Electronics II.

3. measurement : Tuned circuits

This laboratory session involves circuits which contain a „double-T" (or TT), a passive RC circuit:

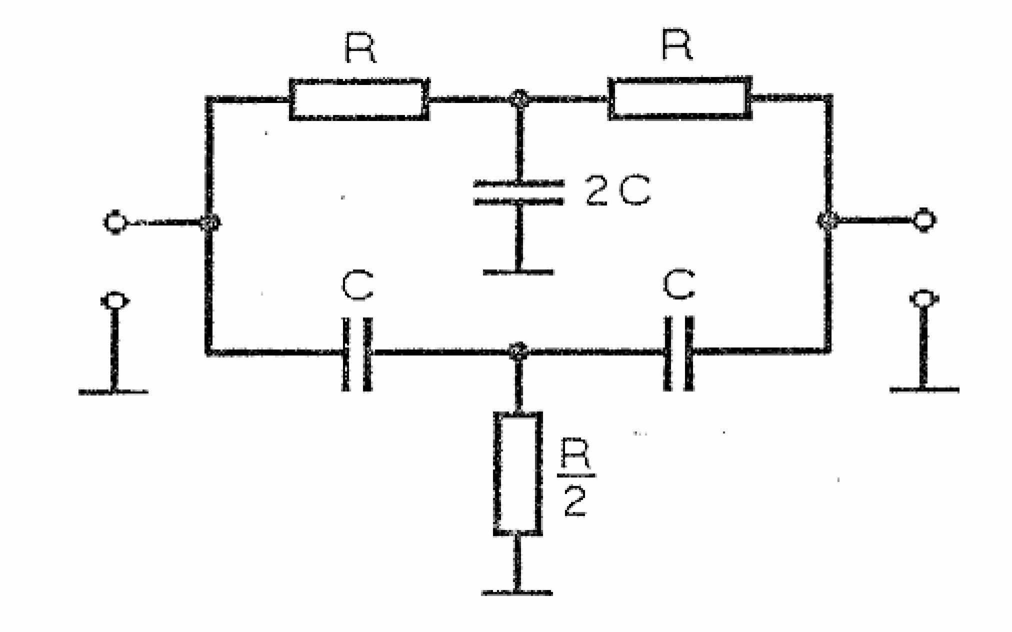

Figure 1. Double T passive RC circuit module

The upper branch constitutes a low-pass filter, the lower branch a high-pass filter. Choosing symmetric values for resistors and capacitors (as in figure 1.), on the resonance frequency f_0, the two branches provide output voltages of same magnitude, but opposing phase; thus ideally the attenuation on this frequency would be infinite. The resonance frequency is

$$f_0 = \frac{1}{2\pi RC}$$

This four-pole acts like a band-stop filter (figure 2.) Its quality factor Q can be calculated, using notation of figure 2., as:

$$\Delta f = |f_1 - f_2|$$

$$Q = \frac{f_0}{\Delta f}$$

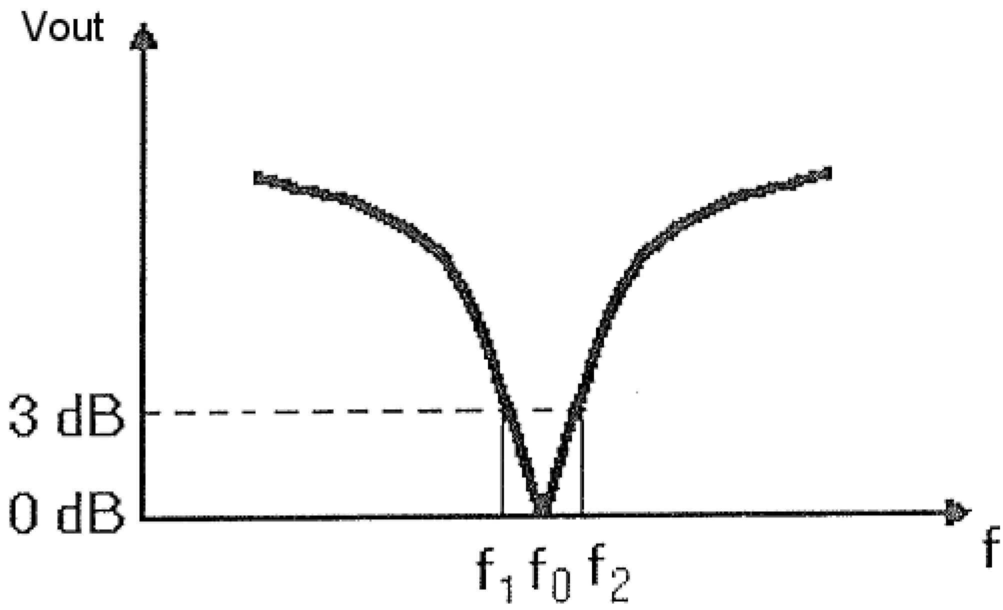

Figure 2. : band-stop filter transfer function

The attenuation at f_0 is greater if the R and C components are more exact in value and have smaller temperature coefficients.

