

ECE3424 Electronic Circuits Laboratory

Experiment #7

Application circuit: Phase splitter/shifter

vers. 1.5

OBJECTIVE: Measure the performance characteristics of a single-transistor phase-shifter circuit.

Commentary: The circuit topology is derived from a spice exercise and it is recommended that it be run in pspice concurrently with the workbench assessment. The circuit is shown by figure 7-1.

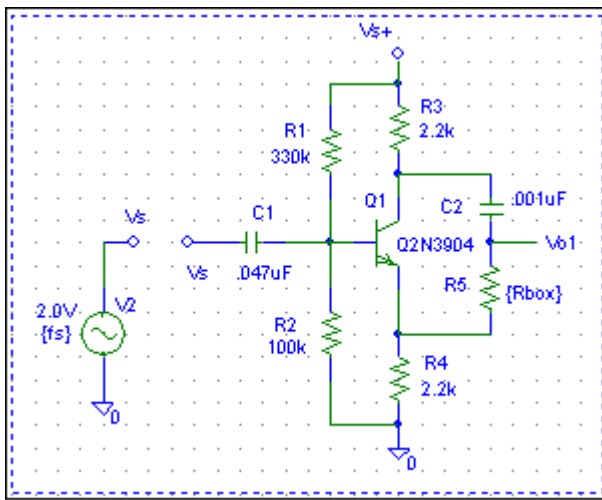


Figure 7-1: Single-transistor phase-shifter. The circuit is designed to shift phase of output V_o relative to V_s without change in amplitude. Phase shift is controlled by the R_{box} .

For the choice $R_3 = R_4$, the amplitudes at collector and emitter are of equal magnitude but opposite in phase. When these equal and opposite signals are applied to the RC pair R_5 and C_2 (as shown) there will be no change in amplitude between input to output at any frequency but there will be a phase shift associated with the offset from the single-time constant (STC) frequency $f_0 = (1/2\pi) \times (1/\tau)$. Offset and phase shift can be adjusted by varying resistance R_5 . $\tau = R_5 \times C_2$.

PROCEDURE:

A-1. Set up the phase shift circuit using resistance values given by figure 7A-1. O-scope probes CH-1 and CH-2 should be connected to node V_s and V_o respectively.

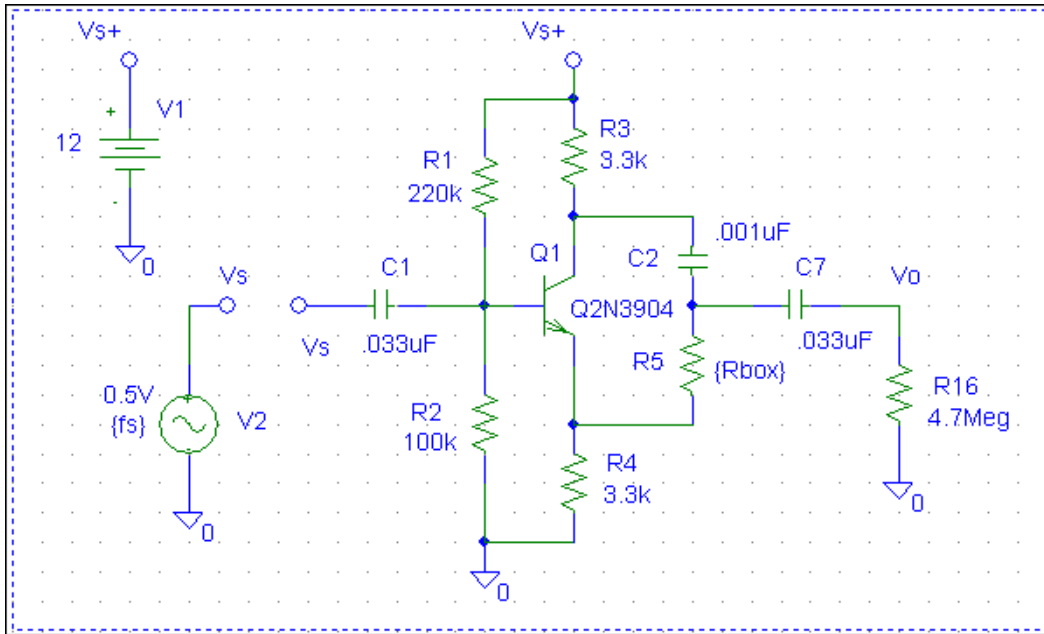


Figure 7A-1. Test set-up for phase-shift network.

