Electronics 2.

2nd Measurement

Measuring impulse technical circuits

In impulse technical circuits the transistors work in switch mode. The closed state transistor implements the break off state of the switch; obviously the 2 PN-junctions get a closing voltage. The current flowing through the closed transistors is very small, only some nA big.

The on-state of the switch is represented by the transistor working in the saturation zone. The bipolar transistor's collector-emitter current - that work in the saturation zone - is ideally 0, practically its some hundredth or maybe tenth Volts. In impulse technical circuits they use special diodes and transistors especially made for these circuits, whose closing and saturating voltage is minimal.

Astable Multivibrator (AMV)

In this measurement we will examine impulse technical circuits made up from bipolar transistors. We call Astable Multivibrator the circuits which do not have a stable state so it varies between 2 states (usually 0V and the supply voltage) with a frequency given by the timer components. So the Astable Multivibrator is basically an impulse oscillator. After the power supply is turned on the circuit oscillates freely. First we have a closer look on the AMV made up from discrete elements.

The circuits can be seen on Fig.1 . In both outputs the signals are in against phase, and the signal amplitude is – theoretically – the same as the supply voltage. The U_B voltage, which we will examine with an oscilloscope, is changing according to the time function between the base and ground. The two-transistor amplifier stage is working in a positive feedback via the C_1-C_2 capacitors.

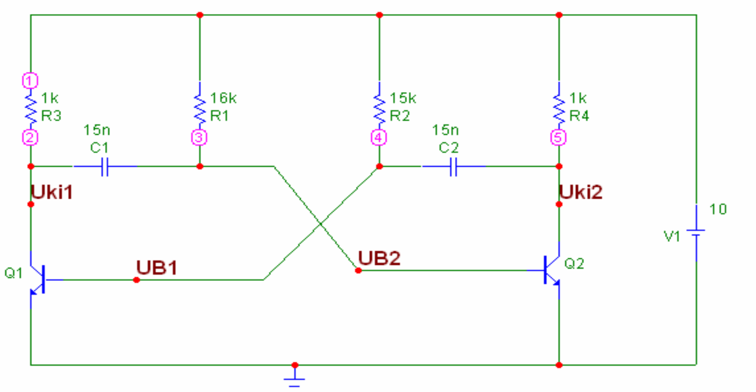

Figure 1

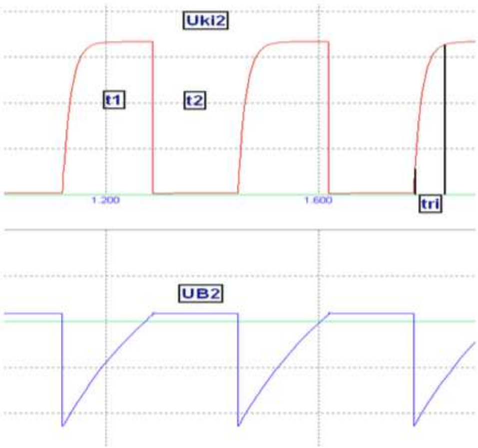

Figure 2

$T=t_1 + t_2$

$f=1/(t_1 + t_2)$ where $t_1 = 0{,}7\ R_1C_1$ (2) and $t_2 = 0{,}7\ R_2C_2$. (3)

The duty cycle: $k = t_1/(t_1+t_2)$

When designing an AMV we have to consider not only the timing factors, but also that the transistor must flip even in the worst case as well!

The requirements for this are:

$R_1 \sim 0{,}8\ B_{min} * R3$, $R_2 \sim 0{,}8 B_{min} * R_4$

(4)

B_{min} is the quotient of the Transistor's (working in saturation zone) collector and base current, which is (considering the transistors we use) approx. 20. In figure 2 t_{ri} transition time (the time between stage 10%-90%) approx. $t_{ri} \sim 2{,}2R_3C_1$ (5) big. The deceleration time is very steep, the value of it is related to the parameters of the transistor.

We have the circuit assembled from smd parts, you will only find the outlets for the measuring points. You will also find the outlets at one of the capacitors 2 terminals, with this C_2 can be changed and inserted separately to the circuit if needed.

Warning: Please use the studs with caution! Insert the panels gently but firmly to the boards!

1.1

Replace C_2 with a 15nF capacitor (C_1), and apply +10V supply voltage to the circuit. The 2 outputs should be connected to the oscilloscopes 2 channel. The resonance will start immediately after applying the supply voltage; you don't have to use any input-generator signals!!!

