Switching Mode Power Supplies

DC-DC Converters: Charge Pumps, Forward Converters, and Flyback Converters

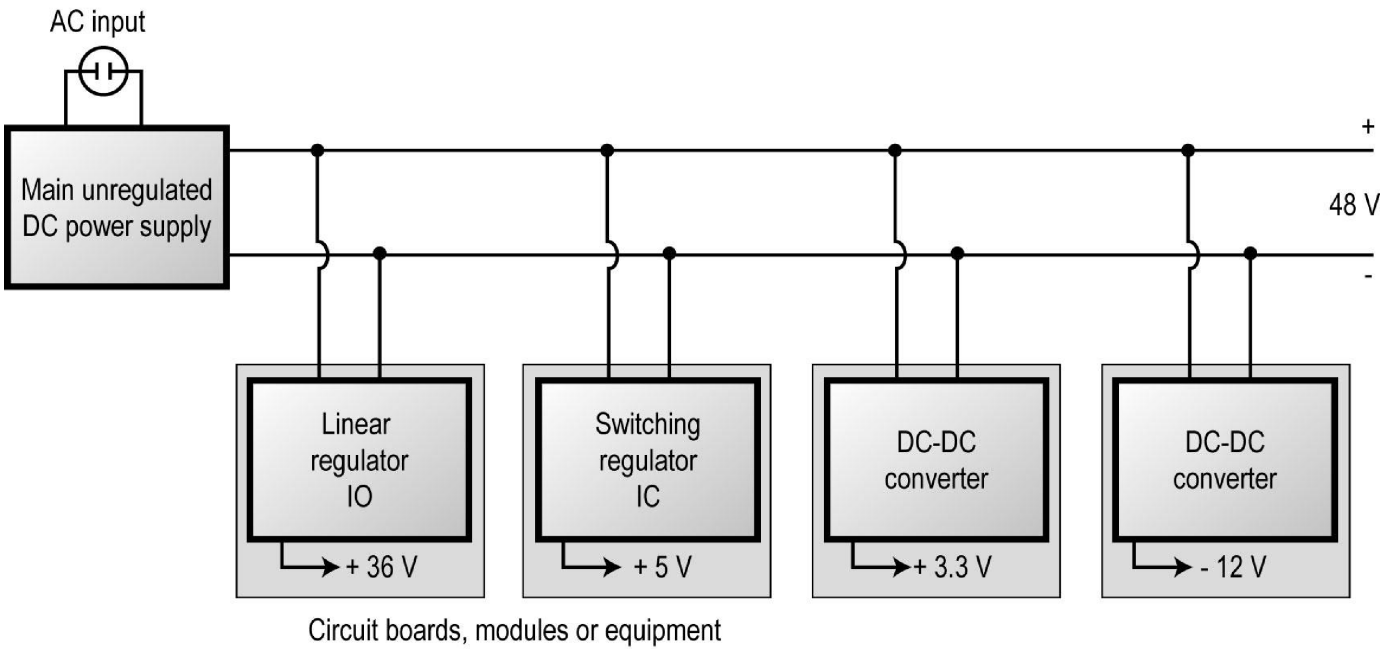
DC-DC Converter

A DC-DC type of power supply converts one DC level to one or more other DC levels and/or changes the polarity. In AC circuits, transformers are commonly used to step up or step down voltages. Since transformers do not work with DC, special power supply circuits have been developed.

DC-DC converters may be used with a battery input or DC input from an AC-DC power supply. Examples include vibrator power supplies in 1940-60 car radios and high voltage supplies used in TVs and video monitors.

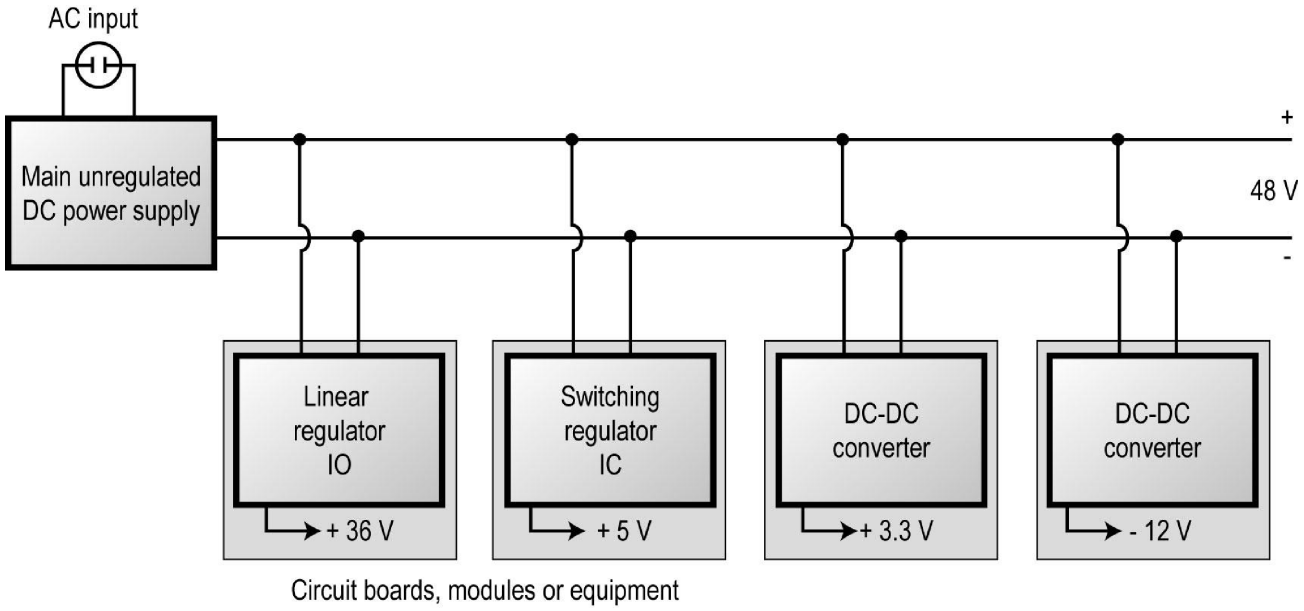
The use of DC-DC converters is growing because of the need for multiple supply voltages in integrated circuits. They are widely used in bus architecture power systems for microcomputers.

