

# PCMCIA Card and Card Socket Power Management

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## INTRODUCTION

Most portable computers have built-in sockets to accept small PC cards for use as extended memories, fax modems, network interfaces, wireless communicators and a wide assortment of other functions. The Personal Computer Memory Card International Association (PCMCIA) has released specifications that outline the general power requirements for these cards.

The specification calls for an unusual amount of voltage switching. Both supplies are switchable to different voltages to accommodate a wide range of card types. The  $V_{CC}$  supply must provide either 3.3V or 5V. The VPP supply must source 12V, 3.3V, 5V, 0V and realize a high impedance state. These diverse, specific requirements call for specialized solutions.

PC card designers may want to design their cards to require the  $V_{CC}$  supply only. Flash memory card designers who need to ensure a clean VPP supply may generate their own 12V on the card. Type I PC cards, at an outside thickness of 3.3mm, require ultra-thin highly efficient circuitry. The DC/DC converter IC, inductor, capacitors and diodes are critical components that require unique design to meet the stringent height requirements.

## PCMCIA SOCKET POWER MANAGEMENT

### PCMCIA Specification Voltage Switching Requirements

Host power delivery to the PC card socket flows through two paths: the main  $V_{CC}$  supply pins and the VPP programming pins. Figure 1 shows a typical system's connections. The  $V_{CC}$  supply must be capable of providing up to 1A at either 3.3V or 5V. The latest specification has provisions for a future voltage referred to as X.XV (X.X to be less than 3.3V). The actual voltage value will be determined at a later date. The VPP supply must source 12V at up to 120mA, the  $V_{CC}$  voltage at lesser currents, 0V and realize a high impedance state.

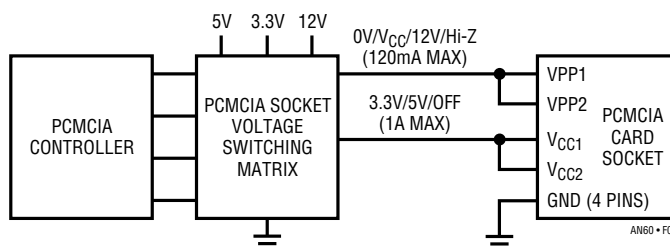


Figure 1. Typical Single Socket Power Management

The PCMCIA specification requires the  $V_{CC}$  voltage to be selectable from 3.3V, 5V or an off state. The X.X voltage of the future will not be addressed until the voltage has been defined. The specification does not outline any current draw requirements. The industry standard maximum current that the socket will support is 1A. This number is derived from the maximum connector rating of 500mA per pin and assumes both pins in good condition with current being shared equally. In practice this amount of current draw is exceptional and should not be encouraged for continuous use. One of the most stringent actual requirements is a Type III hard disk drive card. Present hard drives require 5V at 600mA to 820mA for a short duration during spin-up with current draw dropping to 300mA to 420mA during read and write operations.

The PCMCIA specification requires the VPP voltage to be selectable from 0V,  $V_{CC}$ , 12V or a high impedance state. Again, the specification does not outline any current draw requirements. The VPP voltage's primary use is for programming flash memory with the current requirements derived from the flash memory needs. A single byte wide flash memory device will require 12V at 30mA for write or erase operations. The PC card bus is 16-bits wide necessitating two flash devices being written to at the same instant. A standard flash memory card will require at least 60mA of current during write or erase operations. Many flash cards designed as solid state disc drives, often referred to as ATA

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flash drives, will have two 16-bit wide banks of memory to facilitate simultaneous writing and erasing. This speeds card operation but will double the current requirement. These cards will draw 120mA while writing/erasing.

## Additional Practical Considerations

While the PCMCIA specification provides the basis for the voltage switching requirements, there are many real world requirements that must also be considered. These issues include switch resistance, inrush current during voltage switching, voltage ringing during switching, short-circuit protection and cost effectiveness as a system, not just the function.

