



POWER DEVICES AND SYSTEMS LABORATORY

Exercise 7^C

Design and Prototyping of a Switched-Mode Power Converter

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Łódź 2014

Contents

B Exercise Introduction	5
1. Exercise Aim and Plan.....	5
C Experiment	7
2. Setting the Prototype Working, Tests and Measurements	7
2.1. Assembly check – Task 17	7
2.2. Pulse wave generator – Task 18	9
Controller start-up	9
Proper operation of the generator	10
Pulse wave parameters measurement.....	11
Report completion.....	12
2.3. Power supply block – Task 19*	13
General proper operation test.....	13
Rectifier filter.....	14
Controller supply filter	14
Report completion.....	15
2.4. Circuit start-up with the target load – Task 20**	17
2.5. Chopper with a halogen lamp – Task 21.....	19
Assembly documentation.....	19
Transistor switch operation	19
Voltage chopper operation	19
2.6. Conclusion	21
Measurement termination	22
Report completion.....	22
E Information	23
3. Expected Report Contents.....	23
4. Required Knowledge.....	23
4.1. Prerequisites	23
4.2. Test scope.....	23

Exercise Introduction

1. Exercise Aim and Plan

In this part of the exercise, the prototyped circuit will be set working and tested. This manual contains detailed instructions how to do it and how to fill in the last part of the report. All actions, such as assembly check, measurements, calculations, results elaboration, report fill-in, should be taken within the scope and in the sequence given in the manual.

Tasks applying only to the full option have been marked with one asterisk, while those applying only to the basic option, with two asterisks. In addition, some particular steps may only apply to a given option or to a given oscilloscope type. This is indicated in frames, usually at the beginning of a given step (or sub-step).

In the case of particular steps (and not whole tasks), an asterisk means they are not obligatory, as usual (hence it does not mark an exercise option).

Testing the light dimmer comprises two stages. First, the prototype will be checked for:

- PCB connection correctness,
- lack of alarming symptoms in operation (e.g. too high a voltage, too high a current consumption or even a short-circuit etc.),
- pulse wave generator correct operation, determining the key numerical parameters on this occasion.

After proper operation of the controller is ensured, the circuit will be complemented with the target load—the halogen lamp, and will be tested for:

- transistor switch operation, determining the switching time on this occasion,
- agreement between waveforms in the power circuit with the DC voltage chopper operating principle.

To perform the above measurements, laboratory stands are available equipped with:

- a transformer with a breaker switch,
- a halogen lamp,
- a power supply board for the basic option,
- any multimeter,

- a Hameg HM1507, Tektronix TDS224 or Tektronix TDS1002B oscilloscope.

In the course of measurements or afterwards, based on oscilloscope images recorded, basic parameters describing circuit operation should be determined. Print-outs of oscilloscope images as well as of the photograph taken should be enclosed with the report.

In the report, in appropriate fields, it should be stated whether the individual design requirements have been met. A positive or negative answer is not the main criterion for exercise evaluation. They should be considered as guidelines for a hypothetical prototype modification that would follow in the case of real design.

2. Start-up, Tests and Measurements of the Assembled Prototype

2.1. Assembly check – Task 17

1. Leave the prototype unconnected to the power supply nor to the lamp (both terminal blocks free) and do not mount the integrated circuit in its socket.
2. Turn on the multimeter and set it to the circuit continuity check mode (sound beep symbol).
3. FULL OPTION Using the multimeter, check (by performing measurements on the component side, not the solder side) the connections in the input AC loop:
 - one of the terminals of the u_{sec} input to one of the “~” terminals of the B₁ bridge,
 - the other terminal of the u_{sec} input to to the other “~” terminal of the B₁ bridge,
 - the “+” terminal of the B₁ bridge to the anode of the D₁ diode.

Confirm accomplishment by putting a ✓ mark in the appropriate box in the report.

