Power Management Basics

1. Power Supply Fundamentals

Power management plays a major role in virtually every electronic system because it controls, regulates, and distributes dc power throughout the system. Therefore, the dc power management subsystem can affect the reliability, performance, cost, and time-to-market of the associated electronic equipment.

Power management subsystems enable an electronic system to function properly by supplying and controlling its dc power. An analogy is that a power management subsystem functions in a manner similar to the body's blood vessels that supply the proper nutrients to keep the body alive. Likewise, the power management subsystem supplies and controls the power that keeps an electronic system alive.

The key component of the dc power management system is the power supply that provides dc power for the associated system. The specific type of dc power management subsystem depends on its power input, which includes:

- **Battery input (for portable equipment)** – Because of size and weight restrictions of portable equipment this power management subsystem is usually integrated with the rest of the electronic system. Some of these systems also include an ac adapter, which is a small power unit that plugs into the ac wall outlet and provides a dc output voltage. Usually, the ac adapter is used to power the unit and can also recharge the system battery.
- **AC input –** This subsystem employs a power supply that accepts an ac utility power input, rectifies and filters it, then applies the resulting dc voltage to a regulator circuit that provides a constant dc output voltage. There are a wide variety of ac-dc supplies that can have an output voltage from less than 1V to thousands of volts. This dc power management system usually employs a switch-mode power supply, although some linear supplies are available.
- **DC input –** This power management subsystem employs a power supply that accepts a dc voltage input, typically 5 V, 12V, 24V, or 48 V and produces a dc output voltage. At the low end, a supply of this type can produce less than1Vdc, whereas other dc-dc supplies can produce thousands of volts dc. This power management subsystem usually employs a switch-mode power supply.
- **Ultralow voltage input (energy harvesting)** - Energy harvesting can provide the power to charge, supplement or replace batteries. A key component in energy harvesting is a power converter that can operate with ultralow voltage inputs. In operation, this power converter captures minute amounts of energy, accumulates it, stores it and then maintains the stored energy as a power source. Low voltage inputs can come from solar power, thermal energy, wind energy, or kinetic energy.

Isolated vs. Non-Isolated

In terms of their response to a dc input, there are two types of dc-dc converters: isolated and non-isolated, which depends on whether there is a direct dc path from the input to the output. An isolated converter provides isolation between the input and output voltage (usually with a transformer). In the non-isolated converter, there is a dc path from input to output.

For some applications, non-isolated converters are appropriate. However, some applications require isolation between the input and output voltages. An advantage of the transformer-based isolation converter is that it has the ability to easily produce multiple output voltages.

Linear vs. Switch-Mode Power Supplies

There are two basic power supply configurations used with dc power management subsystems: linear and switch-mode. Linear power supplies always conduct current. Differences between these two configurations include size and weight, power handling capability, EMI, and regulation.

The linear regulator's main components are a pass transistor, error amplifier, and voltage reference, as seen in **Figure 1-1**. The linear regulator maintains a constant output voltage by using the error amplifier to compare a portion of the output voltage with a stable voltage reference. If the output voltage tends to increase, feedback causes the pass transistor to the lower the output voltage and vice versa.

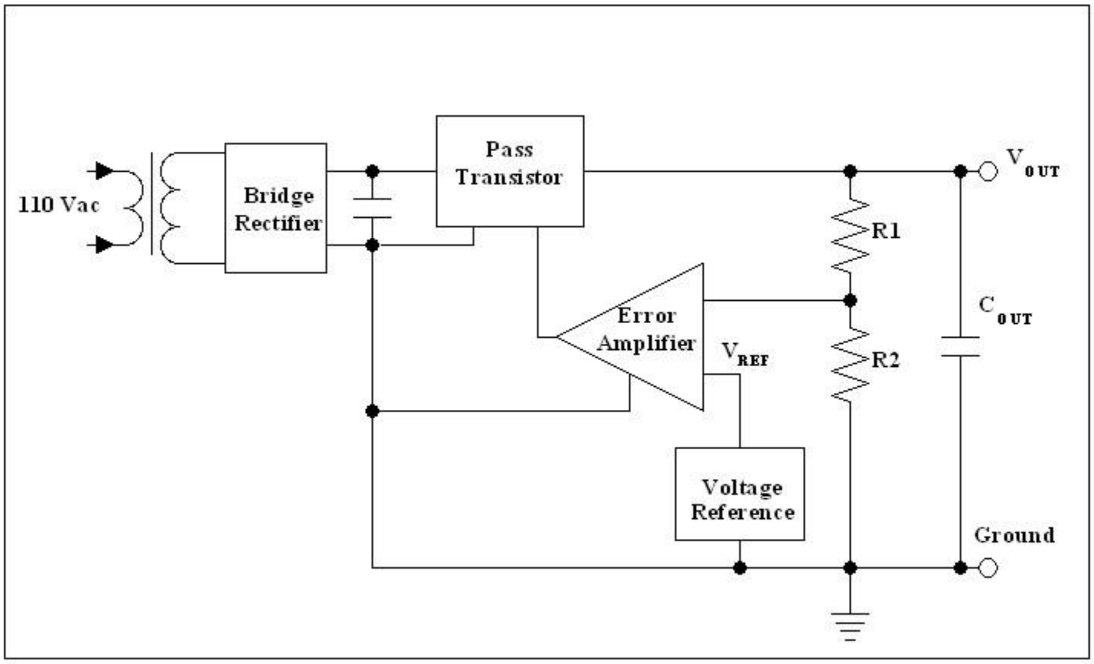

Figure 1-1. *Typical Isolated AC-DC Linear Power Supply*

OEM linear supplies can handle several amperes of current. They are usually bulky benchtop or rack-mounted supplies.

