WORKREADY ELECTRONICS

lab activity

DC-DC Converters

Module: Switching Power Supplies

Lab Summary: The purpose of this lab experiment is to introduce a DC-DC converter circuit. Appropriate calculations will be made, and the circuit will be built using readily available components. The purpose is to learn how to identify major characteristics and functions of SMPS and to gain experience measuring DC output voltage and ripple. Directions for completing the lab are provided. After the lab, the collected data is used to create a report and answer question pertinent to the lab activity.

Student Prerequisites: Before attempting this lab experiment, students should have already completed courses and labs in basic semiconductor components and circuits including coverage of power supplies and the 555 timer IC. Students should also have completed the WRE reading material and Knowledge Probes on switching power supplies.

Lab Goal: Observe the operation of a representative DC-DC converter circuit and execute measurements, related to operations that facilitate understanding of functionality and design.

Learning Objectives

- Build a DC-DC converter circuit.
- Describe the operation of the circuit.
- Measure DC and ripple output voltages, and answer questions relative to measures taken.

Conditions of Performance and Grading Criteria: Students should use standard lab equipment available in most community college and technical schools including an electronic trainer with breadboard socket, digital multimeter, and oscilloscope. Students may work on the experiment individually or in pairs. There is no time limit. The student will be graded on the lab results, questions, and lab report.

Approximate Time Required: 1-3 hours

Equipment and Supplies

Equipment:
DC power supply to furnish 12 volts
Electronic trainer or breadboard socket
Digital or analog multimeter to measure DC voltages
Oscilloscope

Components:
1 x 555 timer IC
2 x 10 K ohm resistors
1 x 100K ohm resistor
4 x 10 µF electrolytic capacitors, 50 VDC
1 x 0.01 µF ceramic capacitor, 50 volt or more
4 x 1N4148, 1N914, or 1N4001 silicon rectifier diodes

Special Safety Requirements: No serious hazards are involved in this lab, but caution should be taken to connect the electrolytic capacitors and diodes with the proper polarity to avoid damaging them.

Lab Preparation

1. Assemble all test equipment.
2. Assemble all circuit components.
3. Read the Introduction.
4. Review and print out the Lab Procedures.

Introduction

One of the simplest ways to create a DC-DC converter is to use a circuit called a charge pump. The charge pump uses DC pulses produced by switching transistors and capacitors or pulses with diode switches and capacitor networks to generate a different higher voltage or different polarity than the input DC. Such circuits are widely used inside integrated circuits where it is necessary to generate additional, usually higher, voltages needed by the circuits without additional external DC power supplies. Perhaps the best examples are the single-chip RS-232 serial interface circuits popular in personal computers. The RS-232 standard calls for serial logic levels in the –3 to –25 volts for a binary 1 and +3 to +25 volts for a binary 0. Most systems use ±12 volts. However, computers and digital systems typically have a standard +5 volt power supply and do not have additional ±12 volt supplies to generate output levels. Since the current requirement of the ±12 volt supplies is low, a charge pump DC-DC converter is a simple and inexpensive way to get the desired voltages.

This lab experiment demonstrates a DC-DC converter using common electronics concepts and circuits. The circuit includes the long-lived and still popular 555 timer IC used by many schools to demonstrate pulse and switching circuits. It is covered in virtually all current electronic textbooks. The circuit uses the 555 as an astable multivibrator to generate a pulse train that can be converted into a voltage different from the DC supply (input) voltage or one of a different polarity using charge pump techniques.

The basic circuit is illustrated in Figure 1. The frequency of oscillation of the 555 timer is set by R_1, R_2, and C_1 as is usual in most 555 astables.