4. Using the multimeter, check (by performing measurements on the component side, not the solder side) the connections in the power loop:
 - the positive end of the u_i voltage (J₂ terminal block or B₁ bridge depending on exercise option) to the positive end of the receiver (J₃ terminal block),
 - the positive end of the u_i voltage (J₂ terminal block or B₁ bridge) to the cathode of D₃,
 - the negative end of the receiver (terminal block) to the drain of the transistor,
 - the negative end of the receiver to the anode of D₃,
 - the source of the transistor to the ground of the u_i voltage (terminal block or bridge).

Confirm accomplishment by putting a ✓ mark in the appropriate box in the report.

5. Check (by performing measurements on the component side, in the IC socket, according to the pin arrangement proper for the 555 IC—see the data sheet) the correctness of supply connection to the integrated circuit:
 - the positive end of the U_{CC} voltage (J₂ terminal block or D₁ diode, possibly through the R₂ resistor if it has been used in the full option) to the VCC pin,

- the negative end of the U_{CC} voltage to the GND pin.

Confirm accomplishment by putting a ✓ mark in the appropriate box.

6. Check (by performing measurements on the component side, in the IC socket) that appropriate pins of the integrated circuit have been shorted:
 - VCC with RST,
 - THR with TRIG.

Confirm accomplishment by putting a ✓ mark in the appropriate box.

7. Set the multimeter to the resistance measurement mode (Ω). Measure (on the component side, not the solder side) and put in the report resistance values proving the correctness of connections adjacent to the integrated circuit:
 - between the OUT pin and the gate of the transistor, which should be equal to R_6 (see Task 12);
 - between the DCH and VCC pins, which should be equal to R_3 and to R_3+R_4 for extreme settings of the R_4 potentiometer;
 - between the DCH and THR pins, which should be equal to R_5 and R_5+R_4 for extreme settings of the R_4 potentiometer.

If resistances are correct, put a ✓ mark in appropriate boxes.

2.2. Pulse wave generator – Task 18

Attention!

An appropriate number of wires without plugs, wires with a plug on their one end only and alligator clips are available in the laboratory. They should be used to connect the circuit board to power supplies and to the receiver. It is forbidden to destroy wires by cutting their plugs off!

After measurements are completed, all the elements of the measurement set-up (including wires) should be left in the state they were found at the beginning!

Controller start-up

1. Place the U_1 integrated circuit in its socket, taking special care of its orientation according to the board design and to the pin arrangement schematic (see data sheet). Leave the J_3 terminal block free.

Improper integrated circuit orientation may cause it to be damaged!

2. Supply the controller:
 - (a) use a power supply with at least one adjustable section; turn all the knobs of the power supply switched off down to zero (extreme counterclockwise position); if a multiple-section power supply is used, set it into the independent section operating mode (two buttons in the middle of the front panel whose function is described on the panel above them);
 - (b) **FULL OPTION** connect one adjustable section of the power supply to the J_1 terminal block, inserting a multimeter set to the DC milliammeter mode in series;

BASIC OPTION connect one adjustable section of the power supply to the J_2 terminal block so that to supply the controller block (not the power circuit), inserting a multimeter set to the DC milliammeter mode in series;
 - (c) **BASIC OPTION** using another multimeter, set in the circuit continuity test mode, ensure that the direction of the supply voltage is correct, i.e. its positive end has been connected to the VCC pin of the integrated circuit and its negative end—to the GND pin;

Improper supply voltage direction will cause the integrated circuit to be damaged!

- (d) turn on the power supply.
3. State that there are no symptoms of erroneous assembly:
 - (a) calculate the expected maximum average current drawn from the supply $I_{\text{sup(av)max,est}}$:
 - **FULL OPTION** as the sum of the maximum supply current of the U_1 integrated circuit $I_{\text{CC(max),U1}}$, the maximum average current drawn by the auxiliary circuitry of the generator $I_{\text{R3(av)max}}$ and the estimated average current delivered to the T_1 transistor's gate $I_{\text{G(on)av}}$, see Task 6;
 - **BASIC OPTION** as the quotient of the charge drawn from the C_3 capacitor during a single period and the duration of this period T_d , see Task 9;
 put the result in the report;

During and after execution of the following sub-step, the current drawn from the supply and indicated on the milliammeter, for the worst case R_4 potentiometer setting, should not be considerably greater than the value determined above. If anything else is observed, turn off the power supply and check for correct connections in the control circuit.