The MOSFET switch on-resistance  $R_{DS(ON)}$ , should be low enough to maintain the correct voltage tolerance at the card input. The most critical case is when the  $V_{CC}$  is 5V. The specification requires the voltage to be  $5V \pm 5\%$  ( $\pm 0.25V$ ). The most stringent requirement would be during hard disk drive spin-up where the card can pull up to 820mA. Many systems will have a main supply with a tolerance of  $\pm 2\%$ . When the main power supply is at its minimum value of 4.90V, this leaves only 0.150V maximum voltage drop across the switch. To ensure that the hard drive will spin-up without dropping the voltage below 4.75V the switch on-resistance must be less than  $0.183\Omega$ . To ensure operation at the 1A limit the switch on-resistance must be less than  $0.150\Omega$ . It is common practice to raise the nominal voltage slightly above 5V to relax the voltage tolerance. For example, raising the nominal voltage to 5.10V will allow the tolerance to increase to  $\pm 4\%$ .

The nature of PC cards and portable systems requires the card being powered on and off as needed to conserve power. With many PC cards drawing up 2W, this power up/down sequencing can put demanding transient requirements on your system power supply. More important than the static current requirement of the card is the dynamic requirement due to input capacitance. Cards will have up to  $150\mu F$  of input capacitance. This large capacitor coupled with a fast switch will pull many amperes of current from the system supply. With a simple switch the only factors limiting the inrush current are the switch's rise time, the switch's  $R_{DS(ON)}$ , the card input capacitor value and the input capacitor's equivalent series resis-

tance (ESR). Many large input capacitors will be for on-card switching power supplies and will likely have an ESR in the  $0.1\Omega$  range. As noted above, the switch's  $R_{DS(ON)}$  would be  $0.183\Omega$  or lower. These low resistance values will do little to limit the inrush current. In a simple switch, this leaves rise time as the only parameter that can keep inrush current to manageable levels. More sophisticated switches will also employ current limiting. Many simple switches, without current limiting, have rise times as fast as  $100\mu s$ . This gives a peak current of over 7A! With the rise time slowed to  $500\mu s$ , the peak current is down to a reasonable 1.5A. Current limiting will protect the system against even larger input capacitors. To make the transient response of the system supply manageable, the PCMCIA switch should have a controlled, slowed rise time and current limiting. Slowed rise time and current limiting eliminate inadvertent system resets triggered by a momentary pull on the main supply.

The VPP lines also require slowed switch rise times. The VPP pins are for flash memory programming and will not have excessive input capacitance. As such, inrush current is not a major issue. The switch times must be slowed to avoid voltage ringing and overshoot at the flash memory device. The flash memory device has a 14V absolute maximum input voltage specification. Voltages beyond this limit, for as little as 20ns, can permanently damage the device. If the switch has a fast rise time there will be ringing due to the trace and connector inductance. It will take only a couple of inches of trace to form enough inductance to cause excessive ringing. For this reason the VPP switch must have a controlled, slowed rise time.

The PCMCIA socket will usually have a small door to protect it from unwanted objects entering. Other than this door, the socket pins are exposed to the outside world. The exposed socket pins are vulnerable to being shorted by foreign objects such as paper clips. The card installer is generally not trained and may have little or no technical knowledge. Some users may attempt to install damaged, possibly short-circuited cards. In short, once the product is in the hands of the consumer, the designer and manufacturer have little control over its use and abuse. To ensure a robust system and satisfied customer, PCMCIA switch protection features such as current limiting and thermal shutdown are

a necessity. These features will protect the card, socket and main system power supply.

System design issues also deserve consideration. The switch matrix's digital interface should connect directly to industry standard controllers. This may seem a trivial issue but additional glue logic will add unnecessary cost and consume real estate. The other system issue is the availability of a 12V supply. Some systems have a general purpose 12V supply in the system design from the start and there are only minor issues to consider. The flash memory devices have a strict  $12V \pm 0.6V$  specification for guaranteed programming. When the main 12V supply tolerance is added to the switch resistance, the main supply tolerance must be very tight. The voltage should also be free of excessive noise spikes that may exceed the flash device maximum voltage limit. In addition, some switch matrix devices need a constant 12V supply to operate while those incorporating on-chip charge pumps require 12V only during flash memory programming. Deriving the clean 12V supply in a simple, cost effective manner is a significant part of the design that must not be overlooked.

