Tiny Controller Makes It Easy to Charge Large Capacitors

by David Ng

Introduction

Emergency warning beacons, inventory control scanners, professional photoflash and many other systems operate by delivering a pulse of energy to a transducer. This energy typically comes from a large capacitor that has been charged to some predetermined voltage.

The LT3750 is a current-mode flyback controller optimized for charging large value capacitors to a user selected target voltage. This target voltage is set by the turns ratio of the flyback transformer and just two resistors in a simple, low voltage network, so there is no need to connect components to the high voltage output. The charging current is set by an external sense resistor and is monitored on a cycle-by-cycle basis. The LT3750 is available in a space saving MSOP-10 package.

The device is compatible with a wide range of control circuitry, being equipped with a simple interface consisting of a CHARGE command input bit and an open drain DONE status flag. Both of these signals are compatible with most digital systems, yet tolerate voltages as high as 24V.

Simple 300V, 400µF Charger

Figure 1 shows the schematic of a LT3750 circuit that charges a 400µF capacitor to a target voltage of 300V. The 1:10 turns ratio of T1 and the R1, R2 resistors set the target voltage to 300V, while the R4 power resistor sets the peak charging primary current to 7.5A.

Operating from a 12V power source, this circuit charges the 400µF capacitor to 300V in 1.04 seconds, as shown in Figure 2.

Design Considerations

The architecture balances a high degree of integration with flexibility—leaving key parameters definable by the user. The important issues to
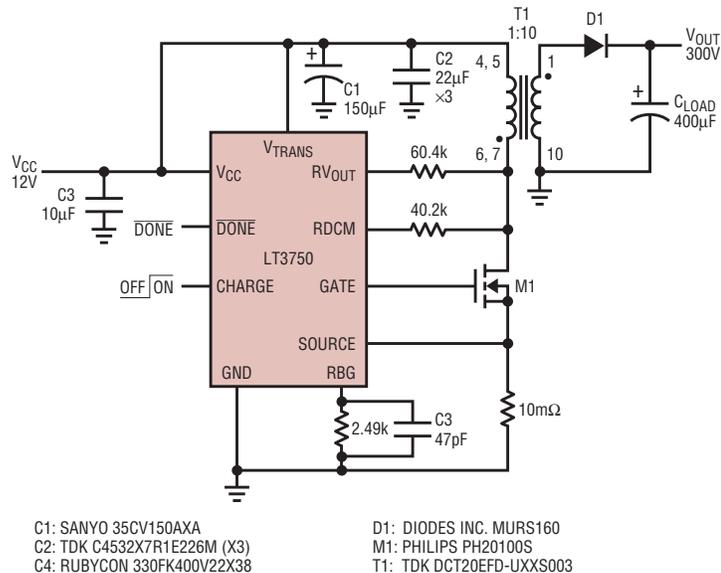

C1: SANYO 35CV150AXA
C2: TDK C4532X7R1E226M (X3)
C4: RUBYCON 330FK400V22X38

D1: DIODES INC. MURS160
M1: PHILIPS PH20100S
T1: TDK DCT20EFD-UXXS003

Figure 1. Simple circuit charges a 400µF capacitor.

consider in completing a design are input capacitor sizing, transformer design and output diode selection.

Power Stage Input Capacitor

Every switching cycle, the LT3750 measures the voltage at its RV_{OUT} pin to determine the transformer, T1, flyback voltage. It also measures the signal at its V_{TRANS} pin, which is the voltage at the input of the power switching stage. The difference of these two signals, accounting for the T1 transformer turns ratio and the D1 rectifying diode, yields the output voltage. In order to get an accurate result, it is important that the signal at the LT3750's V_{TRANS} input

optimally reflects the DC potential of the power stage input. Consequently, the capacitance at the input of the power switching stage must be chosen such that the ripple voltage at the V_{TRANS} input is not excessive. The capacitor bank in the circuit represented by Figure 1 is actually made of five capacitors. C1 is a single 150µF electrolytic capacitor to provide bulk energy, C2 is three low ESR 22µF ceramic capacitors to accommodate the high switching currents, and C3 is low ESR 10µF ceramic capacitor that provides local decoupling to the LT3750. For best results, place C1 and C2 as close as possible to T1, and C3
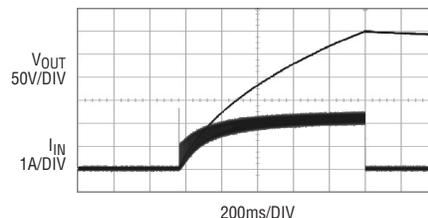

Figure 2. Output voltage and input current waveforms of LT3750 capacitive charging circuit
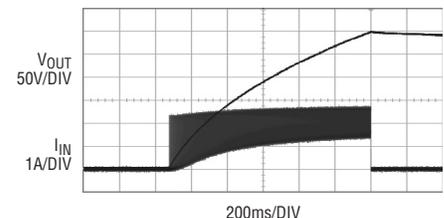

Figure 3. A transformer with a 51µH primary inductance has a longer charge time and larger input current ripple than a transformer with a 10µH primary inductance.

as close as possible to the V_{TRANS} pin on the LT3750.