$f = 1/[0.693(R_1 + 2R_2)C_1]$

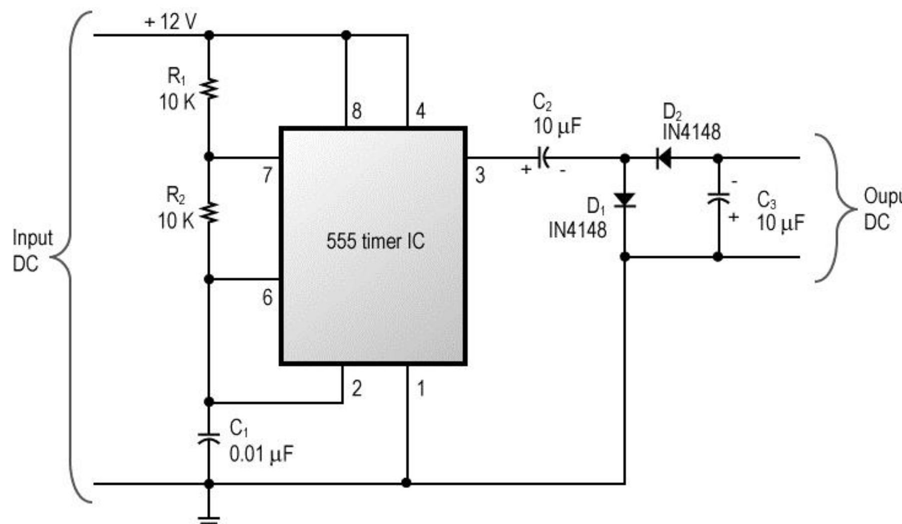

Figure 1. Basic Circuit

When the 555 generates an output pulse, C_2 is charged through D_1. When the pulse turns off, the charge on C_2 is transferred to C_3 via D_2 producing a DC output voltage approximately equal to the DC supply voltages less the diode voltage drops with inverse polarity. The ripple is an inverse function of the values of C_2 and C_3.

The current-handling capacity of this circuit is limited to about 50 mA. It can easily power op amps and miscellaneous low power circuits. Overall, the output current is also bounded by the limitations of the 555 output transistors which can sink and source up to 200 mA. Capacitors C_2 and C_3 also affect the output current limit, with higher value capacitors giving greater output current. If a regulated output is required, it is best to pre-regulate the DC input voltage rather than regulate the output directly, although that can be done with an external regulator at the output.

Figure 2 shows how a positive output voltage, about four times the input voltage, is obtained. Additional diode-capacitor sections can be added as shown to approximately quadruple the output if desired. As the output voltage is increased, current handling capability is reduced by that factor.

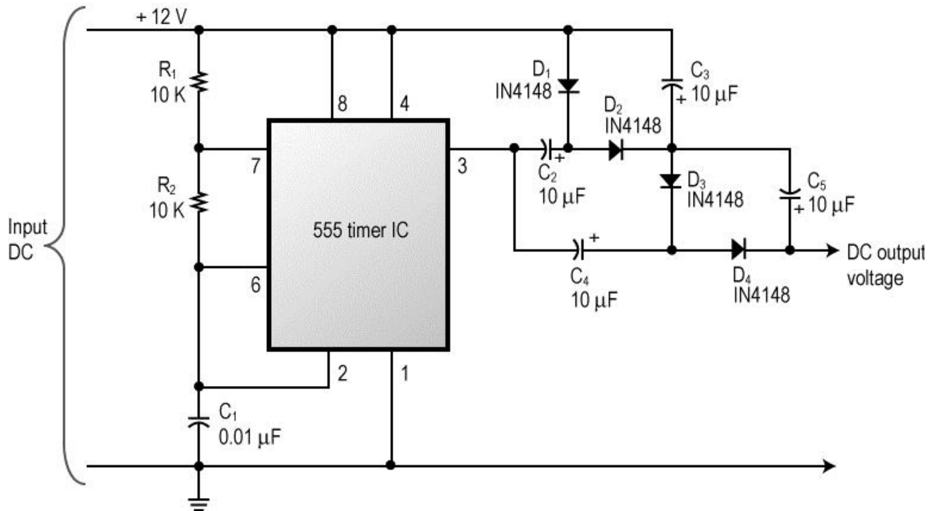

Figure 2. Circuit Modified to Produce Positive Output Voltage

Lab Procedures

1. Construct the circuit shown in Figure 1 at the end of this procedure. Carefully observe the diode and capacitor polarities to ensure proper operation and avoid damage.

2. Use the component values shown and the formulas for the 555 timer to calculate the expected output switching frequency (f). Show your calculations.

   f =
   f =

3. Predict the amplitude and polarity of the output (Vout).
   Vout =
   Volts (calculation) =

4. Apply power to the circuit. Measure the DC output voltage and polarity with a DC multimeter.

   Vout =

5. Use the oscilloscope to observe the 555 timer output pulses at pin 3. Measure the frequency and amplitude.

   Pulse voltage =
   Pulse frequency =

6. Use the oscilloscope to measure the peak-to-peak AC ripple voltage (Vpp). Note the shape of the ripple voltage and sketch it in the box below.

   Vpp =

7. Explain any variances between your calculated and measured values.

8. Modify the experimental circuit so that it is wired like that shown in Figure 2 at the end of this procedure.

9. Observe the circuit and the description provided in the Lab Introduction and predict the output voltage and polarity.

   Vout =

10. Apply power to the circuit. Measure the output voltage and the peak-to-peak ripple.

   Vout =

   Vpp =

11. Turn off the power.

<u>Lab Questions</u>: The following questions should be completed after the Lab.

