Electronics II. laboratory

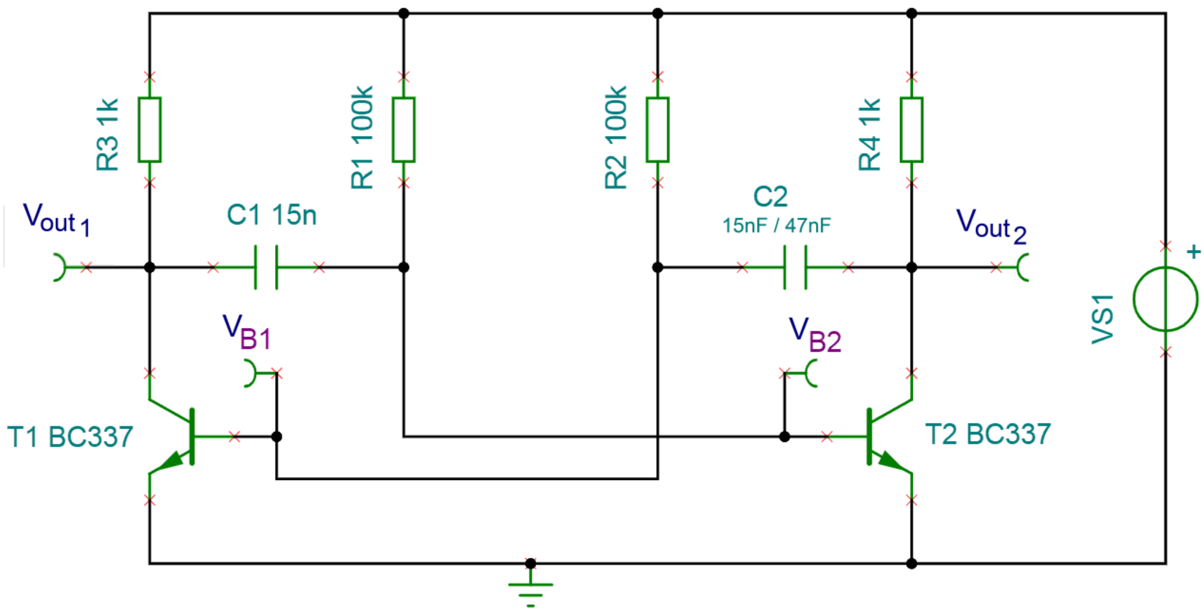
Multivibrators

2022.3.17.

