A look at decoupling capacitors

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Those of us who repair of restore old valve equipment are acutely aware of the difficulty of obtaining high voltage – 400 volts and over – decoupling capacitors. The problem seems to be worse with axial leaded types, they are available but they are expensive. However, many of us have good junk boxes which, needless to say, contain capacitors of not quite the right value. The question is, will they do? This article may help you to make a better informed choice.

Theory and Experiment

Firstly I assumed that a real capacitor can be represented by and ideal capacitor in a series with an ideal inductor. The resonant frequencies of some of my junk box capacitors were measured to get some idea of their inductance. The technique used was to solder the leads of the capacitor to form a loop which was coupled to a GDO. The frequency of the GDO, at dip was determined by using an SW receiver which had a good digital read out. Measurements were only done on one example of each type of capacitor as I was only trying to see the big picture.

The results were:

Capacitor	MHz	Xc	LµH
0.1µF/1000V	2.0	0.79	0.063
0.01µF/1000V	6.7	2.37	0.056
0.047µF/400V	2.7	1.25	0.074
0.01µF/250V	5.7	2.79	0.078

The capacitors were 10% tolerance but their values were not checked. The frequency was measured to 1KHz and rounded. Therefore I estimate that the values of Xc and LuH are correct to +/- 20%.

The capacitor's leads formed a loop about one inch in diameter from which I calculated the inductance of the loop to be 0.07µH. Hence the inductance of the leads seems to provide all the inductance in the circuit, i.e. the internal inductance of the capacitor seems to be very small – approaching zero. This result surprised me.

A real receiver

Now let's look at a real receiver, the CR100 which covers 60KHz to 30MHz and uses 0.1 µF decoupling capacitors. Making the assumption that the capacitors used have the same characteristics as my 0.1µF test capacitor then we can make the following chart.

Frequency	60 KHz	2MHz	30 MHz
Xc	-26.53	-0.79	-00.05
Xl	+00.02	+0.79	+11.85
Diff	-26.5	-0.0	+11.8

From this it appears that provided that the net reactance of the decoupling capacitor lies in the range –26.3 to +11.8 ohms then the decoupling will be satisfactory.

Examination of the CR100's wiring indicates that the lead length to the decoupling capacitors could well add even more inductance to the circuit. This would adversely impact the decoupling. One inch of wire has an inductance of about 0.02µH.

There are other aspects of the actual circuit and layout that should be considered, for example stray capacitance may cause unwanted resonances. However these factors are not easily determined but should be borne in mind.

A real solution

Suppose we are repairing a CR100 and wish to replace all the decoupling capacitors but the junk box only contains 0.01µF capacitors with the characteristics of the one that I tested. Will these do, or will we have to go out and spend hard earned money?

Based on my 0.01µF capacitor we can draw up the following chart:

Frequency	60KHz	6.7 MHz	30 MHz
Xc	-265.30	-2.37	-00.53
Xl	+00.02	+2.37	+10.60
Diff	-265.30	0.0	+10.0

This shows that the HF performance is slightly better but that the LF performance is very much worse so substitution would not appear to be satisfactory.

Optimising decoupling

Consider a receiver which covers 2 – 30 MHz and has an IF of 455 KHz. Perhaps it would be desirable to fit larger that 0.1 µF in the IF but less that 0.1 µF in the RF stages. The objective is to ensure that the net reactance of the decoupling capacitor is as close to zero over the whole frequency range. You will have to investigate your junk box capacitors to find the value that is best for your need.

Other considerations

The designers of old valve receivers not only seemed to standardise on one value for the decoupling capacitors, but did the same with their voltage ratings. This doubtless helped the production people, but was not really necessary. For example, 400 volt working is appropriate for the 250 volt line but is it really needed for the screens, cathodes and AVC line? As 250 volt working capacitors seem to be easier to find than the 400 volt types, it may be prudent to give some thought to this aspect when repairing. However a word of warning: do check all voltages at both minimum and maximum RF gain control settings before the valves have warmed up. For the AVC line, even lower working voltages that 250 volts should be satisfactory.

Finally, why not use the ceramic disc capacitors instead of the conventional tubular types? They may not look quite right, but could get you out of a hole.

Summary

This piece of work was done by an non-professional using amateur equipment. However, I believe that the overall picture is correct as error analysis does not significantly alter the base data. All you need is a reasonably calibrated GDO and a slide rule or similar device to make sense of the results. If I've got it seriously wrong, then please let me know.