A photo of the suggested placement and wiring is shown by figure 7A-2.

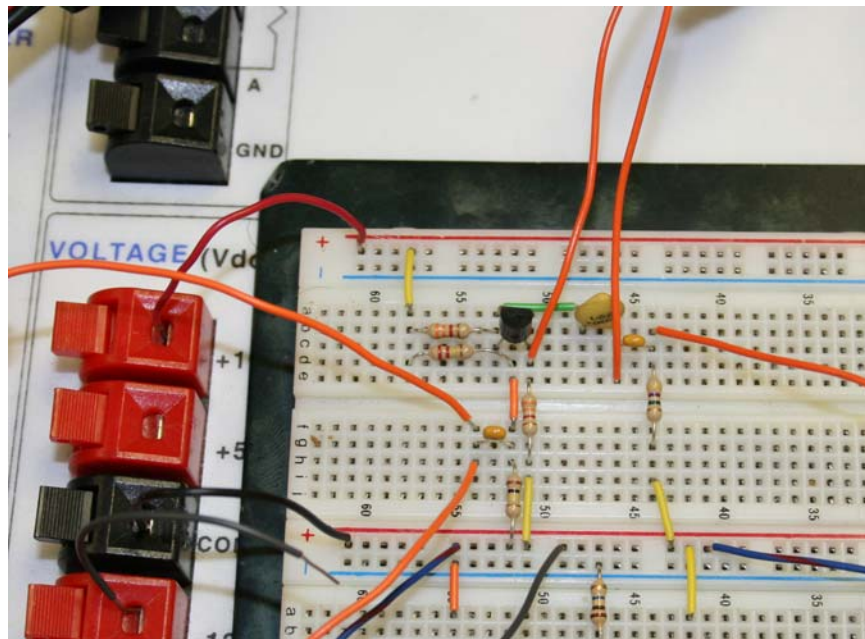


Figure 7A-2. Example placement and wiring for figure 7A-1.

A-2. As a snake check use the DMM to check circuit node voltages V_B , V_C and V_E and confirm that they are consistent for the BJT in a conducting and operational state.

Set the input signal V_S to 1.0V pk-pk at 10kHz. Check and confirm that the signals at the collector and emitter are equal and opposite in phase, and that the signal at the output V_O has magnitude same as that at V_S . Use the 'measure' button on your O-scope to determine input frequency and amplitude.

A-3. Choose the R_{box} to be 3999 Ω (almost 4.0k Ω) and C2 to .001 μ F (as shown) for which $f_0 = 40$ kHz. Connect CH-2 to node V_O . Via comparison between channel-1 and channel-2 (zoom on the sinusoidal signals by shortening the sweep time) determine the observed phase shift.

Phase shift measurements are accomplished by means of a measure of the time shift of one waveform relative to the other and the fact that one complete cycle (360°) corresponds to time $T_p = 1/f$. Set the cursor source to **time** and use the two cursors to measure the shift. Best accuracy is achieved when the cursors are aligned to the zero-crossing points. Figure A-3 shows a typical O-scope trace of CH-1 and CH-2, with cursors (in this case aligned to the peaks). There should be little or no change in magnitude of V_O relative to V_S .