Let's graph the waveforms. Measure (from figure 2) the corresponding t_1,t_2,T time signals and the k duty cycle. Using correlation (2) and (3) define t_1 and t_2 and compare the measured and the calculated values.

1.2

Measure t_{ri} transition time using Figure 2. After, check if it matches the value calculated by correlation (5).

1.3

Lets leave one transistor's output on one channel of the oscilloscope, and to the other channel of the oscilloscope let's connect the same transistor's base. Let's graph the waveforms. Measure the U_B voltage in the positive range (on Figure 2.) with the oscilloscope DC mode.

1.4

Change the C_2 capacitor to a 33nF (or 47nF) one. With this the duty cycle will change. Perform the measurements and calculations mentioned in exercise 1.1 again.

2.0

Monostable Multivibrator (MMV)

The Monostable multivibrator has only one stable state. If we flip the circuit from its stable state with any starting signal, it switches to a "quasi" stable state which duration is given by the timer elements (typically RC parts). So the circuit's output signal is a steep transition and deceleration voltage pulse where the transition and deceleration times are depending on the transistors parameters and the value of the RC parts. The MMV are usually used for signal conditioning, slow or irregular pulses transformation to steep transitioned, and a given period of time long pulses.

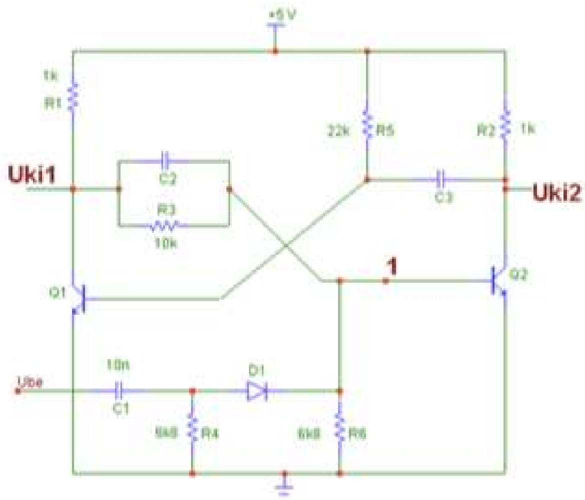

Figure 3

The circuit with 2 transistors is already assembled; only the 2 timer capacitors have to be connected. We also made outlets for the most important measuring points.

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Without starting the Q1 transistor is conducting and the Q2 transistor is closed. When we apply the power supply on the circuit the C1-R4 differentiate the circuit (can be seen on the first measurement's corresponding figure), and the diode cuts the negative spike.

The positive spike hooks up Q2's base and closes Q1 transistor. The increased collector voltage of Q1 leads Q2 into saturation, and U_{out2} output voltage falls down. This "quasi" stable state takes until, time constant given by R_5 and C_3 elapses, and it flips back to stable state.

Time of "quasi" stable state: $t1=0,7*R_5*C_3$

Transition time on $U_{out}(1)$: $t_{rl} = 2,2R_1C_2$

Transition time on $U_{out}(2)$: $l_{r2}=2,2R_2C_3$, (8)

The tf deceleration time is on both outputs (it depends on the transistor's parameters).

2.1

Insert $C_2 = 100$ pF and $C_3 = 5.6$ nF capacitors and apply +5V supply voltage to the circuit. With a DC voltmeter let's measure the DC voltage levels on T1 and T2 transistor's base and collector.

2.2

Let's apply from the impulse generator a positive cca. 2.5 kHz repetition frequency signal, narrow spike-signal (t_i cca.150 us) to the input. Let's also connect this signal to one of the channels on the oscilloscope. Also connect U_{out1} output to the oscilloscope's other channel, and increase the input signal until the response impulse-signal appears. Let's graph the waveforms! Measure the t_i impulse-time (at 50% of the signal). On the oscilloscope change U_{in} to U_{out2} and graph the waveforms again (plot it under U_{out1}) and also measure the impulse-time. The 2 measured impulse time gives the T period of time, and the reciprocal of it will give the frequency (Check on correlation (2).) Give the value of T and f!

2.3

Let's connect U_{out1} to one of the channels on the oscilloscope, and the measuring point (on Figure 3) to the other channel. Let's plot the differentiated input signal and the time-function of U_{out1}. After this check the waveforms on both bases and plot them as well. Let's check on the oscilloscope the collector and base signal on both Q1 and Q2 transistors and plot, and graph the waveforms.

2.4

Apply a high frequency signal on the input which period of time is not smaller than t, impulse-time.(Ex. 2.2) Measure the t_r transition time on both outputs. With the help of correlation (8) lets check if the measured results match the calculated transition times in case of U_{out2}. Perform the measurements from Figure 3., considering 10%-90% signal levels.

