Switched Mode Power Supplies for DC to DC Conversion

Introduction

The widespread use of battery operated portable devices such as cell phones and laptops has created the need for DC to DC conversion power supplies such as switched mode power supplies. According to an Electric Power Research Institute (EPRI) study [1], the amount of electricity that flowed through switched mode power supplies in 2004 was “6% of the national electric bill”. The prominence of distributed energy sources such as solar photovoltaic systems, which produce DC power has created a demand for DC to DC converters. This paper briefly reviews the technology used in switched mode power supplies for DC to DC conversion for transferring energy from input to output. The paper will focus on the use of switched mode DC to DC converters to increase or decrease the output voltage as compared to the input voltage and for providing impedance matching.

Commercial Applications

DC to DC converters have a wide range of applications in power supplies for devices with batteries such as cell phones and laptops, connecting PV (photovoltaic) sources to the electricity grid or a battery bank, in battery connections in hybrid electric cars, and in providing the desired impedance for Maximum Power Point Tracking in solar PV modules. Plug in hybrid cars accept AC power from the grid and utilize a combination of AC to DC and DC to DC converters to charge a battery. In hybrid cars such as the RX400h by Lexus, a boost (step up) dc-dc converter is used “to increase the voltage for the inverters to 650 V DC” [2].

In batteries, switched mode DC to DC converters are needed for charging at the required potential. Solar hybrid cars are powered by solar cells. The DC power obtained from solar cells is used to charge a battery onboard the car. The voltage obtained from the solar panel has to be scaled to the battery voltage using DC to DC converters. Solar photovoltaic systems require the implementation of Maximum Power Point Tracking (MPPT) algorithms in order to extract the maximum power out of a solar array. MPPT is achieved by “the insertion of a power converter between the PV array and load, which could dynamically change the impedance of the circuit by using a control algorithm” [3].

Switched mode DC to DC converters are available from manufacturers such as Maxim Integrated Products and include the MAX 15046 step down converter [4] and the MAX 668 step up converter [5]. The MAX 15046 has a unit price of $3.2125 upon the purchase of 2500 units [6], whereas the MAX 668 has a unit price of $2.65 upon the purchase of 5000 units [7].
Underlying Technology

Switched mode DC to DC converters enable the transfer of power from input to output, increasing or decreasing the output voltage and providing the required impedance to the input. The basic circuit topology of a switched mode DC to DC converter includes an inductor-capacitor (LC) circuit with a switch that is externally controlled and a diode to determine the direction of current flow. Operation of the DC to DC converter is dependent on the transient nature of the inductor current caused by flipping the switch. The switch is controlled by a PWM (Pulse Width Modulation) signal. Depending on the frequency and the duty cycle of the PWM, the desired level of impedance can be achieved and the voltage modified. The ratio of output voltage to input voltage is determined by the duty cycle of the PWM signal.

The different circuit topologies for switched mode DC to DC converters are buck, boost and a combination of buck and boost converters. The buck converter is used to step down the voltage [8]. The boost converter is used to step up the voltage [8]. A single circuit can perform both buck and boost functions and in the case of a battery can operate “as a buck converter in the battery charge mode and as a boost converter when the battery must supply the load (RL) or when the load energy demand is higher than the energy generated” by an external source such as a solar cell [3].

Switched mode DC to DC converters are characterized by their range of input and output voltages, switching frequencies, and conversion efficiency. The step down MAX 15046 accepts input voltages of 18V to 36V and supplies an output voltage of 1.2V [4]. The MAX 15046 operates on a switching frequency of 250 kHz and has a power conversion efficiency ranging from 74% to 82% [4].

Implementation of Technology

Switched mode power supplies achieve DC to DC conversion by the use of linear circuit elements (such as capacitors and inductors) and non-linear elements (such as diodes and MOSFET based switches). In order to increase the efficiency of conversion, a Schottky diode or a MOSFET as a rectifier (synchronous rectifier) is used instead of a regular diode [9]. Depending on the circuit topology, a buck converter, a boost converter, or a combination of the two may be created. The external PWM control is obtained from a control unit such as a microcontroller. In a DC to DC converter for a Maximum Power Point Tracker, the duty cycle of the PWM is varied to achieve the required impedance level. In order to check performance, a control system is used to constantly monitor output voltage and accordingly correct the PWM signal provided to the DC to DC converter. A parallel system of DC to DC converters can be used to accommodate multiple power sources such as different arrays of solar cells. The combination of low loss components such as MOSFET rectifiers, the PWM external control signal and continuous monitoring of the output voltage creates an efficient switched mode DC to DC converter to modify the output voltage and provide impedance matching.
References