Power Supply Bus Architecture



A discussion of this graphic is presented in the pages that follow. You can print this graphic for study purposes before going on.

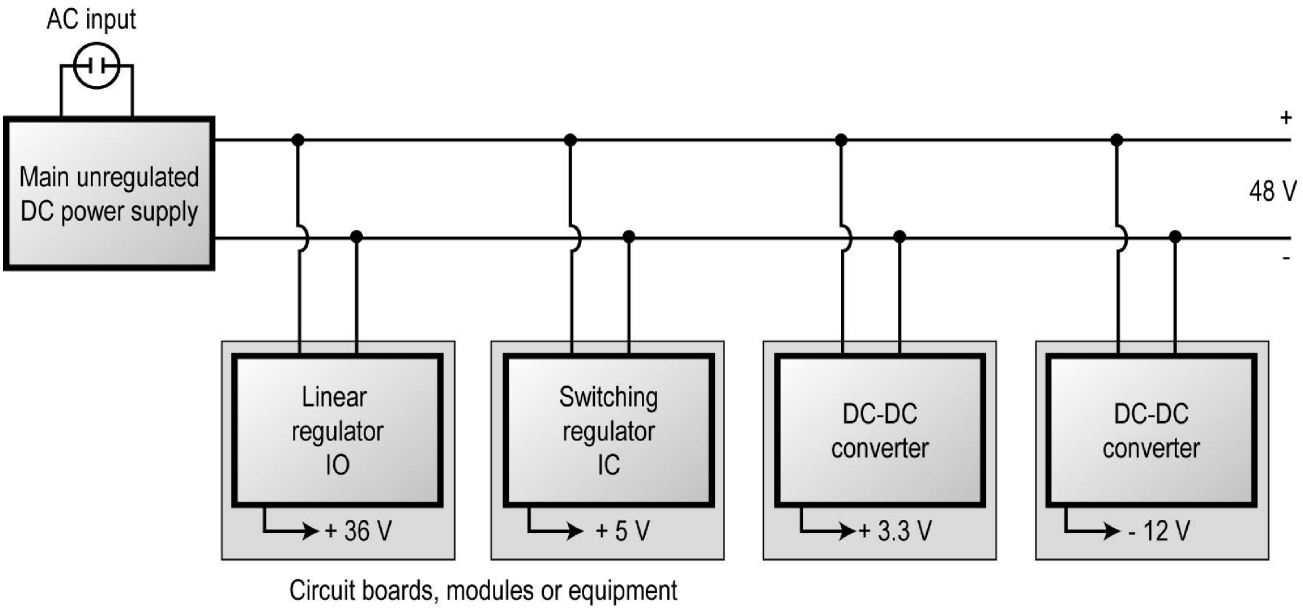
Power Supply Bus Architecture



This power supply arrangement is common in many modern systems. An unregulated AC-DC supply furnishes power to a bus that is distributed on a printed circuit board or on wire buses in rack mounted equipment.

Power Supply Bus Architecture

The unregulated voltage is distributed at a higher voltage than required for any application. This reduces the current on the bus and that in turn minimizes bus voltage drops. Desired regulated DC output voltages are obtained within the circuits being powered by linear or switching regulators and/or DC-DC converters.



Bus Architecture Details

Fixed, unregulated DC supplies provide DC to a common bus. All parts of the system are connected to the common bus.

Buses may be either copper strips on printed circuit board metal strips or heavy wires attached to connectors in rack systems.

The voltages required by the system are derived from linear or switching regulators.

Other voltages are derived from DC-DC converters. DC-DC converters are available in integrated circuit (IC) form or as packaged modules.

Types of DC-DC Converters

The four types of DC-DC converters are switching regulators, charge pumps, forward converters, and flyback converters.

Switching regulators are a type of DC-DC converter whose main purpose is regulation. They also translate one DC level to another.

