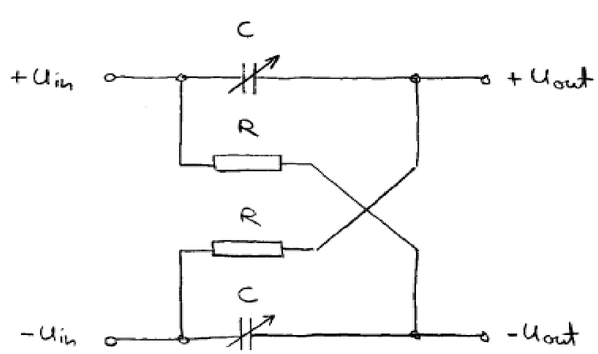
BALANCED VARIABLE PHASE SHIFT CIRCUIT

While working on the new UHF receiver for VESNA, I came across a problem when I wanted to correct for a delay in a 16 MHz sine wave signal. The idea was to have a circuit where you could adjust the phase shift by turning a trimmer of some sort. Delaying a signal of single frequency is relatively simple and shouldn't involve delay lines or other such unusual components.

While searching for circuits that would fit this purpose I came across the single transistor phase shifter. While it isn't directly applicable here, it did give me an idea. Signals in my circuit are balanced, which means that for every signal you have the inverse signal available as well. This fact removes the need for the transistor that only serves as a way to invert the signal.

This line of thinking led me to the following a circuit:

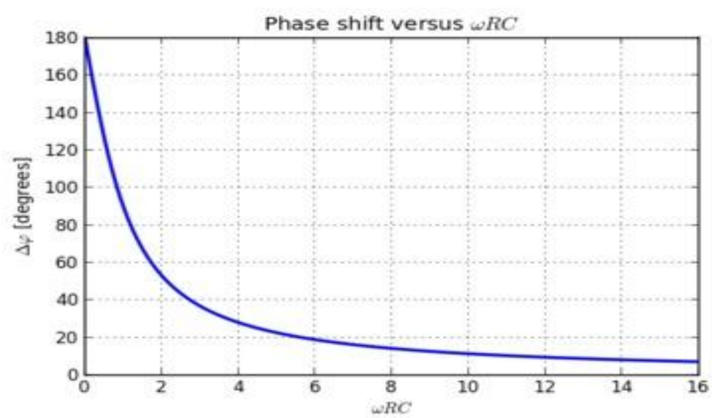


In a single-ended RC circuit the gain as well as phase delay varies when you change the time constant RC. The very nice thing about this balanced version however is that its response only varies in phase. The absolute value of gain remains 1 for the complete range.

You can verify that from the expression for the complex gain:

$$\frac{U_{out}}{U_{in}} = \frac{2j\omega RC}{j\omega RC+1} - 1$$

The characteristic value for the circuit is the normalized angular frequency ωRC. Here is the relationship between it and the signal phase shift $\Delta\varphi$.



Note that you can affect the phase by changing either capacitance or resistance. I've chosen a variable capacitor for my circuit because trimmer capacitors characterized for high frequencies are simpler to find. Small variable resistors seem to be mostly designed for low frequency signals and don't have defined characteristics for higher frequencies.

You can also make a similar LR circuit, but tunable inductors are even rarer these days.

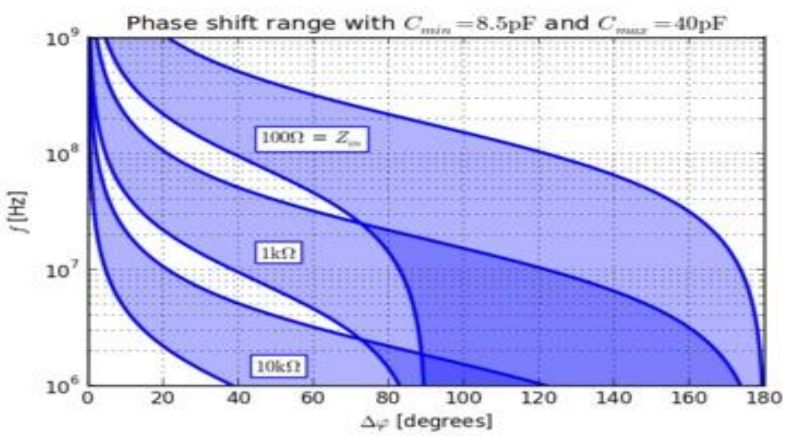
From the graph above it looks like you could achieve any phase shift for any frequency with this circuit. In reality however several factors limit the usable range.

The maximum phase shift is limited by how low you can get your time constant *RC*. With capacitances below 1 pF stray effects of the circuit board start to get significant. On the other end, you are limited by the circuit's input impedance Z_{in}. Typically the lower bound is dictated by whatever is driving the circuit.

$$Z_{in}=R+\frac{1}{j\omega C}=R\left(1+\frac{1}{j\omega RC}\right)$$

This expression shows that the impedance is lowest for the lowest phase shift and that the chosen resistance value directly affectsZ_{in}. Therefore in general, you want to keep the range of capacitances as low as you can and keep the constant resistance high.

To illustrate, here are usable ranges for phase shift $\Delta\varphi$ for frequencies between 1 MHz and 1 GHz and three different lower bounds on Z_{in}. For the range of capacitance values I used a common trimmer capacitor.



In conclusion, this circuit can be quite useful when you are dealing with balanced signals, but you need to drive it from a low-impedance source to have a wide setting range. For electronic phase adjustment I guess a varactor diode could also be used instead of a trimmer capacitor.

Unfortunately, I had to leave this part out of my final design because I ran out of circuit board real-estate for an additional voltage-follower and trimmers. I'm describing it here however, because I'm sure it will come handy in the future, perhaps as an add-on daughterboard for the receiver (I left provisions for that).

Source:https://www.tablix.org/~avian/blog/archives/2014/05/balanced_variable_phase_shift_circuit/