Facultative exercise:

2.5

Perform the measurements in exercise 2.2 with the change of C_2 = 22pF. With the help of correlation (6) check if the measured times match the calculated ones.

2.6

Perform the measurements in exercise 2.2 with the change of C_2 = 68pF and C_3 = 150pF. With the help of correlation (6) check if the measured times match the calculated ones.

3.0 Schmitt-trigger (ST) circuits

ST is also mostly used for signal conditioning, which special attribution is that at a given value of the input voltage – at the starting (comparating) level – the output voltages increases rapidly. At this moment the circuit flips from one of it's state to the other. If we decrease the input voltage than compared to the comparating level before the will flip back to it's original state at a lower voltage.

The absolute value of the 2 "flipping" voltage differences: $U_h = | U_1 - U_2 |$

It's also called the hysteresis voltage (Figure 5.). Because of the hysteresis the circuit is less sensitive to noises because, it doesn't react to the changes in the input voltage at U_h interval.

Other than signal conditioning the STs are also used for sinus and triangle waves "conversion" to square waves and to discharge the bounce effect in case of push-buttons.

The basic multivibrator and trigger circuits are made from 2 transistors, which funtion in opposite mode. The time of the closing-saturation switches is given by the value of the timer parameters and the charge-holding factors of the transistor in use.

3.1 Transistor trigger circuit:

You can see the figure of the basic trigger circuit (which you can find in the measuring box) on Figure 4. All the elements can be found in the box except C_1 capacitor.

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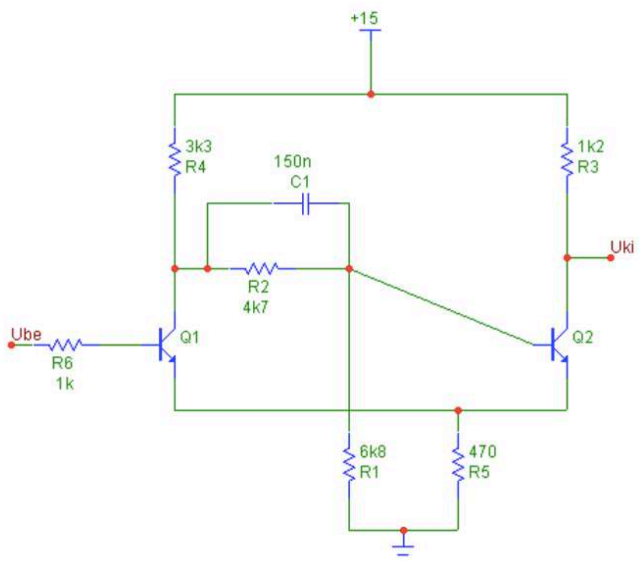


Figure 4.

Figure 5 illustrates the transfer function of the circuit.

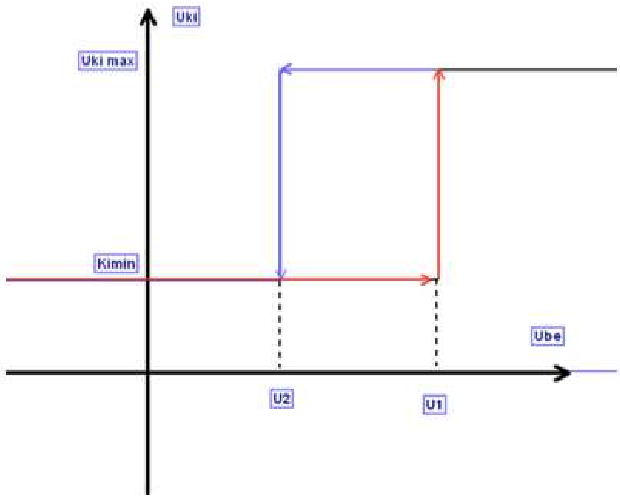


Figure 5

On the figure the 2 transistors transfer function are graphed alternately, both in the conducting and the closing zone. Supposing that the transistor in the conducting state reaches the saturation zone, U_1 voltage is approx.: $U_1=U_E+U_{IN}$ (9)