Charge pumps are combinations of MOSFET switches and/or diode switches with capacitors that switch and store input DC and change DC level or polarity.

Forward converters use MOSFET switches to chop DC input into pulses that are applied to a transformer. The transformer steps the pulse voltage up or down. The pulses are then rectified and filtered into a new DC level.

Flyback converters are similar to forward converters but they use a transformer as an energy storage component instead of a capacitor. They are widely used in high voltage power supplies.

Charge Pumps

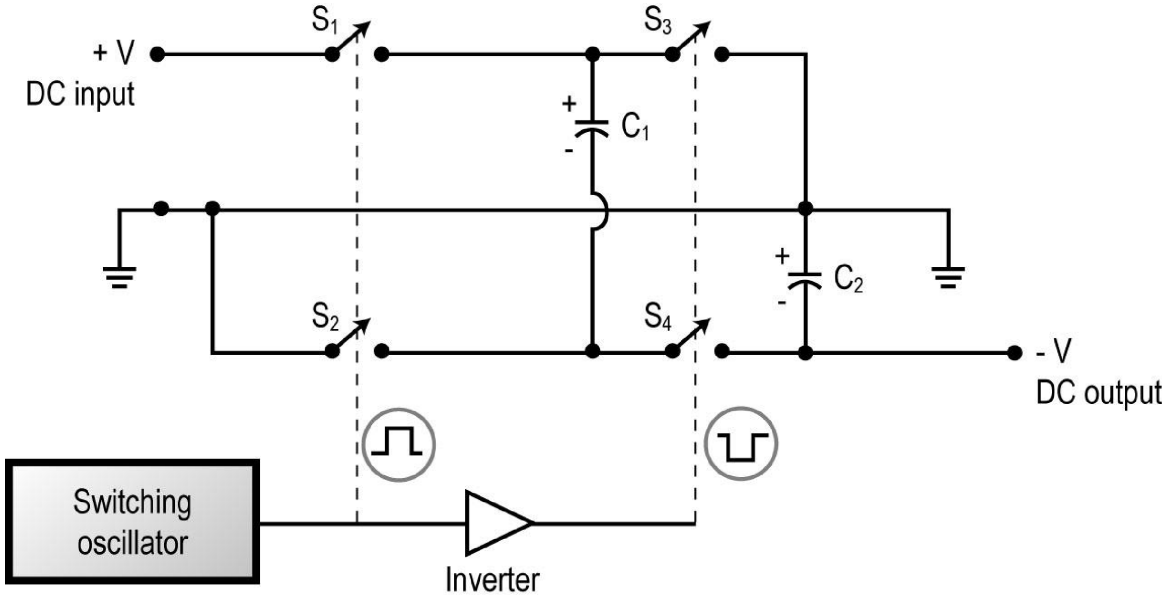
Charge pumps use MOSFET switches and capacitors to convert one DC level to another. They are designed mainly for low current, low power applications. Charge pumps are built into other circuits so it is not unnecessary to provide extra external power supply voltages.

Example:

±12 volts needed by the RS-232 interface is derived from the +5 volt power supply in the host computer.