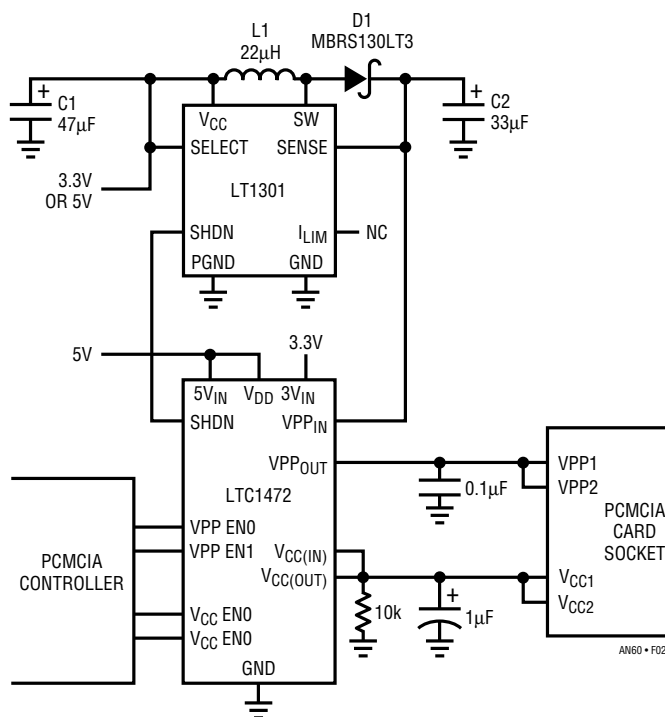
## LTC1472: Fully Protected Switch Matrix

The LTC<sup>®</sup>1472 is a complete  $V_{CC}$  and VPP switch matrix that addresses all the PCMCIA socket switching needs. The part is fully integrated with no need for external switching FETs.  $V_{CC}$  switch  $R_{DS(ON)}$  is below  $0.120\Omega$  to support the current requirement of up to 1A. The  $V_{CC}$  output is switched between 3.3V, 5V and high impedance. VPP 12V switch  $R_{DS(ON)}$  is below  $0.5\Omega$  to support its current requirement. The VPP output pin is switched between 0V,  $V_{CC}$ , 12V and high impedance. The  $V_{CC}$  logic inputs are exclusively OR'd to allow direct interfacing with both logic high and logic low industry standard controllers without any external glue logic. The LTC1472 is available in the space saving narrow 16-pin SOIC package.

The LTC1472 features SafeSlot<sup>™</sup> protection. Built-in SafeSlot current limiting and thermal shutdown features are vital to ensuring a robust and reliable system. The  $V_{CC}$  current limit is above the 1A socket limit to maintain compatibility with all existing cards yet provide protection

against inadvertent short circuiting. The VPP current limit is above 200mA to also maintain compatibility and provide protection. All switches are break-before-make type with controlled rise and fall times for minimal system supply impact. The LTC1472's slowed rise time combined with the current limiting minimizes inrush current to manageable levels. Slowed rise time on the VPP switch ensures smooth voltage transitions without damaging ringing and overshoot.

Figure 2 shows a typical LTC1472 application used in conjunction with the LT<sup>®</sup>1301 to supply the 12V input. The LT1301 is optional. If your system already has a suitable 12V supply it can be directly connected to the VPP<sub>IN</sub> pin. You should be cautious when using a general purpose 12V supply. Make certain that it does not have spikes or transients exceeding the flash memory 14V maximum voltage rating and that the regulation is within the 5% flash memory tolerance.