Where U_E unmerged emitters DC voltage and U_{IN} base-emitter opening voltage approx. 0.6V. The value of U_E depends on which transistor (Q1 or Q2) is in saturation zone. The voltage of the unmerged emitters, is equal to the divided supply voltage by R_3,R_4 and R_5. If the input voltage is lower than U_1 than Q1 is closed, and the high voltage on its collector goes to Q2's base and drives it into saturation. Using this we get almost the same value as U_E this will be $U_{out\ min}$ value on Figure 5. With increasing the input voltage and reaching U_1 , Q1 opens and it's collector voltage drops, and Q2 closes. In this moment on the output we can measure a voltage close to the supply voltage ($U_{out\ max}$). For defining U_2's "flipping" voltage, we need to analyze the circuit more in depth. For this we have to consider that during operation, Q2 usually doesn't reach the saturation zone, it usually working on the edge of the normal active zone, and also don't forget the fact that because R3 > R4 , when Q2 is on than U_E is bigger than when Q1 is on. Because of this the value when Q1 turns on happens at different values of U_{IN} . $U_H=U_1-U_2$ U_H, hysteresis voltage depends on the charge-holding of the transistor's and on the R_2 x C product as well. The result of these effects is that U_1 and U_2 becomes level dependent, it means it depends on that, if U_{IN} only reaches U_1 or exceeds it. The C capacitor – depending on its value – speeds up the flipping process.

3.1.1

Apply +15V supply voltage on the circuit, but do not insert C into the circuit. Put 0V on the input (connect it to the ground), than with a DC voltmeter measure the DC voltage on the transistor's emitter, base and collector.

After this, put +15V 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

Apply a 2 kHz sinus signal from the function generator and connect its output 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 and check if it matches the one in correlation (9). Measure the resulting square wave's k, duty cycle (correlation (3)). Increase the input signal's amplitude to its double, and measure the duty cycle again. Put a huge signal on the input that yet not distorts the output signal, and measure the duty cycle again. Graph all 3 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 not start the circuit. After this insert the accelerator capacitor (C_1) into the circuit. Then graph the time functions of U_{IN} and U_{OUT}

3.1.2

Hysteresis examination

Apply a 2 kHz sinus wave and connect it on the oscilloscope, also on it's channel responsible for the horizontal diversion. The output square wave should be connected to the channel responsible for the vertical diversion. Put the oscilloscope into X-Y mode (turn down the time base), now the output response signal appearing on the screen is depending on the input voltage not the time. In case of right amplification settings, you can see the hysteresis curve, which we should now also plot.

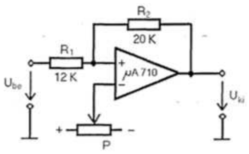
Attention!

Both channels should be in DC mode, and also before we connect any signals on the oscilloscope let's set the electron beam to the origin.

Facultative exercise:

In the examined circuit, uA 710 analog comparator is a basic operational amplifier. The special thing about this circuit is that its output is TTL compatible, so typically it gives 3.6V positive voltage. Due to this the uA 710 analog comparator is a very simple analog-digital converter. The comparator needs a double voltage supply with the values, +12V and -6V. The maximum input voltage is ± 5V , so do not exceed this value during the measurement!

The comparator-IC Schmitt-trigger circuit can be seen on Figure 6.



6. ábra

All the elements can be found on the measuring board, you should only connect the P-potentiometer with the negative output. In the circuit, R_2 performs a positive feedback with this the switching is very quick, with the speed of the integrated operational amplifiers, signal-following slope. The resistors in use can give the hysteresis voltage with a close approximation:

$$U_H = \frac{2R_1}{R_1 + R_2} U_{ki\,max} \qquad (10)$$

where $U_{out\,max}$ the right signal magnitude corresponding to the TTL level. We connect the 2 ends of the P potentiometer to the supply voltage (on the panel) so with moving the slider on the potentiometer we get ± DC voltage. After we put this voltage to the comparators input, we are able move the “flipping” levels.

3.2.1

Apply supply voltage on the comparator, and connect the (-) input to the P-potentiometer. First connect the input sinus wave to the oscilloscope and set it’s amplitude to level yet not increases the maximum applicable ± 5V. Let the frequency be approx. 2kHz. Connect the slider of the potentiometer to the voltmeter, and the common point of the voltmeter should be connected to the ground. With this we can measure the amplifiers DC voltage and its polarity on the (-) input. Set the potentiometer to a level the signal is yet recognizable. Now, measure the duty cycle and the DC voltage. Find the other end value with the potentiometer and measure the duty cycle and the DC voltage again. Measure the magnitude of the output signal ($U_{ki\,max}$).

3.2.2

Graph the hysteresis curve, with the help of Ex. 3.1.5.

3.2.3

Let’s go back to the settings used in Ex. 3.2.1. Find the signal with the potentiometer. Graph the waveforms in case of 2kHz, 100kHz and 500kHz frequencies. At 100kHz and 500kHz let’s measure the signal’s transition and deceleration times, with the method used before.