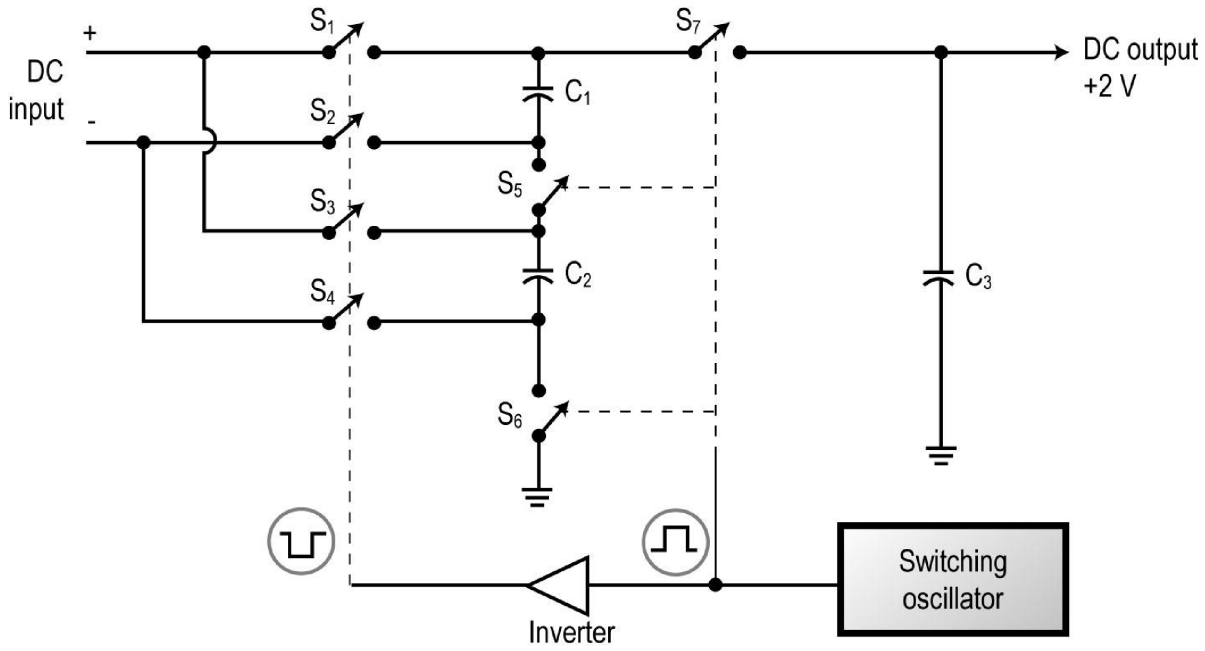
Charge Pump Operation

A switching oscillator alternately opens and closes switches S_1-S_4. The switching rate is in the 10 kHz to 300 kHz range. When S_1 and S_2 are closed, S_3 and S_4 are open and vise versa. With S_1 and S_2 closed, C_1 charges. When S_1 and S_2 open, S_3 and S_4 close. The charge on C_1 is transferred to C_2. Because of the grounding arrangement, the output voltage is equal to input voltage but of the opposite polarity.



Charge Pump Operation (continued)

When S_1-S_4 are closed, S_5-S_7 are open and vise versa. The switching rate is in the 10 kHz to 300 kHz range. With S_1-S_4 closed, C_1 and C_2 charge to the input voltage. When S_1-S_4 open, S_5-S_7 close. Voltages on C_1 and C_2 add in series and charge C_3. The output voltage across C_3 is twice the input voltage.



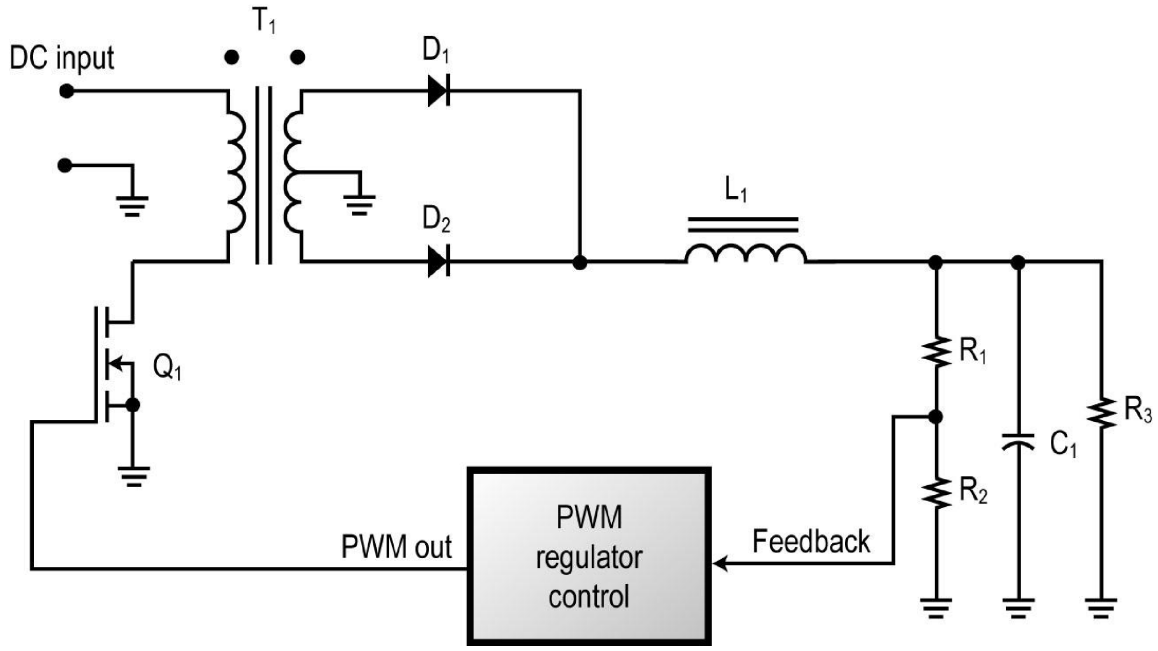
Forward Converters

A forward converter is the most commonly used DC-DC converter configuration. It uses a MOSFET switch to convert the constant DC input into pulses.

However, the forward converter uses a transformer to step up or step down the pulse voltage. The transformer provides complete electrical isolation between the input and output allowing the input and output circuits to use separate grounds if necessary. The AC transformer output is converted to DC by conventional rectifiers and filters. PWM is used to provide regulation.

Forward Converter Operation

Q_1 "chops" input DC into pulses. The switching rate is in the 50 kHz to 1 MHz range. The transformer T_1 steps up or steps down the voltage and provides complete galvanic isolation between the input and output so separate grounds may be used. Rectifiers D_1 and D_2 rectify the output of T_1. L_1 and C_1 filter output into DC. PWM feedback regulator maintains a constant output voltage.



