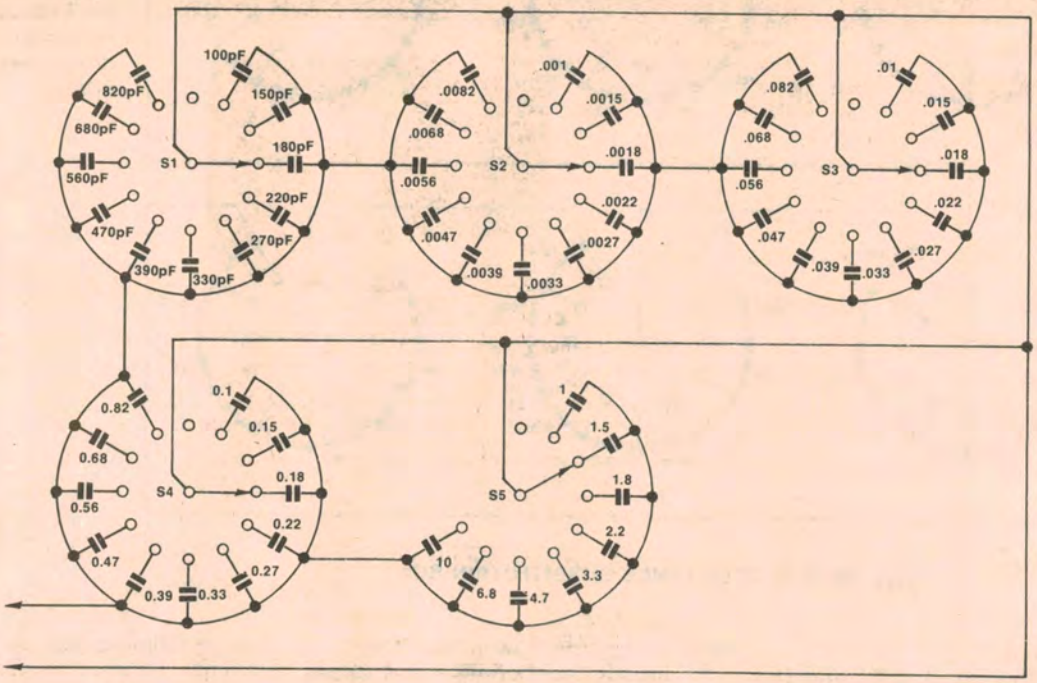
Here is the capacitance substitution box used for RF work.



CAPACITANCE SUBSTITUTION BOX

7/MS/-

The circuit of this unit is simple, comprising only 12 capacitors and a switch. Despite its simplicity, it can prove valuable for RF work.



DECADE CAPACITANCE SUBSTITUTION BOX

7/MS/-

This is the circuit of the decade capacitance substitution box. Note: one position on each of the switches is left unconnected, this being position No. 1.

CONSTRUCTION

The circuit diagrams of the four substitution boxes show how the units are wired up, while the photographs give an idea of the actual physical construction. As can be seen, the switches in the decade resistance box are wired in series, whereas the switches in the capacitance substitution boxes are wired in parallel.

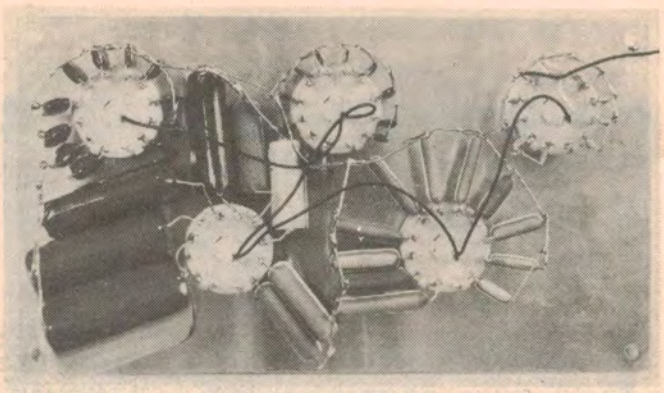
All four circuits are housed in plastic utility boxes fitted with light-gauge aluminium lids. The front panel labels were made from Scotchcal photo-sensitive aluminium, and ready-made labels should be available from Radio Despatch Service, 869 George St, Sydney by the time this article appears.