**Figure 2. Typical LTC1472 Application with the LT1301 3.3V/5V Boost Regulator**

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The LTC1472 does not require a continuous 12V supply. The device has on-chip charge pumps, running from the 5V supply for driving the switches. For this reason the LT1301 is in shutdown mode, consuming only 10 $\mu$ A, most of the time. The LT1301 becomes operational only when the controller programs the LTC1472 to deliver 12V to the VPP pin. The LTC1472 also conserves power by going to a low 1 $\mu$ A standby mode when both  $V_{CC}$  and VPP outputs are switched off. The schematic in Figure 2 includes a 10k pull-down resistor on the  $V_{CC(OUT)}$  pin. This resistor will ensure that when switching the  $V_{CC}$  voltage from 5V to the off state, the voltage will not float at 5V. The current PCMCIA specification requires the voltage be pulled down to 0.8V within 300ms when turned off. This pull-down resistor is adequate to ensure proper operation.

## LTC1470 $V_{CC}$ Protected Switch Matrix with the LT1312 VPP Linear Regulator

Another approach is to use a linear regulator for VPP voltages with a protected  $V_{CC}$  switch. The LTC1470 is a complete  $V_{CC}$  switch matrix. The part is fully integrated with no need for external switching FETs. Performance specifications are the same as the  $V_{CC}$  section of the LTC1472 described above. The LTC1470 is available in the space saving 8-pin SOIC package with a dual version, the LTC1471 in a 16-pin narrow SOIC. The LT1312 is a programmable output voltage linear regulator designed specifically for PCMCIA VPP drive applications. The LT1312 takes a raw, unregulated 13V to 20V input supply and produces a clean, regulated, selectable output voltage in conformance with the PCMCIA standard. It comes in an 8-pin SOIC with a dual version, the LT1313 in a 16-pin narrow SOIC.

The LT1312's VPP pins are programmable to provide either 0V, 3.3V, 5V, 12V or a high impedance state. Figure 3 shows the basic block diagram of the LT1312. Two enable inputs (EN0 and EN1) and the  $V_{CC}$  Sense inputs select these five states. The logic inputs interface directly with logic high and logic low industry standard controllers. When a  $V_{CC}$  voltage is selected, a comparator in the LT1312 automatically switches the  $VPP_{OUT}$  pin to 5V or 3.3V depending on the voltage present at the Sense pin. The LT1312 has a 200mA nominal output current capability with a 250mA short-circuit current limit and thermal shutdown. These protection features can be very important when considering the overall reliability and robustness of the main system. As shown in Figure 4, the rise time of the LT1312 is sufficiently slow to avoid ringing and overshoot. An additional feature of the LT1312 is its low 25 $\mu$ A quiescent current in 0V or high impedance modes.