1.1 Measurement of the double-T circuit

The double-T circuit is ready in a printed circuit board. Its parameters are:
R=20kΩ, C=10nF
The resistors' tolerance is 5%, the capacitors' is 10%.

Measurement exercises:
a) Calculate the f_0 resonance (band-stop) frequency using the provided formula and values.

b) Use the function generator to provide a 10 Vpp sinewave to the input of the double T. Measure the transfer function (V_{out} vs frequency) between 20Hz and 20kHz. Use more detailed sampling in places where the function changes rapidly. Find values of f_0, f_1 and f_2 (as in figure 2). Use an oscilloscope or multimeter (in AC setting).

Note: because the circuit elements (R,C) have a tolerance, that is, they are not equal, the circuit will not be ideal, there will be a low amount of output voltage at frequency f0. This is a small voltage, with added noise. Take its averaged value to be 0dB and use it as reference for the 3dB points.

c) Measure the phase shifting at f_0 frequency using an oscilloscope.

Note: The output voltage will be small, with added noise; storage mode of the oscilloscope (RUN/STOP) is strongly advised.

d) Calculate the quality factor Q according the given formula and the measured frequencies. Measure the attenuation of the circuit (Vin/Vout) at 20Hz and at 20kHz as well.

1.2 Active band-stop filter

Using an operational amplifier and external resistors, build the circuit of figure 3.

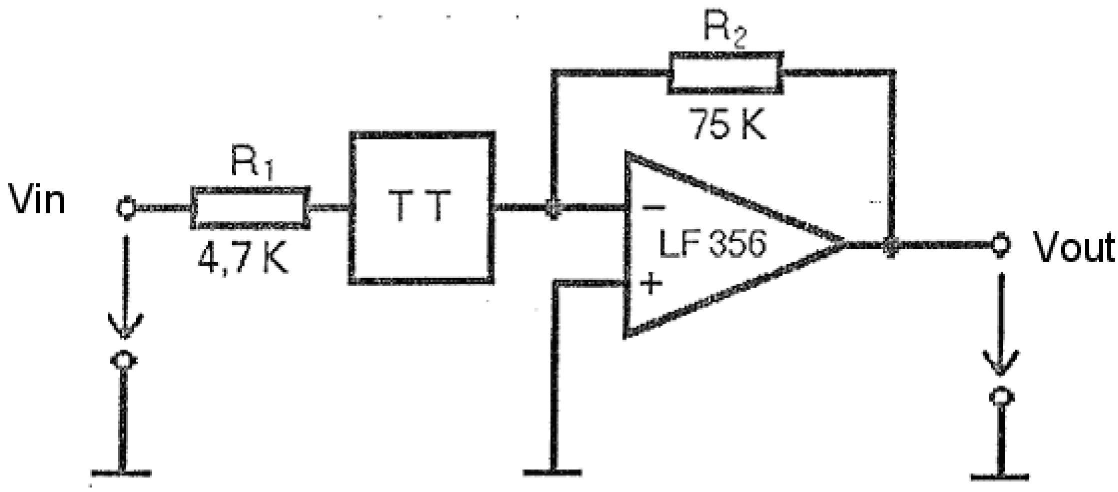

Figure 3. Active band-stop filter circuit

The opamp needs ±15V (double power supply). This circuit is basically an inverting opamp circuit, with the double-T in place of the input impedance. The resistor R1 is there to provide a load for the function generator on frequencies where the double-T's impedance is low.

The inverting amplifier's gain is

$$A_v = \frac{R_2}{Z_1}$$

Z_1 is maximum at f_0, thus the circuit's transfer function behaves as in figure 2.

Measurement exercises:
Set up a 5kHz sinewave with an amplitude such that the output is not yet distorted.

a) Measure the transfer function between 20Hz and 5kHz. Measure f_0 and Q.

b) Measure the attenuation at 20Hz and 5kHz.