The first step in the assembly procedure for each unit is to affix the adhesive Scotchcal panel to the lid of the case and drill the holes for the rotary switches and terminals. Note that the terminals for the two decade boxes are mounted on the top of the case, and must be placed so that they do not foul the front panel rotary switches.

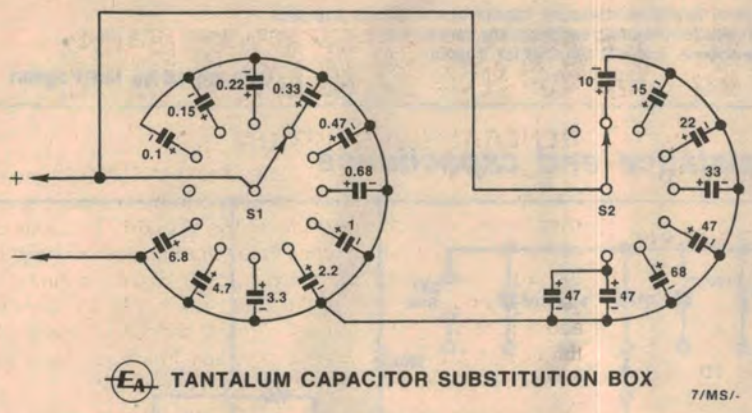
In practice this means mounting them well towards the rear of the case, away from the front panel.

With the rotary switches and output terminals mounted in position, all that remains to do is to wire up the unit according to its circuit diagram. The resistance box is easy — it's simply a matter of wiring nine identical resistors in series around each switch, starting at switch position No. 1. Stout pieces of tinned copper wire were used to make the series connections between the switches, in order to ensure a low resistance path. For the same reason,

The completed decade capacitance substitution box.



An internal view of the decade capacitance unit. We suggest that you follow our layout quite closely as things can become a little cramped with the larger capacitors.



The circuit of the tantalum capacitor box. The 100uF capacitor is made up of two 47uF capacitors in parallel.

use heavy duty hook-up wire to make the connections to the terminals.

Once construction of the resistance box is complete, the lid may be secured in position. A quick check with a multimeter will soon tell if the unit is correctly wired.

The capacitance substitution and tantalum substitution boxes are also easy to build. The capacitors are all wired between the various switch terminals and a common rail of stout tinned-copper wire that runs around the outside of each switch. This common rail is connected to the black terminal post

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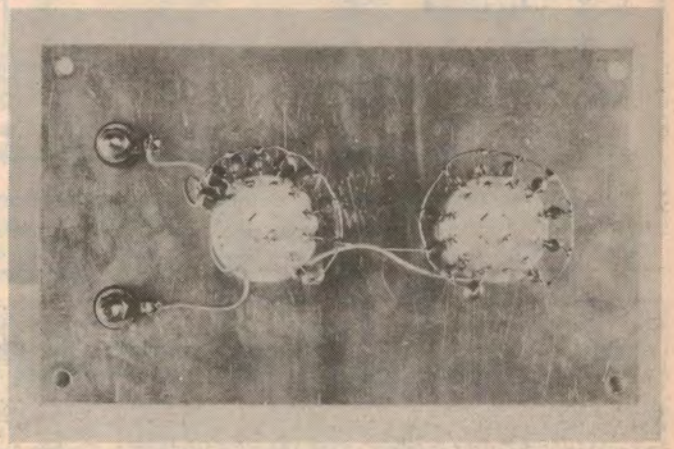

These two photographs show the internal and external views of the tantalum substitution box. The negative electrodes of the capacitors are connected to the common rail.

PARTS LIST

DECADE RESISTANCE BOX

RESISTORS (½W, 2% or 5% tolerance, see text)
9 x 10 ohm, 9 x 100 ohm, 9 x 1k, 9 x 10k, 9 x 100k, 9 x 1M.