Push-Pull Forward Converter

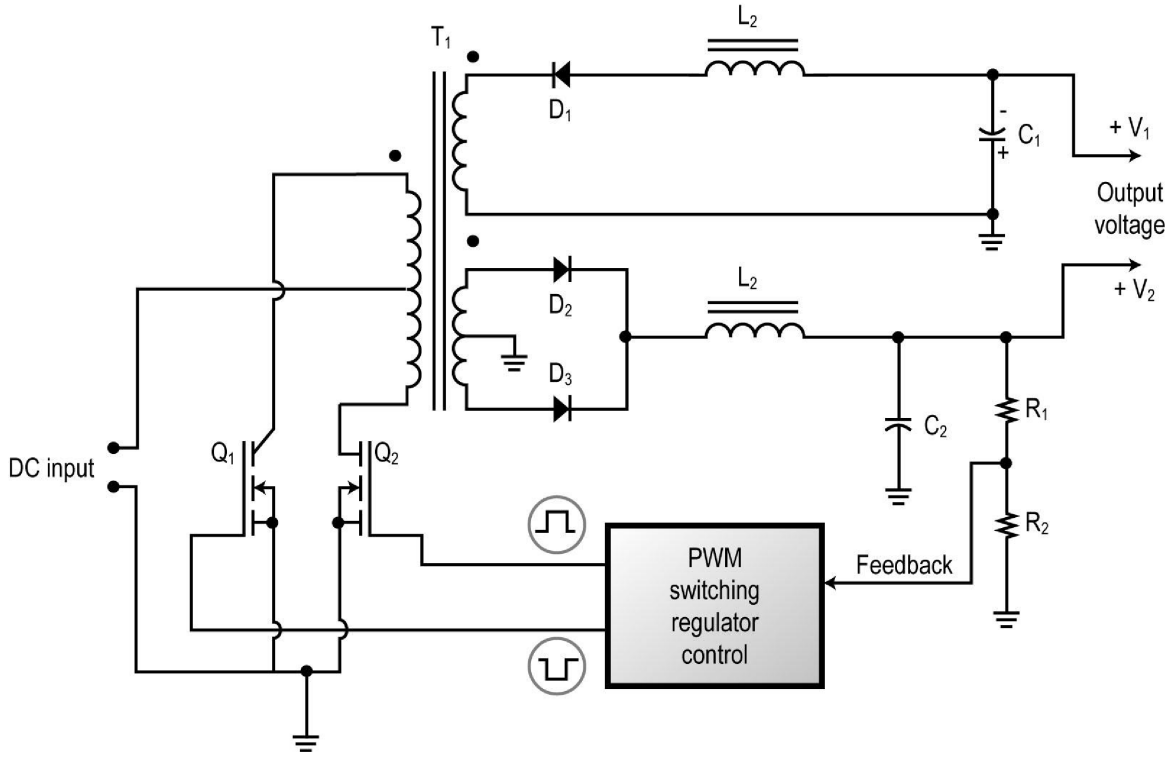
A push-pull forward converter is similar to the single transistor forward converter except it uses two transistor switches in the primary winding of the transformer.

By splitting the primary winding and using two alternately conducting transistors, this circuit can usually provide twice the output power of the single transistor circuit.

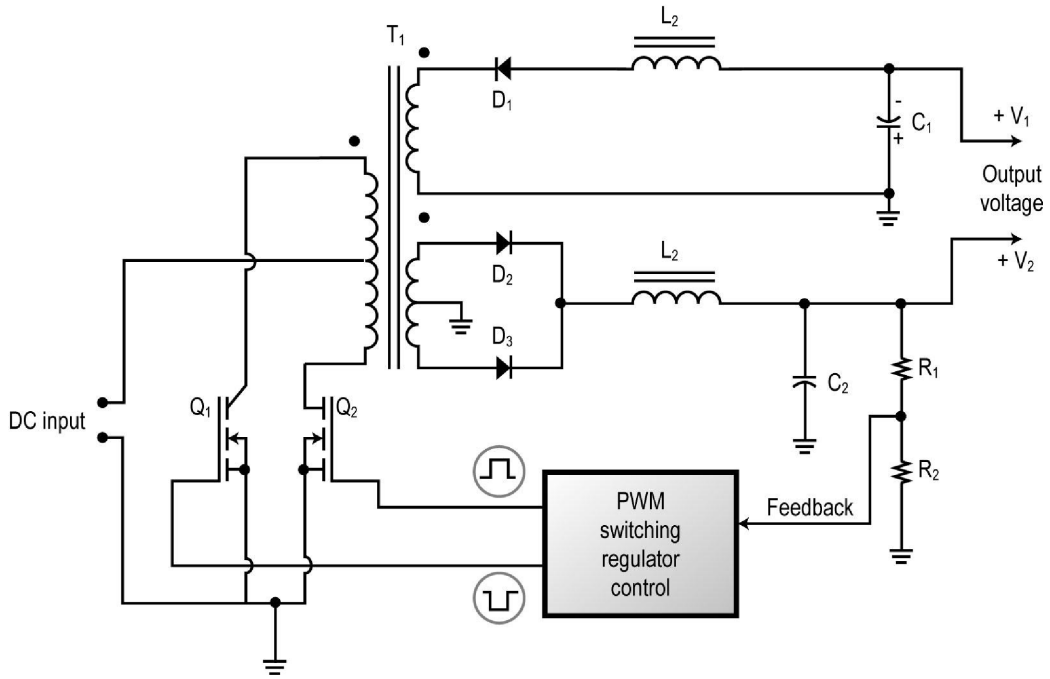
Furthermore, the transistors are typically subjected to lower voltages. The push-pull forward converter circuit is the preferred circuit for high voltage (over several hundred volts) applications.