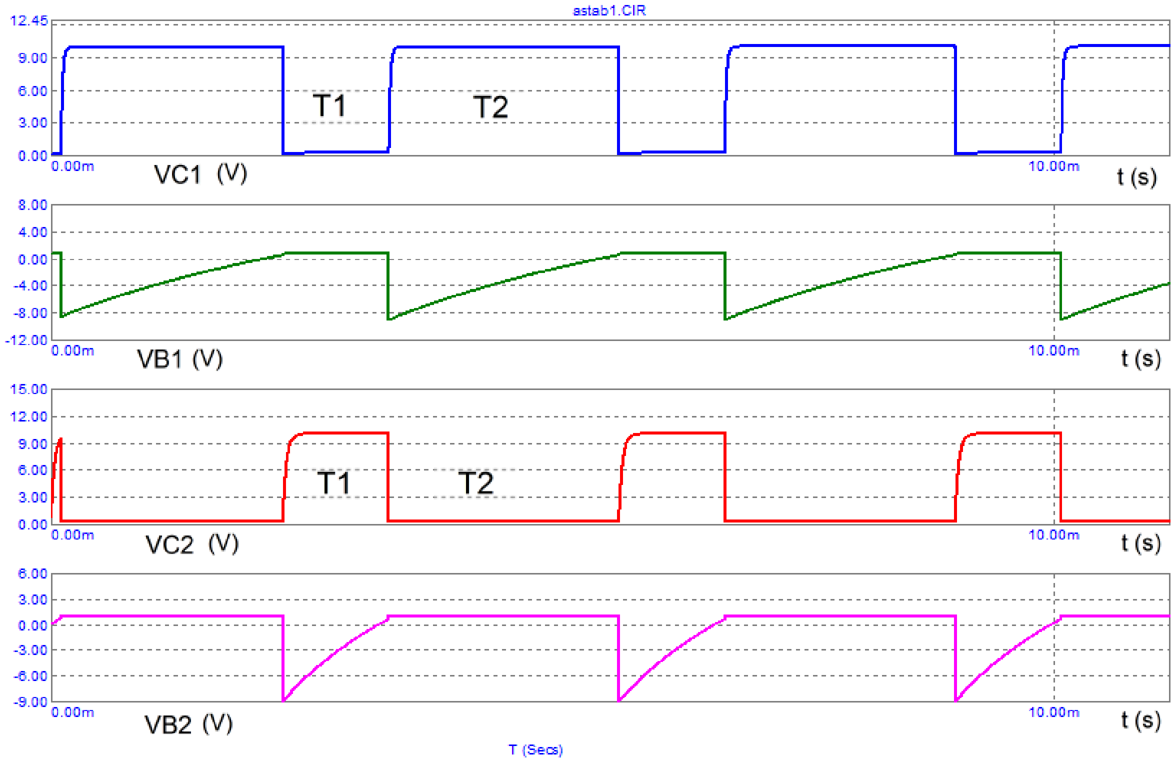
In many circuits, such as the multivibrators of this measurement, the transistors work in switching mode. When the base-emitter junction is reverse biased (or has zero voltage), the transistor - as a switch - is “off”. The current flowing through the transistors in this mode is very small, only in the order of a few nA. The on-state of the switch is represented by the transistor working in the saturation zone. The collector-emitter voltage in the saturation zone is ideally 0, practically it’s a few ten or hundred mV. Today mostly MOSFETs are used in switching mode both for low-current digital gates and for high-current switching, but bipolar transistors are still used in some similar applications. The following circuits using bipolar transistors are useful for practicing the methods of analyzing and measuring behaviour of such circuits.

1. Astable Multivibrator (AMV)

We call astable multivibrator the circuits which do not have a stable state, so the output periodically changes between two states (usually approximately 0V and the supply voltage) with a frequency given by the timer components (usually R and C). Thus the astable multivibrator is basically an impulse (or square wave) oscillator. After the power supply is turned on the circuit oscillates freely. Its two output signals have opposite phase, and the signal amplitude is – approximately – the same as the supply voltage.



1. The astable multivibrator circuit



2. Waveforms of astable circuit. [1]

The period T and the frequency can be calculated from the measured/calculated T_1 and T_2 values.

$$T = T_1 + T_2$$

$$f = \frac{1}{T}$$

$$T_1 = 0.7 \cdot R_1 \cdot C_1$$

$$T_2 = 0.7 \cdot R_2 \cdot C_2$$

$$d_1 = \frac{T_2}{T_1 + T_2}$$

$$d_2 = \frac{T_1}{T_1 + T_2}$$

Also, d1 is the duty cycle for output one, d2 is duty cycle for output two. It is defined as the ratio of times of the signal being in "1" (ON) to the total period.

The design requirements for proper operation are:

$$R_1 \approx 0.8 \cdot B_{min} \cdot R_3$$

$$R_2 \approx 0.8 \cdot B_{min} \cdot R_4$$

where B_{min} is the beta (I_C/I_B) when the transistor is in saturation which can be low (such as 20).

Time t_{ri} is defined as the rise time (transition time) between 10% and 90% of the voltage. It is approximately $t_{ri} \approx 2.2 \cdot R_3 C_1$

[1] Notice how the VB2 starts from zero and thus VC2 has a shorter initial impulse. You won't see this on the scope, as it passes very quickly. Also note that we can't always know in advance which transistor will turn on sooner. So here we have to care about the rest of the impulses only. We'll call it "steady state", meaning when the waveform has become periodic, after the initial transients are over.