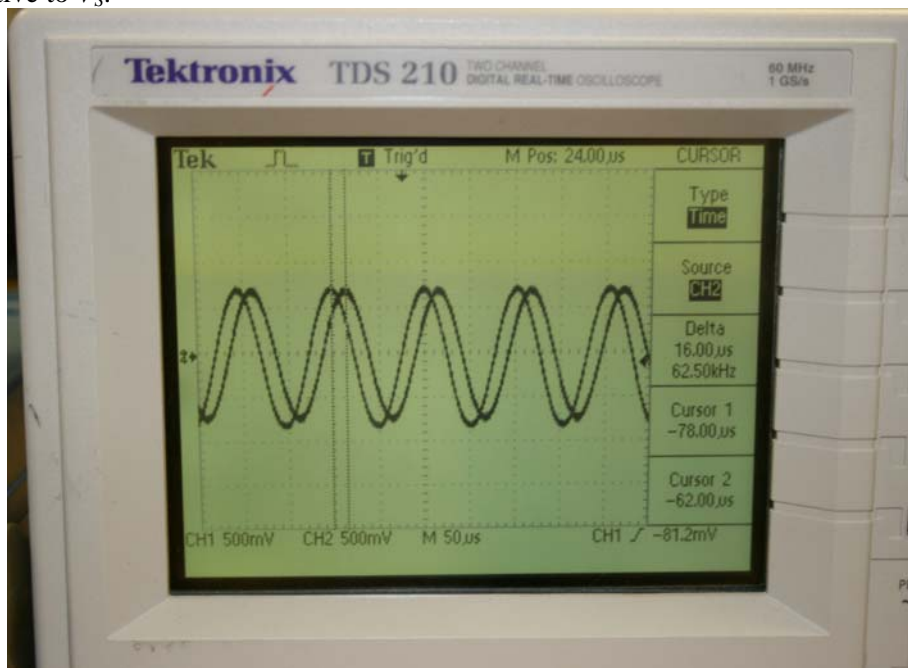


Figure 7A-3. Example scope trace readings. R_{box} is set to 9999 Ω in this example. Note that the relative shift of one signal relative to the other can be measured by means of the 'Delta' reading of the Oscilloscope.

A-5. Repeat for R_{box} settings at 999 Ω , 9999 Ω , 39999 Ω , 99,999 Ω , and 399,999 Ω . Some of these measurements may become a little flaky at the range limit of the resistances and thereby may require a mild readjustment of the input amplitude.

B-1. Set the input frequency to 100kHz and repeat steps A-2 through A-5, except also include a measurement at 399 Ω .

C-1. Set the input frequency to 500kHz and repeat step B-1. Take particular care in your measurement of the phase shifts at the resistance extremes (i.e. 399 Ω and 999,999 Ω). Be sure to include error assessments along with your data.

ANALYSIS:

1. Using the plot utilities of your Excel spreadsheet make a plot of phase-shift vs R_{box} by means of the X-Y plot option. The x-axis scale should be logarithmic, consistent with the decade range of measurements used for R_{box} measurement process.

2. Set up the circuit in pspice with f_s and R_{box} in parametric form (as indicated by figure 7-1.). Using the **Analysis>Setup>Parametric** menu and R_{box} as a Global parameter, step R_{box} from 0.1k to 1Meg on a decade step of 2 pts per decade. These should give a nearly one-one correspondence with the experiment step values used in parts A thru C. Import these values into your Excel spreadsheet and make comparison plots to the measured values of phase shift vs R_{box} .

$P(\varphi(out)-\varphi(s))$ can be displayed as a function of R_{box} using SPICE and its Goal function option. See Appendix A.

3. Show that: (derivation), using the assumption $R_3 = R_4$

$$(1) \quad \frac{v_C}{v_B} = -\frac{g_m}{g_m + G_4} \quad \text{and} \quad \frac{v_E}{v_B} = \frac{g_m}{g_m + G_4}$$

Then show that

$$(2) \quad \frac{v_o}{v_I} = \frac{G_x - sC_x}{G_x + sC_x} \quad \text{for which} \quad \left| \frac{v_o}{v_I} \right| = 1$$

and for which $1/G_x = R_x = R_{box} = R_5$, and $C_x = C_2$, respectively.