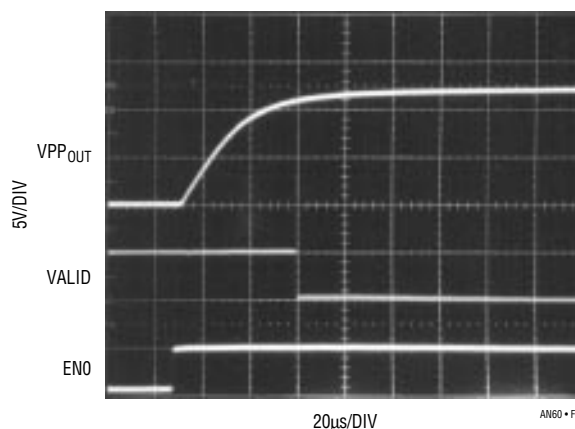


Figure 4. LT1312 VPP Switching Waveform

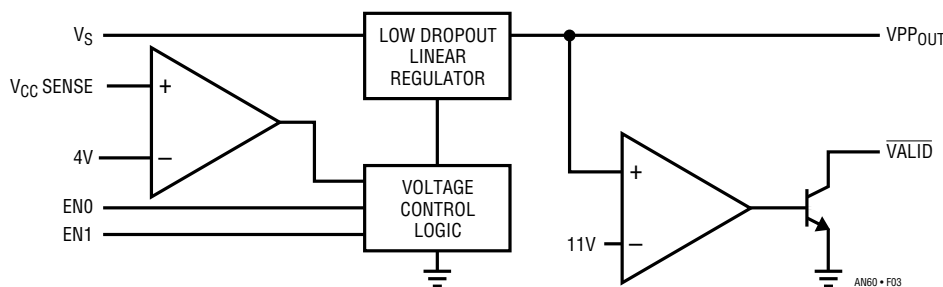
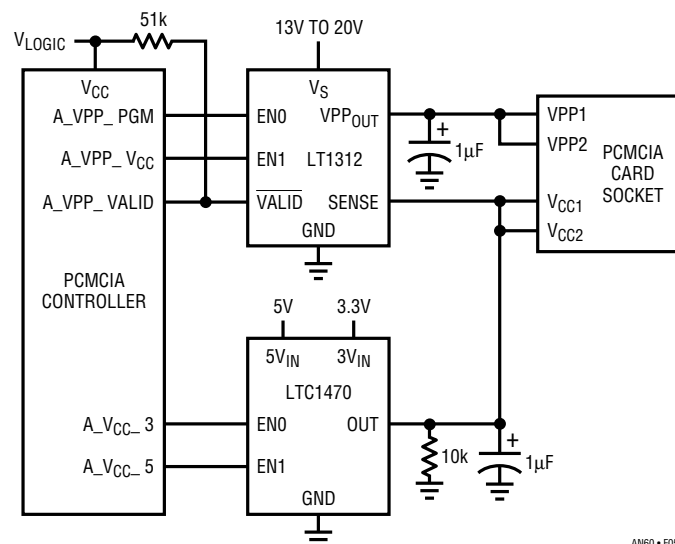


Figure 3. LT1312 Block Diagram

Like the LTC1472, the LTC1470 also features SafeSlot protection. The switches are break-before-make type with controlled rise and fall times for minimal system power supply impact. The built-in SafeSlot current limiting and thermal shutdown features are vital to ensuring a robust and reliable system. The LTC1470 also does not require a continuous 12V supply. The device has on-chip charge pumps running from the 5V supply for driving the switches.



**Figure 5. Typical LTC1470 Application with the LT1312 VPP Driver/Regulator**

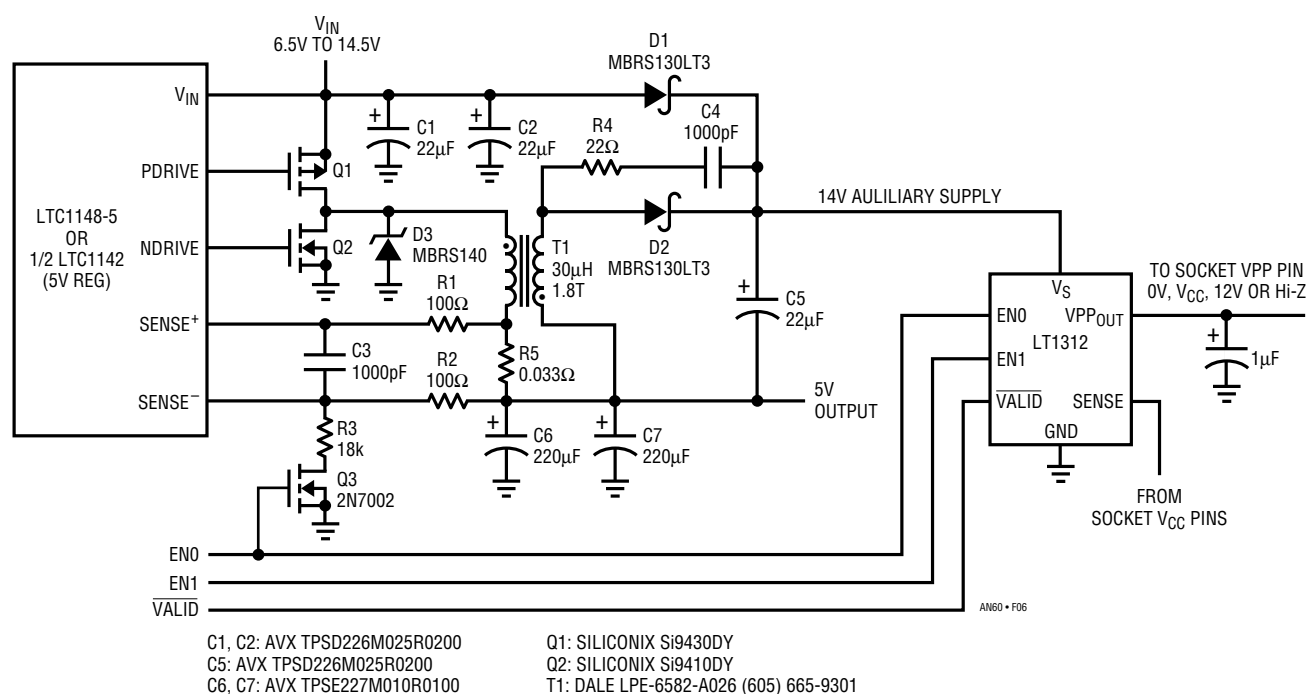
Figure 5 shows a typical LTC1470 application with the LT1312 used to control the VPP section. If your application does not require VPP switching, the LT1312 is eliminated. The LTC1470 conserves power by going to a low 1 $\mu$ A standby mode when the output is switched off. The schematic in Figure 5 includes a 10k pull-down resistor on the V<sub>CC(OUT)</sub> pin to guarantee that the V<sub>CC</sub> voltage will not float when turned off.