NOTE: We have the circuit assembled from SMD parts, you will only find the pins for the measuring points. There is also a jumper that can be used to change the capacitor value.

WARNING: Please use the pins with caution! Insert the panels gently but firmly onto the boards!

Measurement tasks

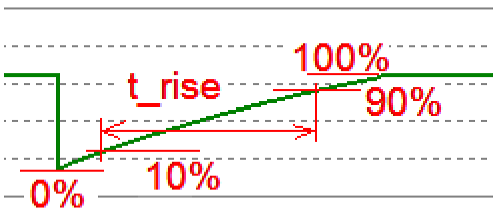
1.1 Use C_2=15nF capacitor (use the jumpers), and apply +10V supply voltage to the circuit. The 2 outputs should be connected to the oscilloscope. The resonance will start immediately after applying the supply voltage; **you don't have to use any function generator signals as input!**

Graph the waveforms. Measure (using figure 2 as reference) the corresponding T_1, T_2 and T times and the d_1 or d_2 duty cycle. Using the equations from above, calculate T_1 and T_2 then compare the measured and the calculated values.

1.2 Measure t_{ri} rise time using cursors on the scope. Check if it matches the value calculated.

1.3 Leave one transistor's output on one channel of the oscilloscope, and to the other channel of the oscilloscope connect the same transistor's base. Graph the waveforms. Measure the maximum of V_B voltage. (Make sure scope is in DC mode.)

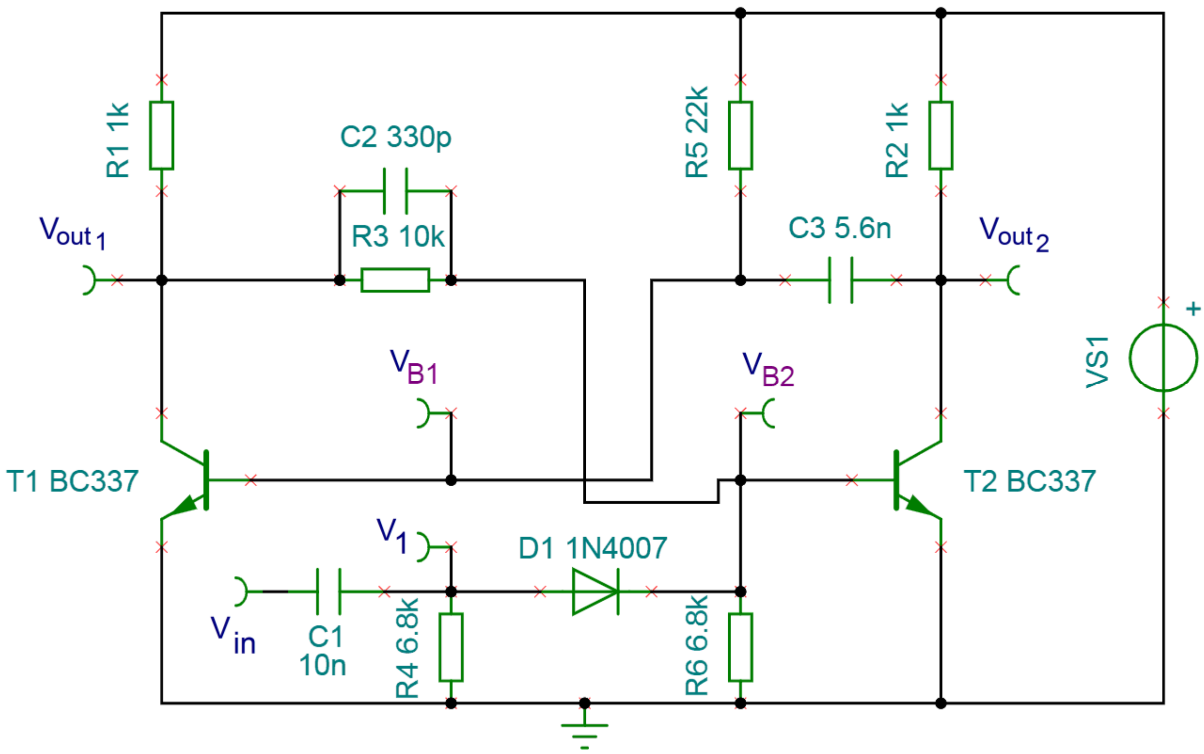
1.4 Change the C_2 capacitor to a 47nF one. With this the duty cycle will change. Perform the measurements and calculations mentioned in exercise 1.1 again



