How can pulsating direct current be transformed into smooth direct current?

EEP 12.5 **S**

Problem

Using capacitors and coils, try to reduce the ripple of a pulsating direct current produced by rectification as much as possible.

Equipment

Plug-in board	06033.00	1
Lamp holder E10	17049.00	1
Filament lamp, 4 V/0.04 A, E10, 1 pc.	07505.03	(1)
Electrolytic capacitor, 47 μF, bipolar	39105.45	1
Electrolytic capacitor, 470 μF, bipolar	39105.47	2
Bridge rectifier	39135.00	1
Headphones, 2 kΩ, 4-mm plug	06811.00	1
Coil, 400 turns	07829.01	1
U-core	07832.00	1
Yoke	07833.00	1
Tightening screw	07834.00	1
Wire building block	39120.00	3
Connecting cables, 25 cm, red	07360.01	2
Connecting cables, 50 cm, red	07361.01	2
Connecting cables, 50 cm, blue	07361.04	2
Multi-range meter	07028.01	1
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1

Set-Up and Procedure

— Set up experiment as shown in Fig. 1 with the following exceptions. Leave the 470 μF capacitors C_1 and C_2 out of the circuit to start and plug a wire building block into the circuit instead of the coil.
Note: The 47 μF capacitor C_3 transmits only hum voltage to the headphones and the meter, but blocks the direct voltage part.

— Select measurement range of 30 mA. Switch on power supply unit and set alternating voltage to 6 V~.

— Measure current and enter in Table 1. Note volume of humming in headphones.

— Add capacitor C_1 to circuit. Note volume in headphones and brightness of filament lamp.

— Measure current. Note observations and measurement.

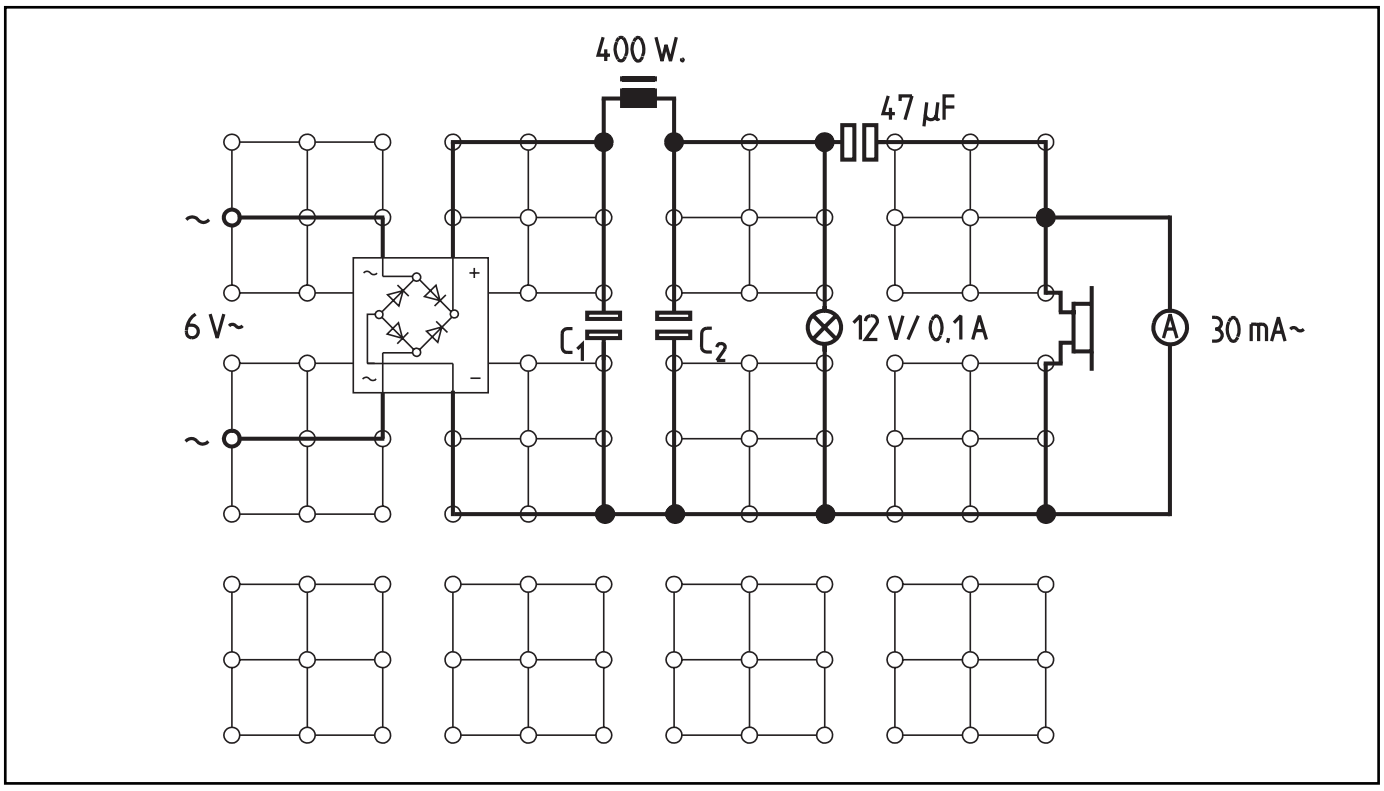
— Add coil with 400 turns to circuit as shown in Fig. 1. Note volume in headphones and measure current once again. Note results.