APPENDIX A.1

The phase function $P(\)$ is not recognized for a $V(t) = V\sin(\omega t + \varphi)$ display because there is ambiguity of the argument $x = (\omega t + \varphi)$ of the sine function as a function of time. So the phase $P(\)$ is acknowledged only for an analysis in which frequency is swept. So the phase-shift circuit of figure 7A-1 when analyzed by pSPICE, must be amended to include a VAC source. The modification is shown by figure A-1.1

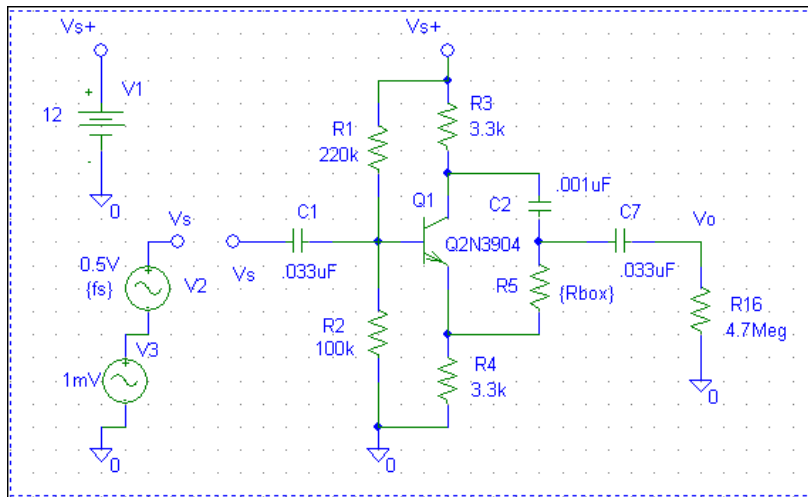


Figure A-1.1 Phase-shift circuit as amended for $P(\)$ function usage. The source V3 is a VAC source that is swept as a function of frequency by means of the **Analysis>Setup>AC sweep** menu.

In your measurement schedule you did not sweep frequency. You selected $f_1 = 10\text{kHz}$, $f_2 = 100\text{kHz}$ and $f_3 = 0.5\text{MHz}$ as test frequencies. At each of these frequencies you measured phase shift vs $Rbox$.

Obviously pSPICE can do this too. And you can pick your way through comparison of the $V_o(t)$ and $V_s(t)$ displays to extract information point-by-point.

It should be expected that pSPICE can extract this information much more easily than the point-by-point process. In order to do so there is an artifact of pSPICE that can be invoked whenever a component value (such as $Rbox$) is stepped by means of the **Parameter** menu. This artifact will be found under the **Probe** trace display menu **Trace>Performance Analysis** option. In order to make use of this artifact for phase analysis, a VAC source such as denoted by V3 in figure A-1.1 much be inserted in series with the $V(t)$ source V2 and the AC analysis menu invoked. It calls for a frequency sweep. The frequency sweep must include the three frequencies f_1 , f_2 , and f_3 of interest. For example a decade sweep from 1k to 1Meg under the menu **Analysis>Setup>AC sweep** (at 101 pts/decade) would accomplish this requirement.

Once you have done so, the goal function

$$\text{YatX}(P(V(V_o)/V(V_s)),10\text{kHz})$$

will accomplish a pSPICE display of phase shift $\Delta\varphi$ vs $Rbox$, as represented by figure A-1.2. It is worthwhile to toggle the display so that $Rbox$ is on a decade scale as shown.

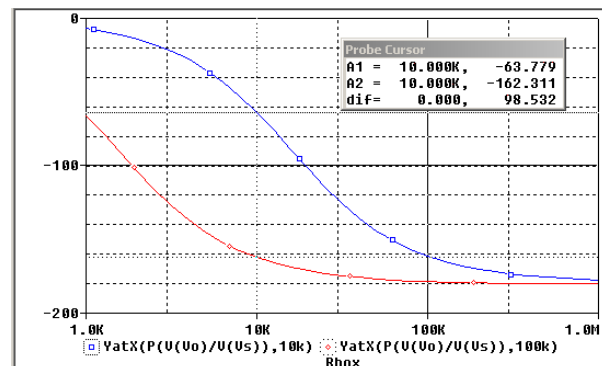


Figure A-1.2. Phase shift $\Delta\varphi$ vs $Rbox$.