MISCELLANEOUS
6 12-position rotary switches
1 plastic utility box, 196 x 113 x 60mm (or equivalent)
2 black binding posts/terminals
Scotchcal label

SMALL CAPACITANCE BOX

CAPACITORS (polystyrene or ceramic, see text)
1 x 100pF, 1 x 150pF, 1 x 180pF, 1 x 220pF, 1 x 270pF, 1 x 330pF, 1 x 390pF, 1 x 470pF, 1 x 560pF, 1 x 680pF, 1 x 820pF, 1 x 1000pF.

MISCELLANEOUS
1 12-position rotary switch
1 plastic utility box, 130 x 68 x 41mm (or equivalent)
2 black binding posts/terminals
Scotchcal label

DECADE CAPACITANCE BOX

CAPACITORS (polystyrene, ceramic & polyester, 100V rating, see text)
1 x 100pF, 1 x 150pF, 1 x 180pF, 1 x 220pF, 1 x 270pF, 1 x 330pF, 1 x 390pF, 1 x 470pF, 1 x 560pF, 1 x 680pF, 1 x 820pF, 1 x 1000pF, 1 x .001uF, 1 x .0015uF, 1 x .0018uF, 1 x .0022uF, 1 x .0027uF, 1 x .0033uF, 1 x .0039uF, 1 x .0047uF, 1 x .0056uF, 1 x .0068uF, 1 x .0082uF, 1 x .01uF, 1 x .015uF, 1 x 0.18uF, 1 x .022uF, 1 x .027uF, 1 x .033uF, 1 x .039uF, 1 x .047uF, 1 x .056uF, 1 x 0.68uF, 1 x .082uF, 1 x 0.1uF, 1 x 0.15uF, 1 x 0.18uF, 1 x 0.22uF, 1 x 0.27uF, 1 x 0.33uF, 1 x 0.39uF, 1 x 0.47uF, 1 x 0.56uF, 1 x 0.68uF, 1 x 0.82uF, 1 x 1uF, 1 x 1.5uF, 1 x 1.8uF, 1 x 2.2uF, 1 x 3.3uF, 1 x 4.7uF, 1 x 6.8uF, 1 x 10uF

MISCELLANEOUS
5 12-position rotary switches
1 plastic utility box 196 x 113 x 60mm
2 black binding posts/terminals
Scotchcal label

TANTALUM BOX

CAPACITORS (tantalum, 6V rating or higher)
1 x 0.1uF, 1 x 0.15uF, 1 x 0.22uF, 1 x 0.33uF, 1 x 0.47uF, 1 x 0.68uF, 1 x 1uF, 1 x 2.2uF, 1 x 3.3uF, 1 x 4.7uF, 1 x 6.8uF, 1 x 10uF, 1 x 15uF, 1 x 22uF, 1 x 33uF, 1 x 47uF, 1 x 68uF, 1 x 100uF

MISCELLANEOUS
2 12-position rotary switches
1 plastic utility box 159 x 96 x 51mm (or equivalent)
1 red binding post/terminal
1 black binding post/terminal
Scotchcal label

R&C Substitution Boxes

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on the front panel, while the switch wipers are connected to the red terminal posts.

Don't forget to connect the wipers of the two switches in parallel when constructing the tantalum substitution box. Remember, too, that tantalum capacitors are polarity-conscious. They must be wired into circuit with their positive leads connected to the switch terminals.

The decade capacitance substitution box is more difficult to assemble because of the number of physically large capacitors that have to be accommodated. The best approach is to mount the smaller values on the top three switches first. You should try to mount them as close to the switches as possible, so as to leave enough room for the larger values.

The accompanying photograph shows the layout we used, and this should be followed closely.

It's a good idea to provide additional support for the large capacitors by applying a small dab of epoxy adhesive to hold them in place against the front panel. This will eliminate the risk of undue strain on the leads.

Check your work carefully before closing the lid of each box, as any mistakes could lead to a great deal of frustration later on. If you have access to a capacitance meter, then it may be used to check as many ranges as possible.

Well, there you have it — four versatile substitution boxes that should prove useful no matter what your interest in electronics. Build them up and you'll find the effort well worthwhile