Power Integrated Circuits

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Introduction

Team Cornflower has been working on a bike safety system that focuses on an improved headlight and taillight. The system also includes Lidar blind spot detection, projected laser lines, and wireless communication. Each of these components requires power to operate. Power integrated circuits (Power ICs) are crucial to circuitry as the available source inputs (voltage or current) may not be exactly what a component requires to function.

Circuit Basics

Electrical circuits are used to transmit power, where power (P) is defined as current (I) times voltage (V).

$$P = I * V \qquad (1)$$

Circuits can be made up of many components; some of the most common are wires, batteries, switches, resistors, capacitors, inductors, and diodes. Wires, batteries, and switches are common in everyday life, however the other parts listed are not so universally seen or known.

Resistors are a passive component that resist electric flow, similar to a mechanical shock absorber. In circuit analysis, resistance (R), current, and voltage are often examined based on their relationship with each other:

$$V = I * R \qquad (2)$$

Capacitors are an active component that can store an electric charge. A capacitor can charge and discharge based on what is happening in the circuit. Similar to capacitors, inductors can store an electric charge and charge or discharge based on what is occurring in the circuit. However, the way in which capacitors and inductors store electric charge is different and the two components have different voltage and current properties. Diodes are an electrical component that typically only allow for current to flow in one direction. A widely used type of diode is a light emitting diode, also known as an LED. While there are many different components that can go into a circuit these are the crucial ones to understanding power ICs.

One important piece of information to note is that an integrated circuit is an electronic circuit put together in one, small chip. They have pinouts that can be connected to a larger circuit made up of discrete components. Integrated circuits save space and can have many different functions. Power ICs focus on altering the voltage or current input so that it fits what is required of the larger circuit as a whole.

Power Conversion

To understand the operation of power ICs, some of the basics behind power conversion must be understood. The law of inductance states that a time varying current will flow when a voltage is forced across an inductor, providing the equation:

$$V = L\frac{di}{dt} \qquad (3)$$

The di/dt term is the measure of how the current changes with time and is only linear when the voltage is constant.

Pulse width modulation (PWM) is a form of output voltage regulation where a feedback loop adjusts the output voltage by varying the on time of a switching element.

A transformer can be used to alter a time-varying voltage or current. The turn ratio of the transformer determines how the voltage or the current is increased or decreased. When there are more turns the voltage is increased and the current is decreased, while the opposite is true for transformers with a smaller turn ratio. However, the overall power on both sides of a transformer is constant as the voltage and current are altered but retain the relationship shown in formula (1).

Switching Regulators

Switching regulators use a power supply and a switching device to alter current or voltage. They are flexible in their abilities, which makes them a popular choice to use in power ICs. When the switching device is "open," current is prevented from flowing and when "closed," current is allowed to flow with very low resistance. The high efficiency of switching regulators is due to the low resistance allowing for power dissipation to be low across the path as well. Switching regulators come in many different topologies, with the two most common being the buck converter and the boost converter.

Buck Converter

A buck converter (Figure 1) reduces an input voltage to produce a lower output voltage. This is necessary when an available source voltage is higher than a circuit or component can safely handle. A buck converter supplies this reduced voltage to a load, modeled as a resistor. When the switch is closed, the input voltage is sent to the inductor to charge it and then to both the capacitor and the load (Figure 1a). When the switch is open, the input voltage can no longer flow (Figure 1b). However, due to the previously mentioned law of inductance, the current across the inductor cannot change instantaneously. Thus, the inductor will discharge its stored electric charge creating a current flow to the capacitor and the load.

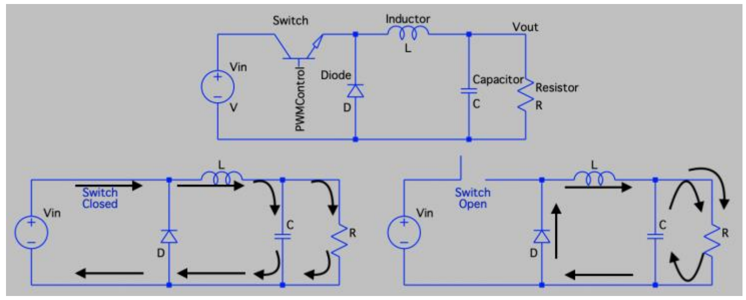

Figure 1. Top is a full schematic of a buck converter. Lower left (1a) depicts current flow (black arrows) when the switch is closed. Lower right (1b) depicts current flow when the switch is open.

Boost Converter

A boost converter (Figure 2) increases a voltage input in order to produce a higher output voltage. This is necessary when an available source voltage is lower than a circuit or component can operate with. A boost converter supplies this increased voltage to a load, modeled as a resistor. When the switch is closed, the input voltage is sent to the inductor and down the low resistance closed switch path (Figure 2a). During this time the capacitor will discharge its stored electric charge creating a current flow to the load. When the switch is open, the input voltage no longer provides voltage (Figure 2b). However, the current across the inductor decreases over time causing it to discharge, thus providing a current flow to the capacitor and the load.

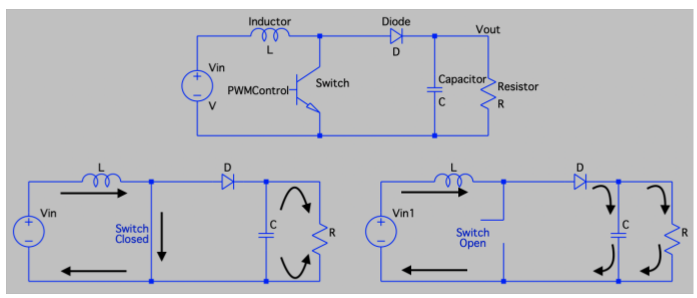

Figure 2. Top is a full schematic of a boost converter. Lower left (2a) depicts current flow when the switch is closed. Lower right (2b) depicts current flow when the switch is open.

Conclusion

Once the power needs (voltage and current) of a circuit are determined, a power IC that fits the needs within its range can be chosen. The power IC will then utilize external components which the user may choose based off the IC's datasheet to create the desired output voltage and current.

Power ICs are very useful as the available source inputs are rarely exactly what is needed for the creation of a new electrical circuit.

References

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