3. Rise time

2. Monostable Multivibrator (MMV)

The monostable multivibrator has only one stable state. If we input a starting signal, it switches the circuit to a "quasi" stable state with duration given by the timer elements, then switches back to original state. The MMVs are usually used for signal conditioning, slow or irregular pulses transformation to pulses with given width and high slope.



4. Monostable multivibrator

The circuit with 2 transistors is already assembled; only the 2 timer capacitors have to be connected using jumpers.

Without a starting impulse on the input, the T_1 transistor is conducting and the T_2 transistor is off. When we apply the input signal, it will be differentiated by C_1 and R_4 and the diode cuts the negative spike, thus a positive spike (short impulse) is left.

The positive spike pulls up T_2's base and turns off T_1 transistor. The increased collector voltage of T_1 leads T_2 into saturation, and V_{out2} voltage falls down. This "quasi" stable state stays until the time constant given by C_3 and R_5 elapses, and it flips back to stable state.

$T_1 \approx 0.7R_5C_3$

$t_{ri1} \approx 2.2R_1C_2$

$t_{ri2} \approx 2.2R_2C_3$

The t_f deceleration time is approx 10..100ns on both outputs (it depends on the transistor's parameters).

2.1 Connect C3=5.6nF capacitor and apply +5V supply voltage to the circuit. With a DC voltmeter, measure the DC voltage levels on T_1 and T_2 transistors' bases and collectors.
2.2 Apply from the function generator a 2.5 kHz squarewave using the TTL output (Trig.Output). The TTL output uses fixed 0 and 5V levels so you don't have to change the amplitude. (If you have an impulse generator then you can set it up to output a narrow impulse, ie. less, than 50% duty cycle.) Connect this signal to channel 1 on the oscilloscope as well. Connect V_{out1} output to channel 2. Graph the waveforms!
Now connect V_{out2} to channel 1. Graph the waveforms again (plot it under V_{out1}).
Measure the time widths and rise times of the impulses and compare with calculations.
Find the difference in V_{out1} when C_2 is connected and when not.
2.3 Connect V_{out1} to one of the channels on the oscilloscope, and the measuring point V_1 to the other channel. Plot the differentiated input signal (V_1) and V_{out1}. After this check the waveforms on both bases and plot them as well. Check on the oscilloscope the collector and base signal on both T_1 and T_2 transistors and plot, and graph the waveforms.

