Exercise 1

AC voltage and current measurements

Manual for the laboratory exercise

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1. Aim

The aim of the exercise is to get acquainted with the AC voltage and current measurements on example of voltage regulators (linear and switched mode) and to improve students' skills in using a digital oscilloscope for measuring time-varying signals, including various oscilloscope triggering modes and acquisition methods.

2. Theory

- Basic voltage regulator circuit (half-wave, full-wave rectifiers)
- Basics of digital oscilloscope operation, AC voltage and current measurements, triggering methods, differential measurements
- Principals of operation of the oscilloscope probe, compensation of the probe
- RMS value measurement, difference between AC and DC input coupling, parameters of time-dependent signals (RMS value, average value, etc.)

3. Setup description

The laboratory setup includes a printed circuit board with the laboratory model, an AC power supply, a digital oscilloscope with two probes, a function generator (Rigol DG1022), a multimeter (Agilent U3401A), BNC cables and adapters.

4. Block diagram

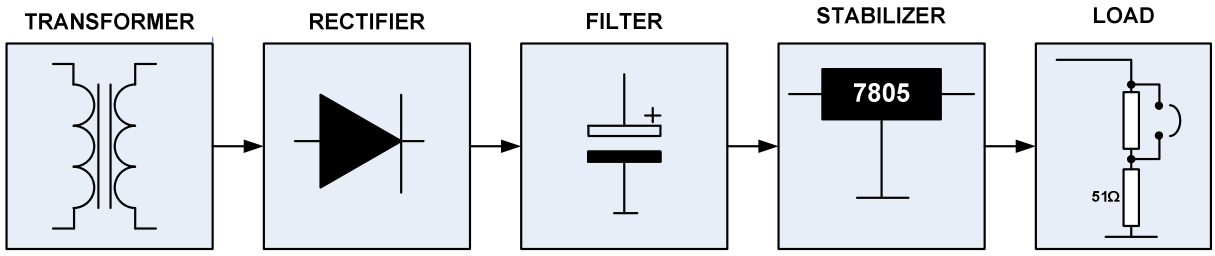

Fig. 1. Block diagram of a half-wave linear voltage regulator.

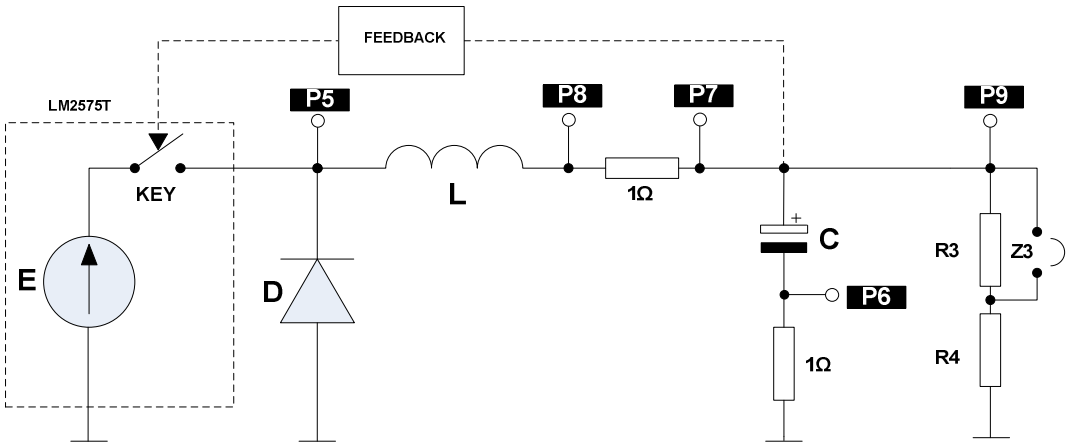

Fig. 2. Schematic of a switched mode voltage regulator.

5. Exercise preparation

1. Sketch a schematic diagram of a voltage regulator composed of a diode, a filter and a 3-terminal integrated voltage regulator. In the circuit mark the points and draw how to connect the appropriate instruments (multimeter or oscilloscope) to observe:
    a. the voltage after a diode
    b. the capacitor charging current
    c. the load current.

    In all three cases sketch the expected signals, assuming that the oscilloscope with two channels and two oscilloscope probes are available. Use the schematics presented in Fig. 3.
2. Figure 2 presents a simplified schematic diagram of a switched mode step-down voltage regulator. In the circuit mark the points and draw how to connect the appropriate instruments (multimeter or oscilloscope) to observe:
    a. switching voltage
    b. output voltage
    c. charging and discharging currents of the output capacitor C
    d. current of inductor L.

    Assume that an oscilloscope with two channels and two oscilloscope probes are available.

6. Measurement plan

Note:

Before performing any measurements, note the attenuation factor of the oscilloscope probe and corresponding oscilloscope settings. Calibrate the probe by connecting it to the oscilloscope calibrator output and perform adjustment if necessary.

Half-wave voltage regulator

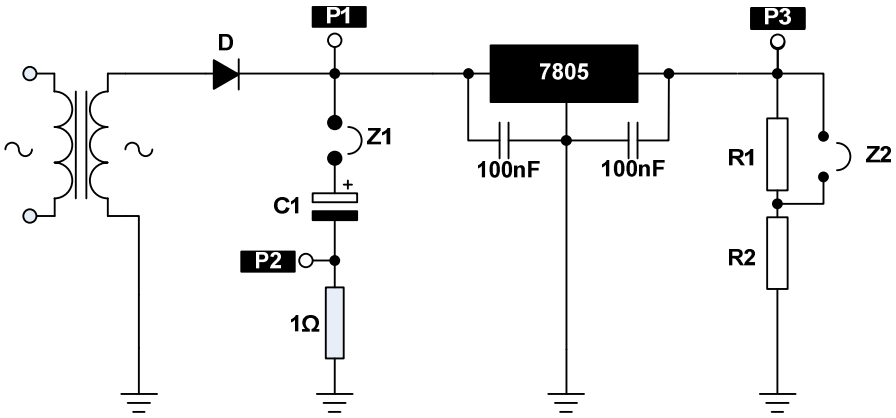

Fig. 3. Schematic of a linear half-wave voltage regulator.