— Place U-core in coil, lay I-core on top, and secure with the tightening screw. Repeat observations and measurement.

— Add capacitor C_2 to circuit. Repeat observations and measurement.

— Switch power supply unit off.

Fig. 1



Observations and Measurement Results

Table 1

	Humming	I /mA
without capacitors and without coil	loud	
with C_1 and without coil		
with C_1 and coil without iron core		
with C_1 and coil with iron core		
with C_1 and C_2 and coil with iron core		

Observation of filament lamp:

Fig. 2

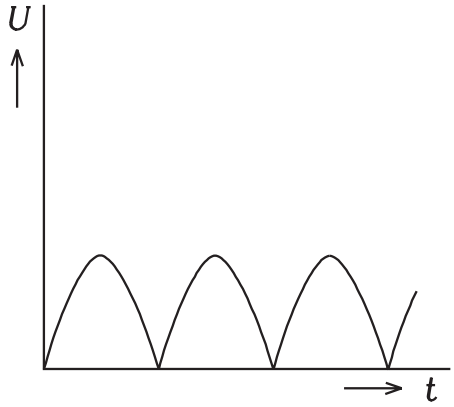
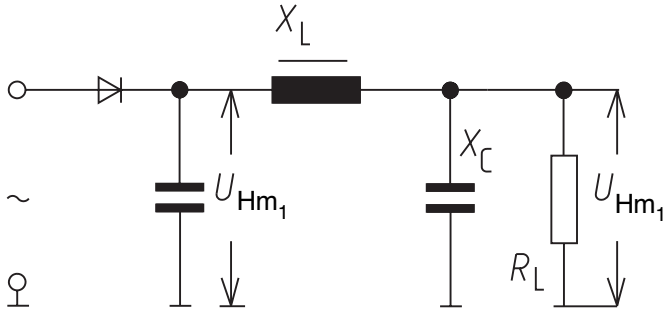


Fig. 3



Evaluation

1. The capacitor C_1 is referred to as a filter capacitor. The series connection composed of the coil and capacitor C_2 is called the filter section.
   Answer the question posed in the header using these terms

2. Fig. 2 shows the voltage curve at the filament lamp without the filter capacitor. Using a different color on the same graph, draw in the voltage curve after the filter capacitor is added to the circuit. Note that the voltage source charges the capacitor to the maximum value of the pulsating direct voltage in each half period but can only discharge via the load resistor.
   Using this graph, explain why direct voltage increases (indicated by the brightness of the lamp) when the filter capacitor is added to the circuit.

3. Why does the filter section reduce the hum voltage connected to the filament lamp? Note that the filament lamp used as a load resistor is connected in parallel to the filter capacitor C_2 and that this capacitor together with the coil forms a voltage divider for the alternating voltage. Use Fig. 3 to answer this question.