Push-Pull Forward Converter Operation

Switches Q_1 and Q_2 alternately connect the transformer primary to the input DC. T_1 steps up or down the input voltage. T_1 may have multiple secondary windings to develop multiple output voltages.

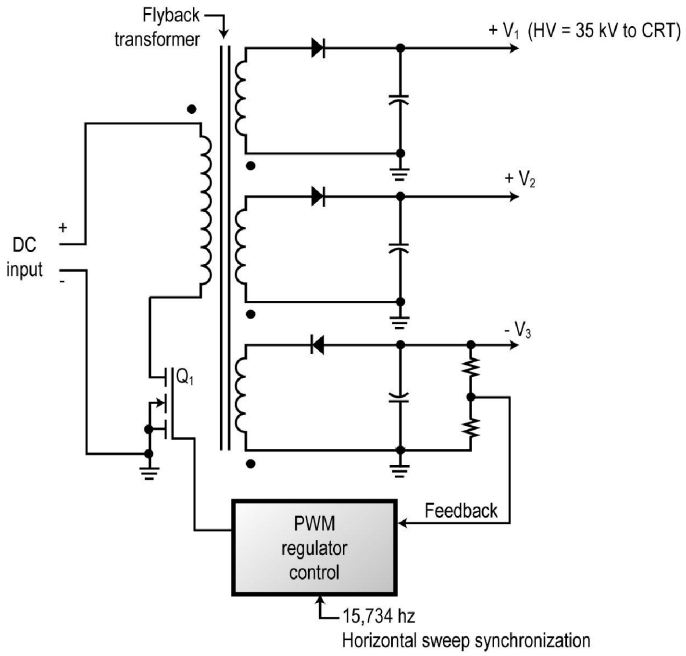


Push-Pull Forward Converter Operation



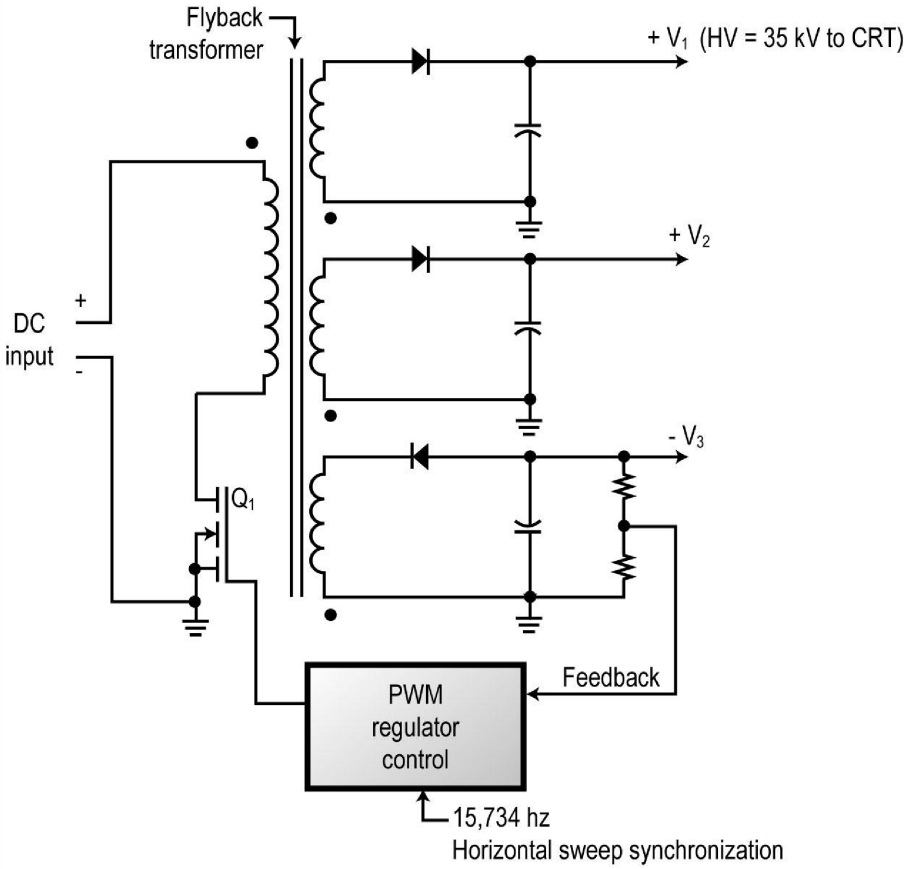
T_1 provides complete isolation between the input and the output. Rectifiers convert AC from T_1 to pulsating DC which is filtered into a constant DC by low pass LC filters. A PWM feedback regulator maintains a constant output. V_1 is regulated only for line variations. V_2 is regulated for both load and line variations.