1. Using the jumper Z1 connect a filtering capacitor. Using the multimeter measure the output voltage (at point P3) for two cases: jumper Z2 closed and opened (use both ACV and

DCV multimeter settings). For each configuration of the Z2 jumper calculate the load current (see example table in the Data processing section).

2. For a given load resistance observe the signal after the diode (at point P1) when a filtering capacitor is disconnected (Z1 is removed). Sketch the shape of the signal in your notebook, including time and amplitude scale and important values of the waveform.
3. Connect the filtering capacitor by inserting the jumper Z1, observe (using the oscilloscope) and sketch in the notebook the voltage on the capacitor (at point P1) and the capacitor charging/discharging current (at point P2). Repeat this observation for another available load resistance. Try to observe the signal using the averaging option of the scope (Acquire -> Average).
4. Using the multimeter measure the RMS value of pulsating voltage after the diode (at point P1) and the stabilized output voltage (at point P3) with the capacitor connected.

Switched mode voltage regulator

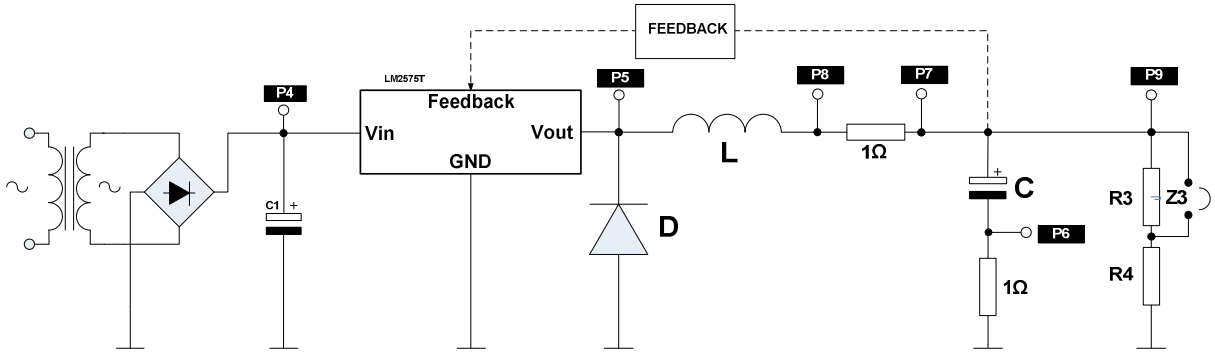

Fig. 4.Simplified schematic diagram of the switched mode voltage regulator.

1. Measure the output voltage using a multimeter (point P9), for two cases: jumper Z3 closed and opened (use both ACV and DCV multimeter settings). Calculate the load current for a given resistance (see example table in Data processing section).
2. Observe and sketch in the notebook the waveform present at the regulator output terminals – point P4.
3. Observe the keying voltage at point P5, for the jumper Z3 closed and opened, respectively. Measure and write down its maximum value, frequency and its duty cycle. Try to choose various reasonable triggering sources (signal and power mains) and use various time base speeds of the oscilloscope (e.g. 2.5µs, 2.5ms). When using AC line triggering source, use a peak detection mode (Acquire -> Peak Detect). Try to sketch observed signal in your notebook.
4. Connect jumper Z3. Observe the signal at the output of the regulator (point P9) using the AC input coupling in the scope. Try to choose an optimal triggering mode and use various time base speeds of the oscilloscope (e.g. 2.5µs, 2.5ms).
5. Observe the capacitor current using point P6 with the oscilloscope (jumper Z3 closed), measure its average value, peak-to-peak value and frequency. Use two different triggering sources: triggering from the same channel as the observed signal and triggering from a separate channel connected to the keying signal (point P5). Use an averaging option

(Acquire -> Average) in order to reduce the noise of the signal.

6. Observe the current of the inductor (points P7 and P8) – measure its average value, peak-to-peak value and frequency. Figure out, how to measure a voltage signal using the oscilloscope on the resistor that is not connected to the ground (so-called differential, or floating, measurement). Use the averaging option in the scope in order to reduce the noise.
7. For curious students: open jumper Z3. Measure a voltage signal on the regulator's output (P9). Measure a signal using the probe, connecting both probe terminals to the ground. Where does the signal come from? Can we get rid of it somehow?

7. Data processing

1. Fill out the table below (separate for the linear regulator and switched mode regulator):

Z1	V_{DC}	$V_{RMS\ AC}$ *measured*	$V_{RMC\ AC+DC}$	R	$V_{RMS\ AC}$ *calculated*	I_{DC}
On						
Off						

2. Sketch observed waveforms from the oscilloscope display (points 2 and 3 in the measurement plan), mark scales on the axes, comment characteristic values and features.
3. For the half-wave rectifier calculate the RMS value of the pulsed voltage at the output. Approximate measured signal with triangles and rectangles and use a definition of RMS value. Compare this result with the value measured using multimeter.
4. For the half-wave rectifier calculate a ripple factor, defined as a ratio of RMS value and the average value.

Further analysis:

1. What are the basic parameters that can be used to describe alternating signals?
2. What is the influence of the load current on pulsing voltage measured across the filtering capacitor?