1.3 Active band-pass filter

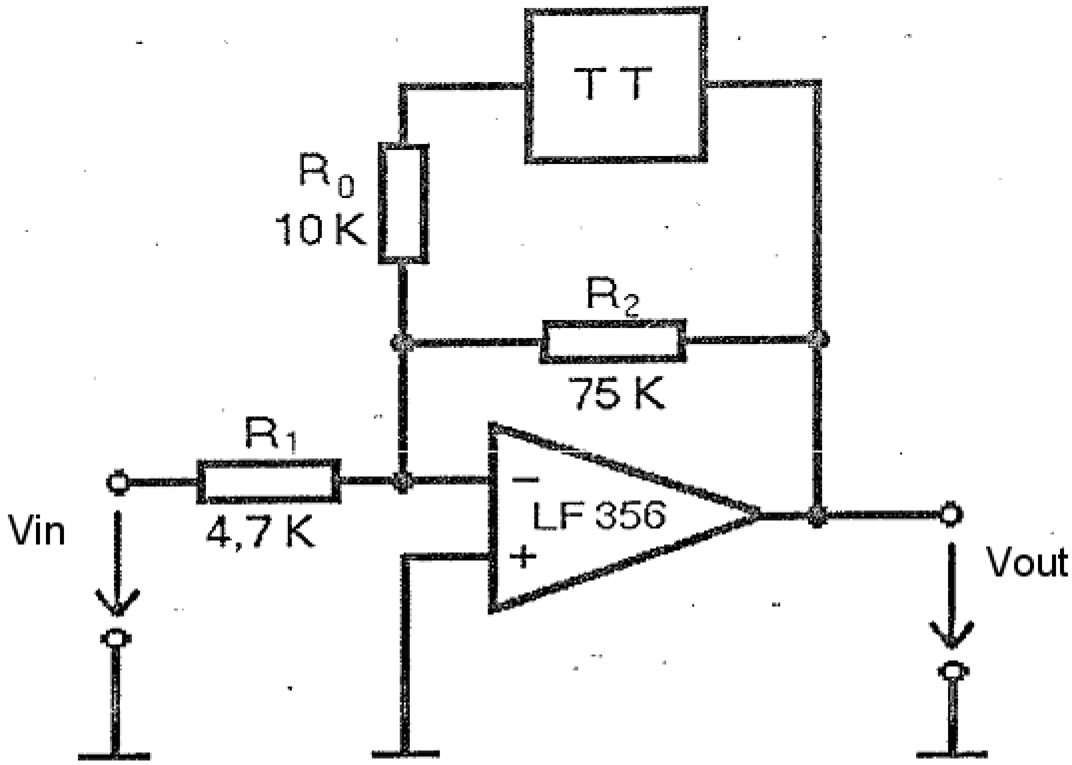

Figure 4. Active band-pass filter circuit

Change the circuit according to figure 4. Now the transfer function will be a mirror of the previous one. R2 is needed to avoid overdriving around f_0.

a) Use 0,5Vpp input. Measure the transfer function between 20Hz and 5kHz.

b) Measure f_0 and Q.

c) Measure the attenuation at 20Hz and 5kHz.

d) Make a table and compare the f0, Q and attenuation values for the three measurements (double-T in itself, band-stop filter, band-pass filter). Evaluate the results.

1.4 Double T oscillator

We can make an oscillator by using the double-T as feedback to the opamp as seen in figure 5. Theoretically the oscillator only works if the R and C values are not ideal; this is automatically done by the nonzero tolerances. The oscillation frequency will be the same as the double-T's f_0.

We need amplitude limit to avoid overdriving, this is done by the diodes. The output voltage is determined by the diodes (U_{zener} + 0.6V)