In most applications older, high current linear supplies have been superseded by switch-mode supplies. Shown in **Figure 1-2** is a typical isolated switch-mode supply. Here, the ac input voltage is rectified and filtered to obtain a dc voltage for the other power supply components. One widely used approach uses the on and off times pulse-width modulation (PWM) to control the power switch output voltage. The ratio of on time to the switching period time is the duty cycle. The higher the duty cycle, the higher the power output from the power semiconductor switch.

The error amp compares a portion of the output voltage feedback with a stable voltage reference to produce the drive for PWM circuit. The resulting drive for the PWM controls the duty cycle of the pulsed signal applied to the power switch, which in turn controls the power supply dc output voltage. If the output voltage tends to rise or fall, the PWM changes the duty cycle so that the dc output voltage remains constant.

An isolation circuit is required to maintain isolation between the output ground and the power supplied to the power supplies components. Usually, an optocoupler provides the isolation while permitting the feedback voltage to control the supply's output.

The inductor-capacitor low pass output filter converts the switched voltage from the switching transformer to a dc voltage. The filter is not perfect so there is always some residual output noise called ripple. The amount ripple depends on the effectiveness of the low pass filter at the switching frequency. Power supply switching frequencies can range between 100kHz to over 1MHz. Higher switching frequencies allow the use of lower value inductors and capacitors in the output low pass filter. However, higher frequencies can also increase power semiconductor losses, which reduces power supply efficiency.

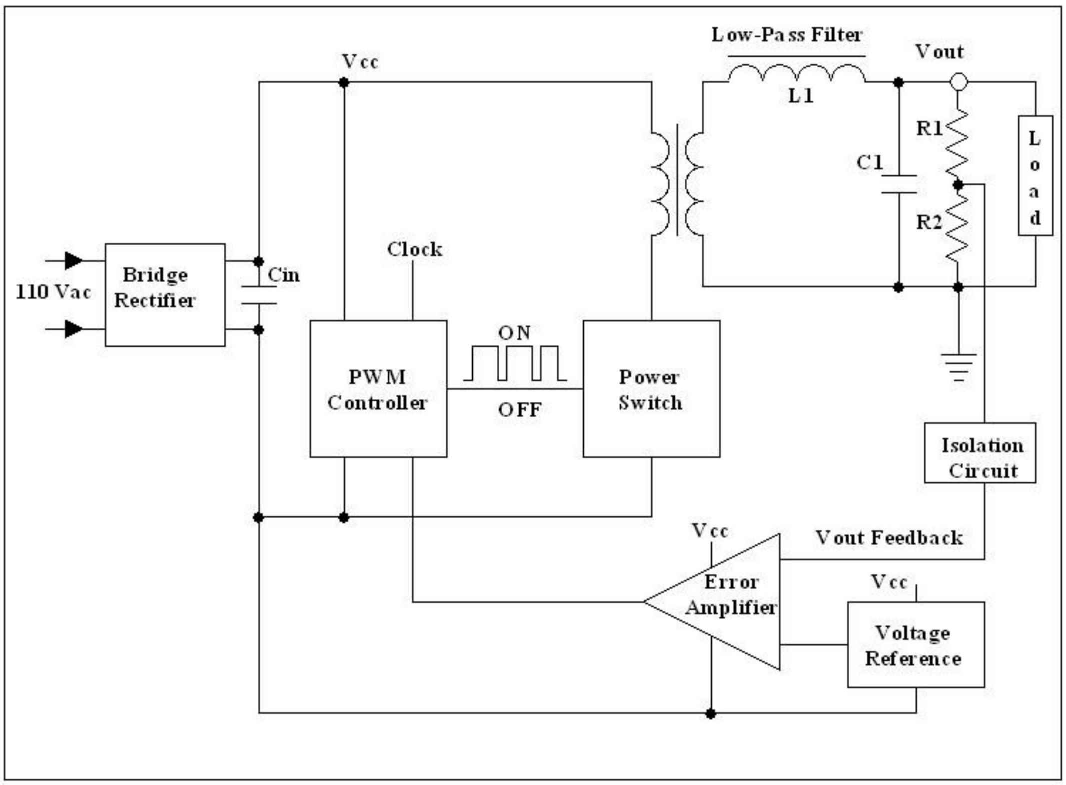

Figure 1-2.*Typical Isolated AC-DC Switch-Mode Power Supply*

The power switch is key component in the power supply in terms of power dissipation. The switch is usually a power MOSFET that operates in only two states - on and off. In the off state the power switch draws very little current and dissipates very little power. In the on state the power switch draws the maximum amount of current, but its on-resistance is low, so in most cases its power dissipation is minimal. In the transition from the on state to the off state and off to on the power switch goes through its linear region so it can consume a moderate amount of power. The total losses for the power switch is therefore the sum of the on and off state plus the transition through its linear regions. The actual losses depend on the power switch and its operating characteristics. **Table 1-1** compares the characteristics of isolated, ac-dc linear and switch-mode power supplies.

Parameter	Linear Power Supply	Switch-Mode Power Supply
Size	Can be twice the size	Half the size
Weight	Heavier because of ac input power transformer	Higher frequency, lower weight switching transformer
Efficiency	50-70%	80-90+%
Design Complexity	Simpler	More Complex
EMI	“Quiet” (None)	More (depends on switching frequency and layout)

Table 1-1. *Linear vs. Switch-Mode Power Supply Comparison*