3.Schmitt-Trigger (ST) Circuit

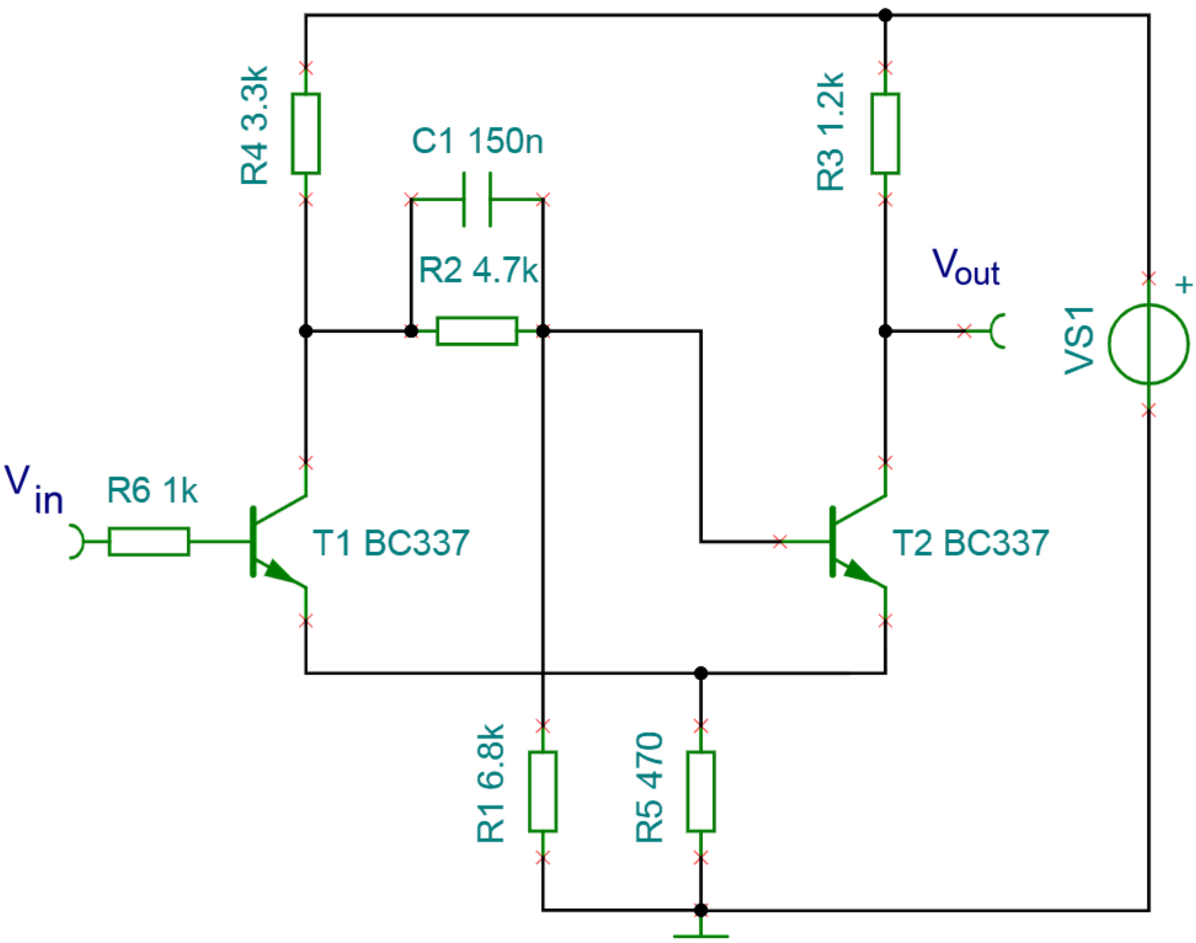
ST is also mostly used for signal conditioning.At a given value of the input voltage – at a comparison level – the output voltages increase rapidly. At this moment the circuit flips from one of its states to the other. If we decrease the input voltage then it will flip back to its original state, but now this happens at a lower comparison voltage.

The absolute value of the two switching voltage differences is called the hysteresis voltage:
$V_H = |V_1 - V_2|$