Flyback Converter



The flyback converter uses a special transformer to produce high voltages (35 kV+) for cathode ray tubes (CRTs) used in television sets and computer video monitors. A PWM feedback regulator maintains constant output.

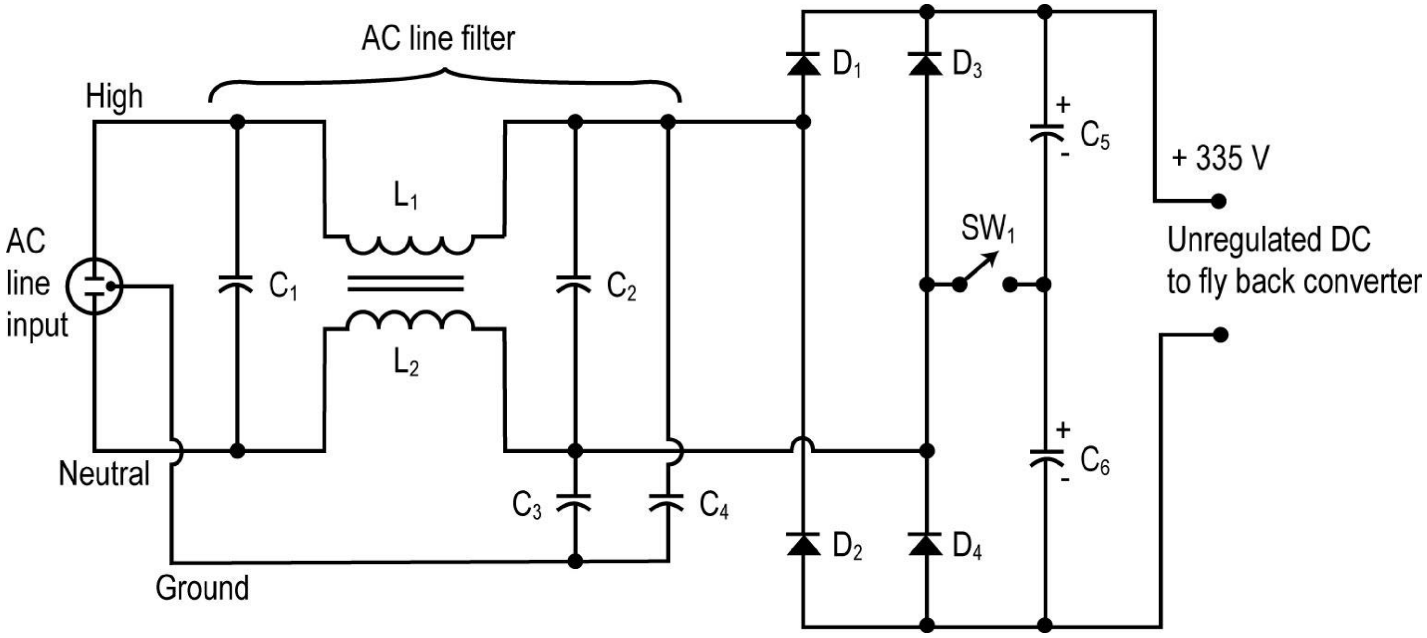
Flyback Converter Operation



Input DC is chopped into pulses by Q_1. The flyback transformer stores energy in the form of a magnetic field. When the input voltage is switched off, the magnetic field collapses inducing voltages into the secondary windings of T_1. Multiple secondary windings permit multiple outputs to be developed. Rectifiers and filter capacitors develop the final DC outputs.