If during voltage adjustment the current limiter turns on, first bring the voltage down to zero and only then increase the current limit, however, still having in mind the above remark.

- (b) slightly increase the threshold current of the current limiter [the *CURRENT* knob] so that the red indicator goes out and slowly set the approximate ($\pm 0,1$ V) maximum integrated circuit supply voltage $U_{CC(max)}$ determined in the course of design process (as used in Task 10).
- (c) put in the report the average supply current indicated by the multimeter (the maximum one, i.e. for the worst case R_4 potentiometer setting) $I_{sup(av)max,meas}$ and put a “+” sign in the box below if it proves proper operation of the circuit.

Proper operation of the generator

In order not to waste time, concurrently with steps 4–5, steps 6–8 should be executed.

4. Turn on the PC and after log on is completed, turn on the oscilloscope.
5. Following the procedure described in an additional manual available at the laboratory stand, start the oscilloscope communication application and set up the connection to the PC.
6. Configure the oscilloscope:
 - (a) [HM1507] Turn on the digital mode of operation [*Stor On* until a beep; the digital mode is on when one of the *Stor. Mode* is lit] (remember that this oscilloscope’s buttons realise various functions depending on whether they are pushed short or long); set the standard screen refresh mode [*Stor. Mode*: RFR].
 - (b) For both channels 1 and 2:
 - show the waveform [TDS] [*CHx Menu*], [HM1507] [*Dual*],
 - choose DC coupling [TDS] [*Coupling*: DC], [HM1507] [*AC DC* next to the channel input connector; the current state (= standing for DC, ~ for AC) is indicated at the bottom of the screen next a channel’s symbol Y1/Y2],
 - make the 1:10 probe attenuation taken into account [TDS1002B] [*Probe*: 10X, Voltage] [TDS224] [*Probe*: 10X], [HM1507] [*AC DC* until a beep; the attenuation is taken into account when the probe symbol \ddagger is displayed next to a channel’s symbol Y1/Y2],
 - turn off waveform inversion [TDS] [*Invert*: Off], [HM1507] [*Inv* until a beep; invert mode is indicated by a horizontal bar above a channel’s symbol Y1/Y2];
 - (c) configure triggering [TDS1002B] [*Trig Menu*], [TDS224] [*Trigger Menu*] by selecting:
 - rising edge triggering [TDS1002B] [*Type*: Edge], [*Slope*: Rising], [TDS224] [*Edge/Video*: Edge], [*Slope*: Rising], [HM1507] [*NM AT* without a beep; the setting is indicated with the \lrcorner or \llcorner symbol at the top of the screen after the “TR:” symbol],
 - DC coupling [TDS] [*Coupling*: DC], [HM1507] [*Trig. Mode*: DC],
 - channel 1 as the triggering source [TDS] [*Source*: CH1], [HM1507] [*Trig*: CH I],
 - automatic mode [TDS] [*Mode*: Auto], [HM1507] [*NM AT* until a beep; the automatic mode is indicated by the *NM* indicator off].
7. Observe the waveforms at the output of the generator and at the C_4 capacitor:
 - (a) connect the grounds of both voltage probes to the circuit’s ground (P_0 connector);
 - (b) [TDS1002B] set the attenuation switch on the probes’ bodies to 10X.
 - (c) connect the hot tips of the probes so that the u_g voltage (generator’s output) is observed in channel 1 and the u_{C_4} voltage (across the C_4 capacitor) is observed in channel 2;
 - (d) use the automated setting function to obtain a stable image on the oscilloscope [*Autoset*].
8. In case of an apparent need, modify the oscilloscope settings so that all the waveforms are displayed stably in the screen in a way enabling discriminating and labelling them in a black-and-white print-out:
 - (a) trigger level [*Level*];
 - (b) time axis, so that waveform periodicity can be seen:

- time base [*Sec/Div*], [*Time/Div.*],
 - trigger moment position [*Horizontal Position*, indicated by the arrow above the graticule], [*Ptr.*], [*X-Pos.*];
- (c) voltage axis, so that the waveforms, from their zero level to their peak value, does not extend beyond the screen and that their amplitude can be optimally seen:
- channel gain [*Volts/Div*],
 - zero level position [*Vertical Position*, indicated by an arrow with the channel number left to the graticule], [*Y-Pos. x*, indicated by the \perp mark].
- The above setting should be appropriately modifier also at the further stages of the exercise if the requirements given above become no longer met.
9. If the observed waveforms agree with expectations (see simulation results obtained in Task 11 or waveforms given in Manual 7^A, Chapter 5), put a “+” sign in the next box in the report.
10. Download the oscilloscope image:

- click *Get Screen*,
- click *Save As* and save to a file using a lossless format (not JPG),
- the oscilloscope image can also be copied to an OpenOffice Writer document using the *Clipboard* button but in this case first paste it into the Paint application, copy it again from there and only then paste to the text document;

- create a new *Notes Sheet* type sheet or a new OpenOffice Writer document,
- drag (*Data* ► *Display* ► *Screen Copy* in the side panel) and drop it in the created sheet or the document;

- click *Read*,
- click *WMF-Export* and save to a file (*Save as WMF*) or paste to an OpenOffice Writer document through the clipboard (*Copy to Clipboard*).

Pulse wave parameters measurement

11. Hide the u_{C4} waveform:
- [*CH2 Menu*],
 - [*CH I*].
12. Zoom in the u_g waveform so that its 1 to 2 full periods can be seen (not more; see step 8).
13. For 3 settings of the potentiometer: $k = 0$, $k = 1$ and $D \approx 0,5$ (without too much accuracy):
- (a) for $k = 0$ and $k = 1$, check roughly if the duty cycle conforms with expectations (see simulation results obtained in Task 11);
- (b) determine and put in the report the parameters of the waveform—the pulse width t_p and the frequency f_p (do not calculate the precise duty cycle D nor ΔD and Δf_p deviations now):
- automated measurement on the oscilloscope (the result will be displayed in the oscilloscope image) [*Measure*], set in any two fields: *CH1 Pos Width* for t_p measurement and *CH1 Freq* for f_p ;
 - automated frequency measurement on the oscilloscope [*Measure*, set in any field *Source: CH1, Type: Freq*], pulse width measurement using cursors [*Cursor* ► *Type: Time, Source: CH1*, cursors are moved with the *Cursor x = Vertical Position CHx* knobs];
 - automated frequency measurement in the SP107E application (*Freq.* readout from the *Automeasurement* window), pulse width measurement using cursors (*dt* readout from the *Cursor* window);
- (c) put the multimeter indication, which is the average supply current $I_{\text{sup(av)}}$, in the report;

- (d) for $k = 0$ and $k = 1$, record the oscilloscope image.
14. By moving the oscilloscope probe—carefully not to cause a short-circuit of neighbouring leads—check whether the pulse wave appears at the gate lead of the T_1 transistor. If so, put a “+” sign in the appropriate box in the report.
15. Turn off the power supply and disconnect it from the board. Disconnect the multimeter.

Report completion

This part of the exercise may be carried out after the class.

16. Fill up the result table:
- based on t_p and f_p results, calculate the duty cycle D ;
 - calculate the deviations from the required value ΔD for both extreme values of the duty cycle [Manual 7^A, formula (5.10)];
 - state whether the deviations are below the admissible limit of $\pm 0,05$ and put the “+” or “-” sign accordingly in the box below;
 - for the $D \approx 0,5$ case, calculate the relative deviation from the required value $\Delta f_p / f_p$ [Manual 7^A, formula (5.11)];
 - state whether the deviation is below the admissible limit of $\pm 20\%$ and put the “+” or “-” sign accordingly in the box below;
 - state whether $I_{\text{sup(av)}}$ results show that $I_{R3(\text{av})}$ values stay below the required limit and whether the tendency of changes agrees with simulation results obtained in Task 11—it can be assumed that the current drawn by the transistor’s gate is much lower than other components of the $I_{\text{sup(av)}}$ current, hence it is sufficient to take into account the supply current of the U_1 integrated circuit $I_{\text{CC(max),U1}}$ (see Task 6 for full option or Task 9 for basic option); put the “+” or “-” sign accordingly in the box below.
17. Comment on results obtained in this task. Formulate general conclusions concerning any necessary modifications (e.g. increasing the C_4 capacitance etc.) if results demonstrate such a need.