## Auxiliary Winding Power Supplies for Use with the LT1312

Because the LT1312 provides excellent output regulation, the input voltage may come from a loosely regulated source. One convenient and economic source of power is an auxiliary winding on the main 3.3V or 5V switching regulator inductor of the system power supply.

### LTC1142 or LTC1148-5 Auxiliary Winding Power Supply

An auxiliary winding to the 5V inductor of an LTC1142 or LTC1148-5 based 5V power supply creates a loosely regulated 14V power supply as shown in Figure 6. Diode D2 rectifies the 9V output from this additional winding adding it to the main 5V output. (Note the phasing of the auxiliary winding shown in Figure 6.)



### Figure 6. Deriving 14V Power from a 5V Auxiliary Winding

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Referencing the auxiliary winding to the main 5V output provides DC current feedback from the auxiliary supply to the main 5V section. Returning the lead of C5 to the 5V output as shown improves the AC transient response.

A TTL logic high on the enable line (EN0) activates the 12V output. This will force the 5V section of the LTC1142 (or LTC1148-5) into the continuous mode of operation. A resistor divider, composed of R2, R3 and switch Q3 forces an offset to counteract the internal offset at the –Sense input of the part. Burst Mode™ operation ceases when this external offset cancels the device's built-in 25mV offset forcing the switching regulator into continuous mode operation. (See the LTC1142 and LTC1148 data sheets for further detail.) In this mode, the LT1312's output can be loaded without regard to the 5V output load.

Only when the LT1312 delivers 12V is the continuous operation mode invoked. The LT1312's input power comes directly from the main power source (battery pack) through diode D1 when delivering 0V, 3.3V or 5V. Again, the LT1312 output can be loaded without regard to loading on the 5V output of the regulator. For cases of fixed  $V_{CC}$  voltage (i.e.,  $V_{CC} = 5V$  only), grounding the Sense pin of the LT1312 automatically selects 5V in the  $V_{CC}$  mode.