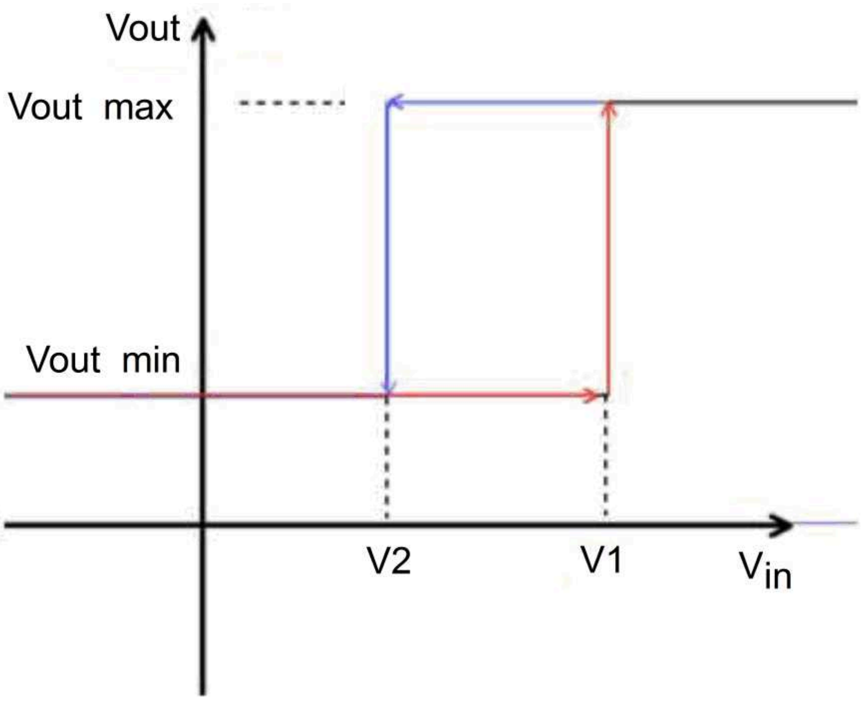
Because of the hysteresis the circuit is less sensitive to noises because it doesn't react to the changes in the input voltage that are inside the V_H interval.

Other than signal conditioning the STs can be used to create square waves out of other periodic waveforms or to de-bounce switches (ie. eliminate the noise created by switches).

The circuit is similar in operation to the hysteresis comparator we realized with opamps in Electronics I, but here the transfer characteristic is totally in the positive quadrant (all voltages are positive), which makes it more useful in many applications. (This can be realized with opamps as well of course.)



5. Schmitt-trigger (hysteresis comparator)



6. Transfer funcion of the Schmitt-trigger

Here the transfer function is graphed in both directions (ie. V_{in} changing from zero to max and then back).

3.1.1 Apply +15V supply voltage on the circuit, but do not yet connect C_1 into the circuit. Connect the input to the ground, then with a DC voltmeter measure the DC voltage on the transistor's emitter, base and collector. After this, put +15V DC voltage on the input (the same value as the supply voltage), and measure the DC levels again, and check the measure results with the calculated ones.
3.1.2 Disconnect the DC from the input (but not from the power supply). Apply a 2kHz sinus signal from the function generator and connect it to one of the channels of the oscilloscope. Increase the amplitude until the square wave appears on the output. On this measure the minimal input signal's amplitude. Measure the resulting square wave's duty cycle. Increase the input signal's amplitude to its double, and measure the duty cycle again. Graph all waveforms. What is the conclusion from the measured values?
3.1.3 The role of the accelerator capacitor. Set an amplitude on the generator at f = 200kHz which yet does not start the circuit. After this insert the accelerator capacitor (C_1) into the circuit. Then graph the time functions of V_{in} and V_{out}.
3.1.4 Hysteresis examination. Apply a 2kHz sinus wave as input into, also on Channel 1. Connect V_{out} to Channel 2. Setup XY mode on the scope (have both channels in DC mode). With right settings you should see the transfer characteristic curve on the scope. (If it looks 90 degree rotated to what you want, then switch channel 1 and 2.) Plot the graph and measure the important voltages.

Entry Test Questions:

1. Describe the goal of using a monostable multivibrator.
2. Write the formula for the duty cycle and give a brief explanation.
3. Briefly describe the difference between the astable and monostable multivibrator.
4. Describe the rise time using graph.
5. Draw the transfer function of the Schmitt-trigger.
6. What can be the applications of a Schmitt-trigger?
7. Draw the waveform V_{C1} and V_{B1} of the astable monovibrator.