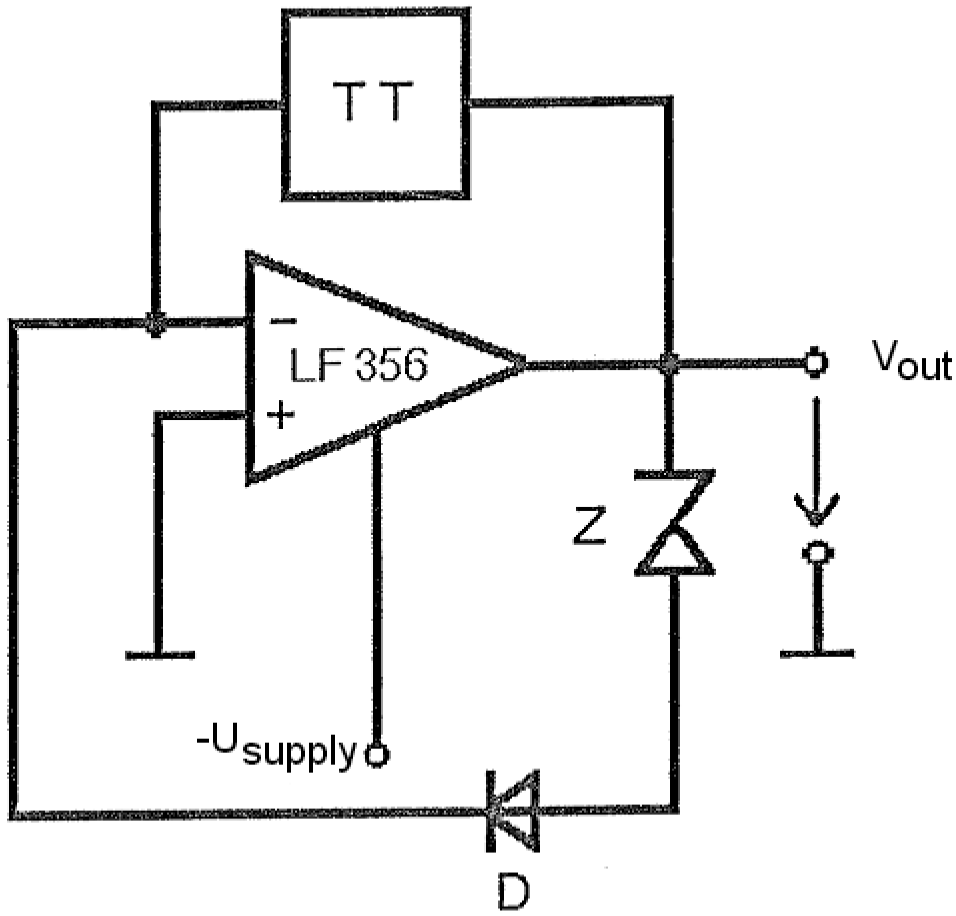

Figure 5. TT oscillator

Measurement exercises:

a) First build the circuit without the diodes! Measure the period T and use it to calculate f_0 and compare it with the calculated value. Measure the peak-to-peak output voltage and draw the waveform.

b) Build the total circuit from figure 5 Measure the output voltage and waveform using different Zener-diodes (different breakdown voltage). Compare the output voltage with calculations.

2. Wien-bridge oscillator

The Wien-bridge oscillator is a well-known oscillator circuit using RC components.
The criterion for oscillation is:

$$\frac{R_1}{R_1 + R_2} = \frac{1}{3}$$

The resonance frequency:

$$f_0 = \frac{1}{2\pi RC}$$

The circuit in figure 6. doesn't contain amplitude limit, thus the output voltage will be approximately the ± voltage supply (and can be distorted). There are versions with amplitude limit, but in this laboratory session we will not measure them.

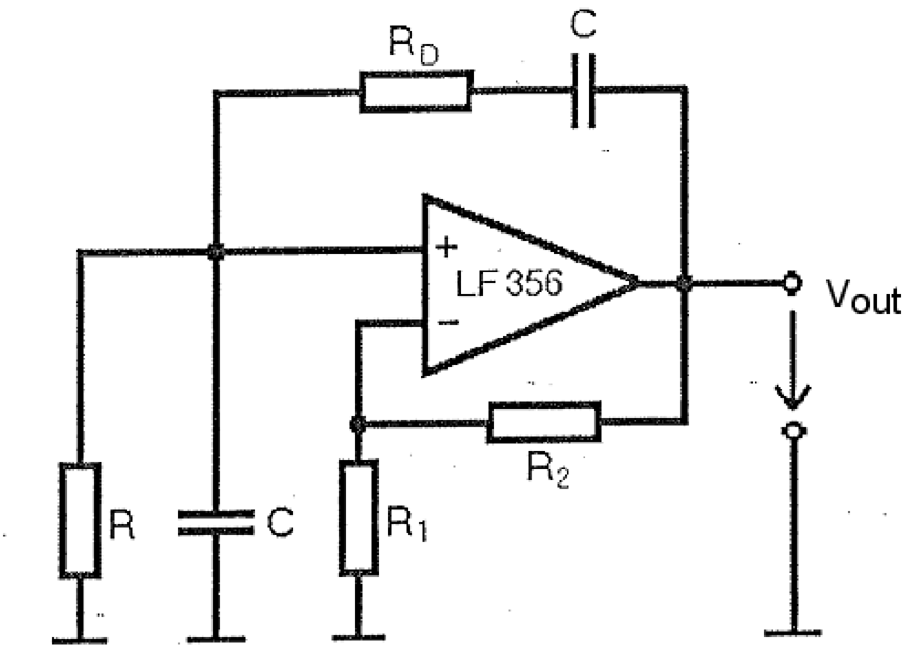

Figure 6.

Measurement exercises:
a) Build the circuit of figure 6. R_1=10k, R_2=20k, R=6.8k. C=22nF. Short circuit R_D for now (R_D=0). Draw the output waveform.

b) Connect the decade resistor in place of R_D. Setup its value to 6.8k. While watching the output signal, start changing the R_D value until the output signal looks like a perfect sinewave (least distortion). Now the product RC is equal to $R_D C$.

Note: the decade restistor is provided by the teacher.

c) Measure f_0. Also calculate its value using the given formula, with substituting R_D instead of R. Measure the output voltage p-p.

d) Change both capacitors to 150nF. Measure f_0 and output voltage.