4. List some practical applications for a rectifier circuit where hum voltage would otherwise interfere with operation.

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In this experiment, the students should examine the effect filter capacitors and filter sections have on the direct and alternating current portions of a pulsating direct current. Since oscilloscopes are generally not used in student experiments, the students must note the brightness of the filament lamp used as a load resistor to determine how much the direct voltage portion is. They can compare hum voltage based on the volume of the humming in the headphones. Furthermore, they can measure how much of it is alternating voltage with the meter. A capacitor is connected in front of the meter to filter out the direct voltage. Since the minimum alternating voltage measurement range of 10 V is too insensitive, we suggest that more sensitive alternating current measurement range of 30 mA be used.

Notes on Set-Up and Procedure

Advise the students of the correct connections for the meter.

The 47 μF capacitor C_3 must be connected in front of the meter. Otherwise, the average of the pulsating direct voltage would also be displayed in the measurement range for alternating voltage.

Selecting the measurement range for current instead of the measurement range for voltage might be a bit confusing for the students, but the change measured in current can be used to surmise the change in hum voltage. The actual figures are not so important anyway.

Observations and Measurement Results

See Table 1

Observation of filament lamp: The filament lamp definitely shines brighter after C_1 is added to the circuit.

Evaluation

1. A filter capacitor and filter network consisting of a coil and capacitor can be used to reduce the alternating current portion of a pulsating direct current, which causes humming in the headphones, to such an extent that a (nearly) perfect direct current is produced.
2. See Fig. 2.
   Explanation: Adding a filter capacitor to the circuit increases the average pulsating direct voltage because the capacitor charges to the maximum value in each half period but does not discharge entirely after that.
3. The filter section acts as a voltage divider for the hum voltage portion of the pulsating direct voltage. The hum voltage is divided between the two impedances X_L and X_C (see Fig. 3). The load resistor connected in parallel to the filter capacitor C_2, only receives a portion of the hum voltage U_{Hm_2}. This hum voltage is lower when the capacity C_2 and the inductivity at the coil are larger. Approximately the following equation applies:

$$\frac{U_{Hm_2}}{U_{Hm_1}} = \frac{X_C}{X_C + X_L} = \frac{1}{1 + X_L/X_C}.$$

4. High hum voltage interferes with mains operated devices used to transmit digital or analog information because it is superimposed on the useful signal.

Fig. 2

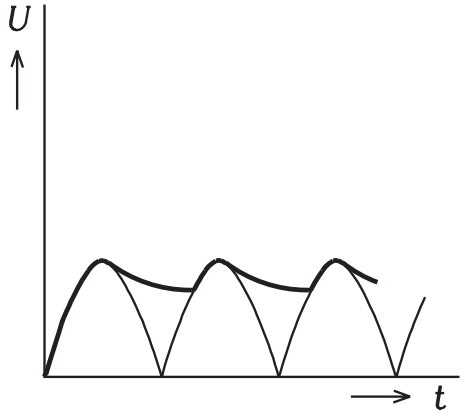

Table 1

	Humming	I /mA
without capacitors and without coil	loud	28
with C_1 and without coil	less loud	6
with C_1 and coil without iron core	hardly any change	5.5
with C_1 and coil with iron core	even lower	3
with C_1 and C_2 and coil with iron core	no longer audible	0

(How can pulsating direct current be transformed into smooth direct current?)

Notes

The pulsating direct voltage produced by rectification can be interpreted as a superposition of the average direct voltage with alternating voltage, i.e. the hum voltage. Since this would interfere with transmission in many electronic devices, it must be reduced as much as possible and/or necessary. Electronic regulation circuits, which are available as integrated circuits, are the most common solution to this problem. A combination of filter capacitor connected in front of a filter section, however, can also be used to solve the problem.

The equation listed under question 3 is only approximately true because, in deriving it, we neglected the fact that there is a residual hum voltage U_{Hm_2} across the parallel connection of the load resistor and capacitor.