2.4. Circuit start-up with the target load – Task 20**

1. Set the minimum duty cycle with the potentiometer R_4 .
2. Bring the supply to the board:
 - (a) plug the transformer to the mains;
 - (b) ensure that the transformer is off which is indicated by the red LED next to the screw terminal at the transformer's output turned off;
 - (c) connect the u_{sec} voltage from the transformer's output to the SUP terminal block on the power supply board;
 - (d) connect the voltages from the output of the power supply board to appropriate sockets of the J_2 terminal block on the prototype board:
 - the ground (marked with \perp on the power supply board),
 - the control circuit supply u_{CC} (marked as CC or with = on the power supply board),
 - the power circuit supply u_i (marked as IN or with $\wedge\wedge$ on the power supply board);
 - (e) using a multimeter set to the circuit continuity check mode ensure that:
 - the ground from the power supply board is connected to the GND pin of the integrated circuit U_1 ,
 - the control circuit supply is connected to the VCC pin of the integrated circuit U_1 ;
 - (f) still leave the J_3 terminal block free.
3. Supply the circuit:
 - (a) turn on the transformer with the switch located next to it in the lamp base; the red LED next to the screw terminal at the transformer's output should light up;
 - (b) using a multimeter set to the DC voltage measurement mode state whether the U_{CC} voltage is of the order of the $U_{CC(max)}$ and $U_{CC(min)}$ values estimated in Tasks 7 and 9; if not, turn off the transformer and ask the teacher for help;
 - (c) turn off the transformer.
4. Calculate and put in the report the expected average load current at maximum duty cycle D .
The load current without the chopper (or at $D = 1$) would have the form of a full-period-rectified sine wave. The average value of this waveform is

$$I_{o(av)max} = I_{o(av)} \Big|_{D=1} = \frac{2}{\pi} I_{o(m)} \quad (2.3)$$

where $I_{o(m)}$ is the amplitude of the current, the upper estimate of which has been found in Task 2. It can be demonstrated that the final average value (after considering the chopper action) will be equal to

$$I_{o(av)} = D I_{o(av)max} \quad (2.4)$$

Improper execution of the following step may result in damaging the multimeter!

5. Connect the halogen lamp to the J_3 terminal block, inserting a multimeter set to DC ammeter mode in series. Choose a measurement range and a socket as appropriate for the current value calculated in step 4.

Before proceeding with the next step, multimeter connection must be checked by the teacher.

6. Check if symptoms of incorrect circuit operation are not observed:

After executing the following sub-step, the current indicated by the ammeter should not be greater than the value estimated above. If anything else is observed, turn off the transformer and check the connections in the power circuit.

- (a) turn on the transformer;
- (b) state whether the lamp lighted;
- (c) state whether for the maximum duty cycle the average current value displayed on the multimeter approximately agrees with the expected one (consider that the latter was obtained from an overestimated amplitude);
- (d) check whether it is possible to change light intensity using the R_4 potentiometer;
- (e) if the circuit operates properly, put the measured average load current for D_{\max} to the report and put a “+” sign in the next box;
- (f) turn off the transformer.

2.5. Chopper with a halogen lamp – Task 21

Assembly documentation

- Using the camera available in the laboratory, make a photograph of the assembled prototype (component side of the board plus facultatively the entire measurement set-up) containing the date and time of taking. Copy the picture to the team's account.

While the picture is being copied, other team members should already go on with next steps.

Transistor switch operation

Due to the risk of accidental short-circuiting which may result in transistor destruction, take special care when switching voltage probes, preferably after turning off the transformer!