Transformer

Other than the turns ratio, there are two issues to remember when selecting a transformer. The first is that the transformer secondary must be constructed to withstand potentials of both the positive and negative voltages associated with charging the capacitor. This withstand voltage is not the same as the isolation voltage rating. In the case of the circuit shown in Figure 1, there is no isolation voltage requirement, as the primary and secondary of T1 are tied to the same ground reference. The secondary winding, however, is subjected to the output potential, or 300V, and care must be taken in selecting for parameters relevant to such high voltages, such as pin spacing and wire insulation.

The other transformer parameter to keep in mind is the primary inductance. The primary inductance determines the operating frequency range, input current ripple and core loss, all of which contribute to the capacitor charge time and efficiency. The charging profile shown in Figure 2 is for a circuit using a transformer with a primary inductance of 10µH. Figure 3 shows the charging profile for the same circuit, but the primary inductance is much larger, 51µH. Note that the 51µH transformer has a longer charge time than the 10µH transformer.

Table 1. Summary of input charging current and charge times for LT3750 circuits for transformers with different primary inductances

Transformer	Primary Inductance	Input Charging Current	Input Charging Current Ripple	Charge Time
TDK DCT20EFD-UXXS003	10µH	2.2A	0.5A	1040ms
Coiltronics CTX02-17314	15µH	2.2A	0.4A	1000ms
Coiltronics CTX02-17144	51µH	2A	1.4A	1120ms

Table 1 gives a summary of the input charging current and charge times for LT3750 circuits for three different T1 primary inductances, with the 15µH device giving the best result.

Output Diode

Finally, it is important to consider the high AC voltages when selecting the output rectifying diode. The circuit in Figure 1 has a 300V output, but the output rectifying diode must withstand the sum of the output voltage and the voltage across the transformer secondary when the MOSFET Q1 is on. In this case, that is about 500V. This is a high voltage, but there are many manufacturers that produce switching diodes suitable for this application.

While it is important to minimize board space, the designer must choose a device that does not cause a violation of the spacing requirements for both safety and producibility. According to table 6-1, "Electrical Conductor Spacing," of *IPC-2221, Generic Standard on Printed Circuit Board Design* (February 1998 release), the minimum spacing between conductors that have a potential up to 500V must be no less than 2.5mm on an uncoated printed circuit board operated below an altitude of 3050m. The output diode must be chosen to ensure that the minimum spacing between the diode pads is at least 2.5mm.

The circuit shown in Figure 1 uses a MURS160, which is offered by a number of manufacturers such as Diodes Inc and Vishay. It is an ultrafast recovery rectifier and has a peak repetitive reverse voltage rating of 600V. The diode comes in an SMB package, which allows the edge-to-edge separation between the pads to be as much as 3mm. ☐

can be used in place of this MOSFET, if the additional voltage drop can be tolerated when running the application from the battery.

Micropower Features Support Extended Battery Use

The LTC4011 has a typical shutdown supply current of 3µA and normally draws much less than 1µA from the SENSE/BAT pin combination when the DC input supply has been removed. In addition, the V_{CDIV} pin offers a means of disconnecting the

V_{CELL} resistor divider in the shutdown state, eliminating the current drawn by that circuit when charging is not possible. These features greatly minimize the load applied to the battery by the charger when disconnected from a DC power source, increasing the useable run time of the battery in portable applications.

Conclusion

The LTC4011 is a nickel chemistry charger that integrates a complete high voltage PWM controller, allowing it to efficiently charge batteries from a 34V input without the need for additional current source control ICs. True standalone operation and flexible control greatly simplify charger design. The PWM operates at a high frequency, enabling the use of surface mount components to save space. Reliable, robust charge termination algorithms backed by solid safety features make the LTC4011 an excellent choice for a wide range of fast charge implementations, providing long life for rechargeable nickel batteries. ☐