1. Define the term charge pump.

2. Explain why the circuits in this experiment are charge pumps.

3. What component(s) converts the input DC into pulses?

4. State three factors used to determine the potential output current of the DC-DC converter.

5. State two ways to reduce the output ripple of the circuit.

6. Name two ways to achieve a regulated output from the circuit.

7. Describe the action of the diodes and C_2-C_5 to explain how the circuit in Figure 2 functions.

8. What type of rectifier circuit is used in Figure 2? (Hint: Refer to standard text covering rectifier circuits.)

9. What type of diode could be substituted for those in this circuit to increase output voltage and otherwise improve performance?

10. Describe the shape of the ripple voltage. What produces it?

Figure 1: Basic Circuit

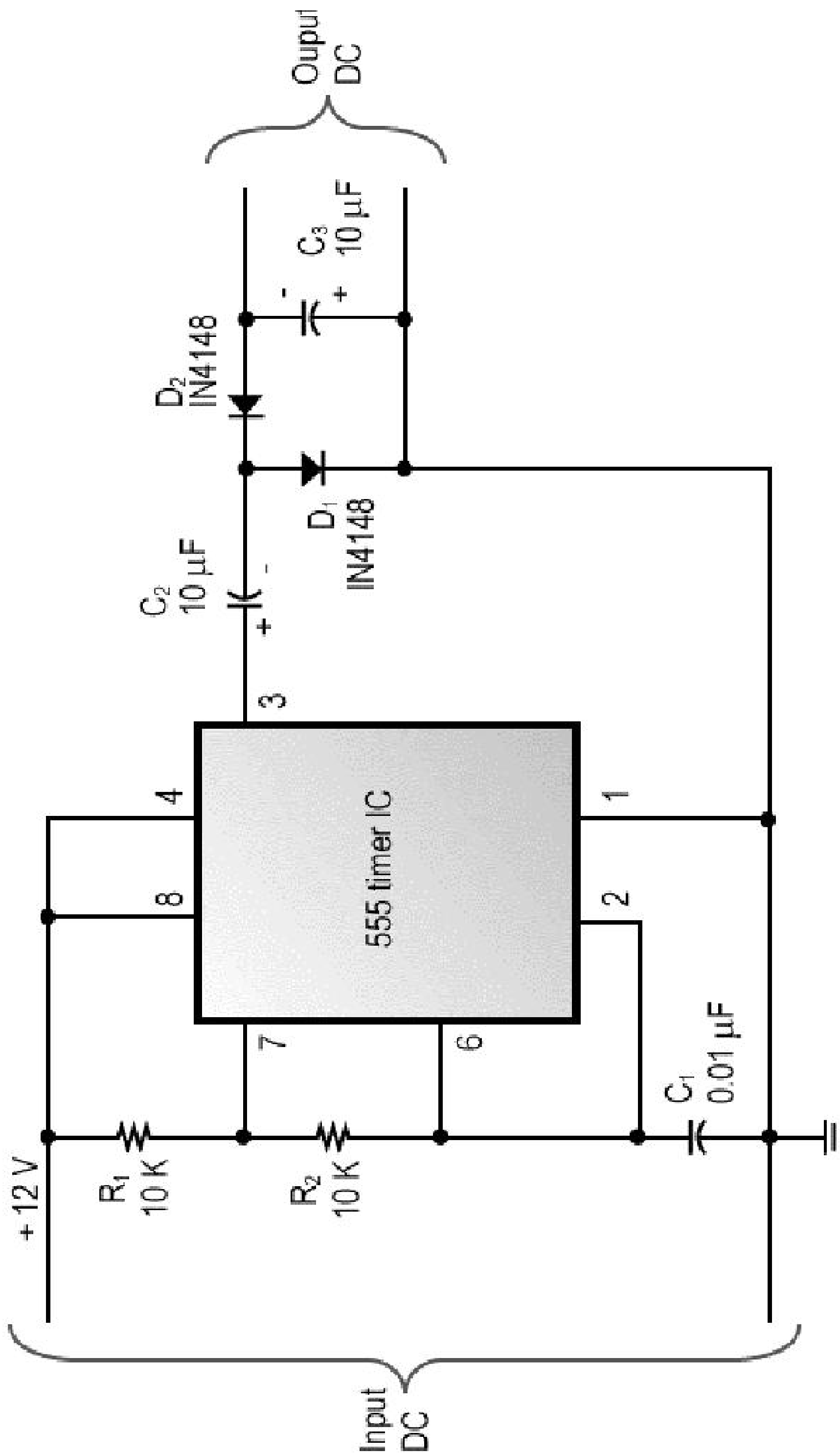

Figure 2: Circuit Modified to Produce Positive Output Voltage