Do not attach probes to the transistor's leads as this would damage the plastic tip covers through melting due to high temperature!

- Determine whether the transistor is switching properly with the $f_s = f_p$ frequency:
 - attach the voltage probes so that to measure the u_{GS} voltage of the T_1 transistor in channel 1 of the oscilloscope and its u_{DS} voltage in channel 2 (according to the electrical schematic, probes may be attached to appropriate leads of the R_6 or R_7 resistors, or the D_3 diode);
 - on the oscilloscope, show the channel 2 waveform TDS [*CH2 Menu*], HM1507 [*Dual*];
 - turn on the transformer;
 - use the automated setup function [*Autoset*] to adjust display settings;
 - in case of an apparent need, adjust oscilloscope settings using functions listed in step 2.2/8;
 - if waveforms prove proper transistor operation as a switch, record the image and put a "+" sign in the next box and give a justification.
- Set the maximum duty cycle.
- On the oscilloscope, set:
 - time base and trigger moment position enabling determining the transistor's rise time TDS [*Sec/Div*], [*Horizontal Position*], HM1507 [*Time/Div., Ptr.*]
 - channel gains and zero level positions appropriate for optimal observation of the waveforms (from their valley to peak value, disregarding possible overvoltages) TDS [*Volts/Div.*], [*Vertical Position*], HM1507 [*Volts/Div.*], [*Y-Pos. I/II*].
- By trial and error, freeze the image [TDS *Run/Stop*; HM1507 *Hold*] in the vicinity of the input voltage u_i sine wave which will be reflected in a maximum u_{DS} voltage value in the blocking state. Record the oscilloscope image.

Voltage chopper operation

- Display the u_i and u_o voltages on the oscilloscope and determine whether the chopper operates properly in the T_d period's scale:
 - turn off the transformer;
 - switch the probe measuring the u_{GS} voltage so that it measures the u_i voltage now;
 - turn on the transformer;
 - modify the oscilloscope settings:
 - select triggering with the mains voltage TDS1002B [*Trig Menu ▶ Source: AC Line*], TDS224 [*Trigger Menu ▶ Source: AC Line*], HM1507 [*Trig. Mode: ~*],

- set the time base such as to observe periodic operation with respect to the T_d period [TDS] [Sec/Div], [HM1507] [Time/Div.],
 - [TDS] set waveform positions at close levels at the bottom of the screen [Vertical Position],
 - [HM1507] set waveform positions at close levels at the middle of the screen [Y-Pos. I/II],
 - change channel gains so that both waveforms are optimally zoomed with the same gain [Volts/Div],
 - [TDS] activate mathematical functions [Math Menu; when the result is displayed, it is indicated with a zero-level arrow with the M symbol left to the graticule],
 - [HM1507] invert the u_{DS} waveform [Inv until beep; when inversion is activated, this is indicated with a horizontal bar above the channel symbol Y2 at the bottom of the screen];
- (e) [HM1507] save the u_i voltage waveform in the oscilloscope's memory [press *Reference* multiple times until only the channel I indicator is lit, then press *Reference* once until beep];
- (f) obtain the output (lamp) voltage waveform u_o as the difference of $u_i - u_{DS}$:
- [TDS1002B] select *Operation: -*, *Sources: CH1-CH2*,
 - [TDS224] select CH1-CH2,
 - [HM1507] press [Add] (remember that a double bar denotes the necessity to push both adjacent buttons simultaneously; when the sum function is activated, this is indicated with the "+" sign between channel symbols Y1 and Y2 at the bottom of the screen);
- (g) on the oscilloscope:
- [TDS1002B] set the same gain for the processing result as for channels 1 and 2 [select *Vertical Scale*, use the large knob in the top left corner of the front panel to adjust],
 - [TDS] hide the u_{DS} waveform [CH2 Menu],
 - set the zero levels of the u_i and u_o waveforms enabling observation of the correlation between them [TDS1002B] [CH1 Vertical Position], [Math Menu ▶ Position, adjust using the large knob in the top left corner], [TDS224] [CH1 Vertical Position, CH2 Vertical Position] [HM1507] [Y-Pos. I/II];
- (h) if waveforms prove proper circuit operation as a voltage chopper (see Manual 7^A, Sub-chapters 3.1 and 3.2), record the image.
7. Observe the operation of the chopper in the T_s period's scale:
- (a) re-configure the oscilloscope:
- [HM1507] hide the u_i waveform coming from the memory [press *Reference* several times until all indicators go out],
 - set a time base enabling observation of the u_o voltage applied across the lamp as the chopped waveform of u_i (with a fairly large number of T_s periods) [TDS] [Sec/Div; [HM1507] [Time/Div.];