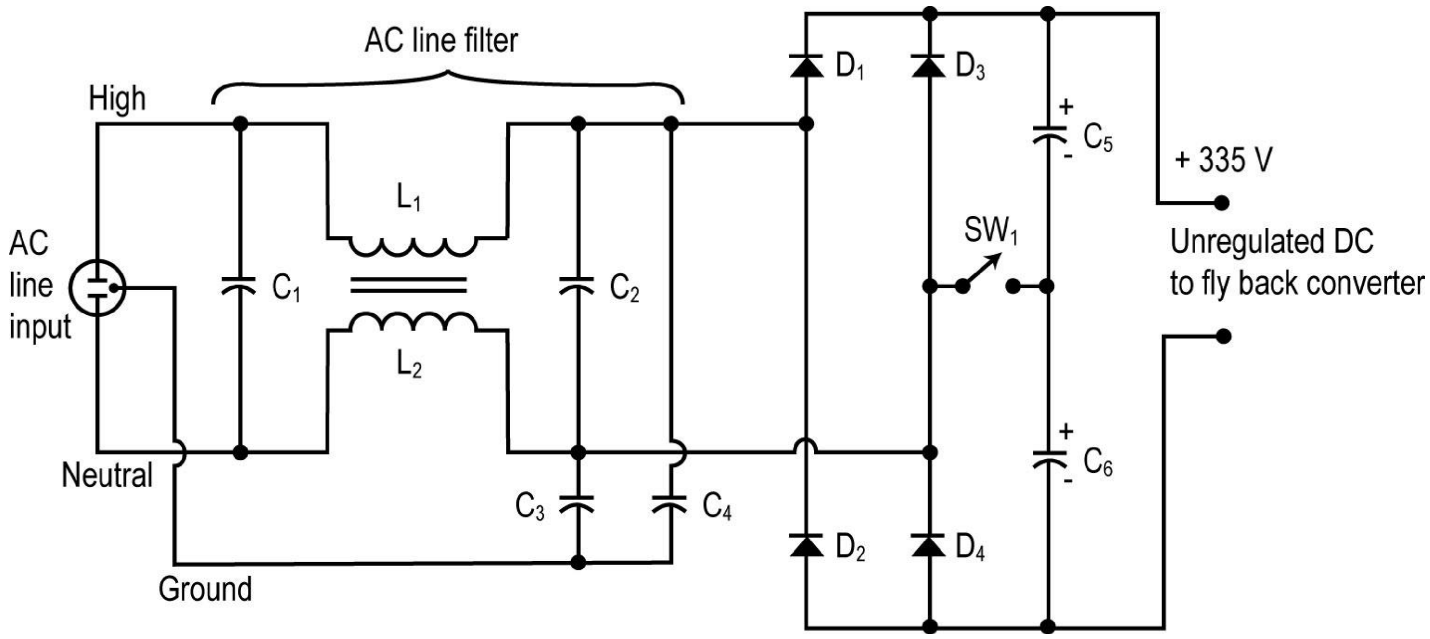
AC-DC Power Supply and DC-DC Converters

This circuit is typically used to generate the input to a DC-DC converter from the AC power line. Conventional rectifiers and capacitor filters are used. AC input may be 120 V 60Hz or 240 V 50 Hz. No step up or step down transformer is used.



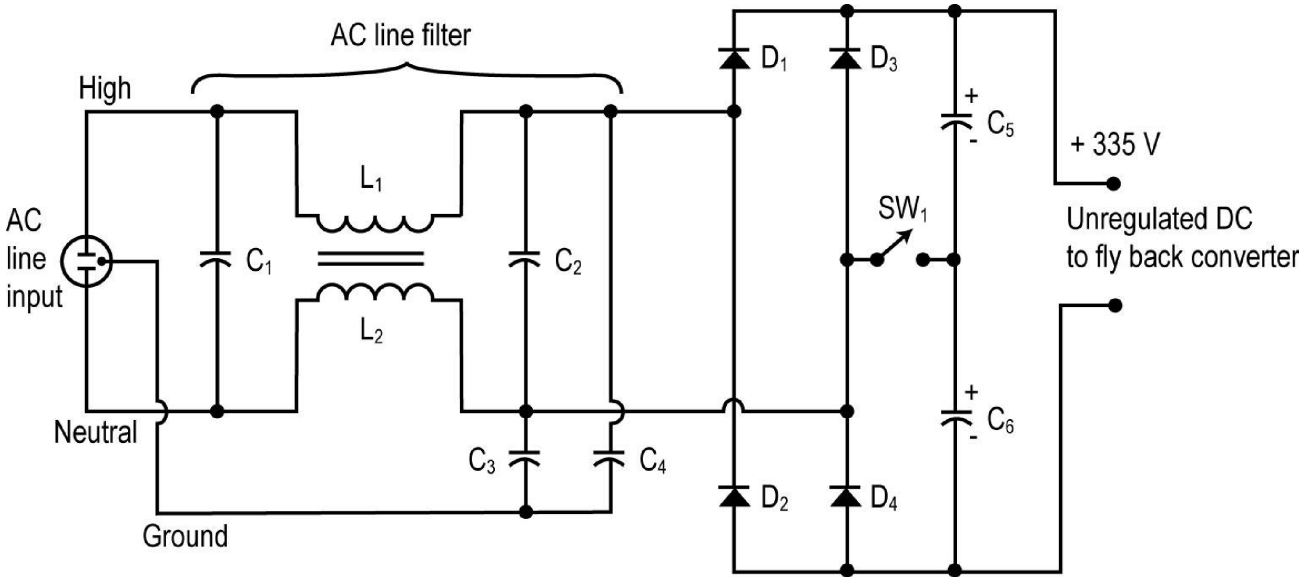
Power Supply Operation (continued)

L_1-L_2 and C_1-C_4 form a low pass filter to keep AC line noise and pulses out of the power supply. They also keep switching transients from the switching supply from getting into the power line.



Power Supply Operation (continued)

Switch SW_1 selects 120 V (closed) or 240 V (open) operation. With SW_1 open, D_1-D_4 form a bridge rectifier that charges C_5-C_6 in series to about 335 volts. With SW_1 closed, D_1 and D_2 act as half wave voltage doubling rectifiers that charge C_5 on one half cycle and C_6 on the other half cycle. Voltages across C_5 and C_6 add producing about 335 volts output.



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