The T_d and T_s periods are not mutually synchronized. Due to this fact, it will be necessary to temporarily freeze the display [TDS] [Run/Stop; [HM1507] [Hold] during execution of the following sub-steps.

- (b) adjust the trigger moment position [TDS] [Horizontal Position; [HM1507] [Level] in such a way that a segment of the rising edge of the u_i sine wave can be seen;
- (c) check whether the duty cycle of the output voltage u_o is changed as expected together with light intensity when the R_4 potentiometer is adjusted (without determining any numerical values);
- (d) set the duty cycle to approx. 0.5 (without too high an accuracy);
- (e) [HM1507] de-activate the sum function [Add], save the current u_i voltage waveform in the oscilloscope's memory [Reference] and then activate the sum function back again [Add];

- (f) if waveforms prove proper circuit operation as a voltage chopper (see Manual 7^A, Sub-chapters 3.1 and 3.2), record the image and put a “+” sign in the next box and give a justification;
- (g) HM1507 de-activate the sum and invert functions [*Add, Inv*] and hide the u_i waveform coming from the memory [*Reference*].

Report completion

This part of the exercise may be carried out after the class.

- 8. State whether the requires switching speed of the transistor has been achieved:
 - (a) from the oscilloscope image recorded in step 2.5/5, read out (approximately) and put in the report the rise time t_r (see Exercise 3^A);
 - (b) calculate and put in the report the relative deviation $\Delta t_r/t_r$ from the value estimated in Task 12;
 - (c) calculate and put in the report the relative deviation $\Delta t_r/t_r$ from the value required;
 - (d) if the deviation from the required value is below the limit of $\pm 50\%$, state that the requirements are met and put a “+” sign in the box below.

2.6. Conclusion

Measurement termination

1. Turn off the transformer.
2. Disconnect the set-up and restore its initial state making sure that:
 - two wires without plugs have been left connected to the screw terminal at the transformer's output,
 - two wires without plugs have been left connected to the screw terminal at the input of the lamp,
 - BASIC OPTION the triple coloured wire has been left connected to the triple terminal block at the output of the power supply board.

Report completion

This part of the exercise may be carried out after the class.

3. Elaborate the recorded oscilloscope images:
 - (a) print out the saved files;
 - (b) clearly label the waveforms;
 - (c) correlate the images of the u_i and u_o waveforms recorded in the T_d period's scale [step 2.5/6(h)] and in the T_s period's scale [step 2.5/7(f)] by marking in the first the location of the latter based on the values of the u_i waveform;
 - (d) number the images assigning each of them a subsequent attachment number (or one attachment number with subsequently numbered graphs if there are multiple graphs on one sheet);
 - (e) enclose the print-outs to the report, writing in the attachment/graph numbers in appropriate fields.
4. Print the picture of the circuit taken and attach it to the report, writing in the attachment number in the appropriate field.

3. Expected Report Contents

The report should be handed in in the paper form, prepared on a standard form filled in by hand. The form is available on the course web site. The report should contain results obtained after completing the tasks described in Chapter 2, according to the consecutive fields of the form. Attachments pointed out in the form should be enclosed in the paper form.

4. Required Knowledge

4.1. Prerequisites

Recall the information about topology (block diagram and electrical schematic) as well as operating principle of the prototyped circuit, given in Manual 7^A, Chapter 3. This knowledge will not be checked, however, lack of orientation may cause problems with completing the exercise.

4.2. Test scope

Not applicable.