Figure 7 is a graph of the output voltage versus output current for the auxiliary 14V supply shown in Figure 6. Note that the auxiliary supply voltage is higher when the 5V

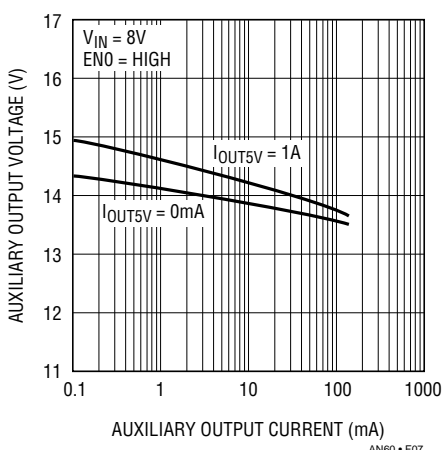


Figure 7. Auxiliary Winding Output Voltage vs Current

output loading is heavier. This is due to the increased energy flowing through the main 5V inductor.

## LTC1142 or LTC1148-3.3 Auxiliary Power for Low Input Voltage Applications

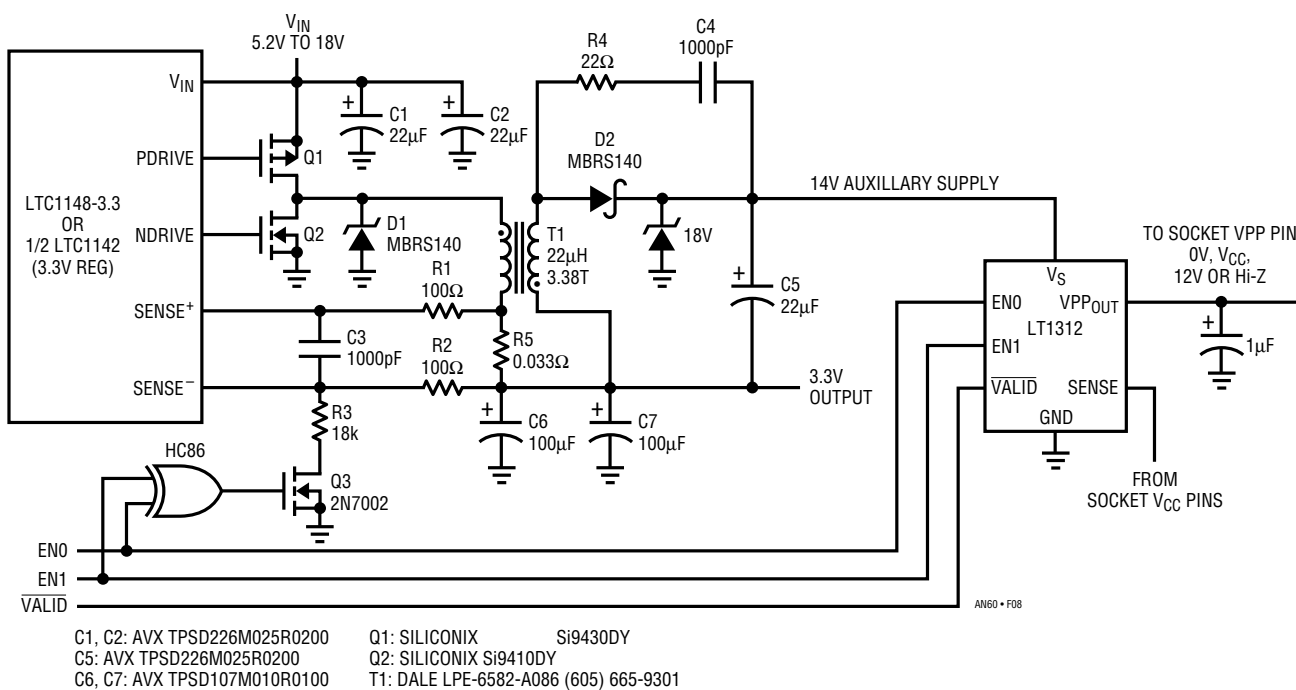
For low-battery count applications ( $<6.5V$ ) it is necessary to modify the circuit of Figure 6. As the input voltage falls, the 5V duty cycle increases to the point where there is simply not enough time to transfer energy from the 5V primary winding to the auxiliary secondary winding. For applications where heavy 12V load currents exist in conjunction with these low input voltages, the auxiliary winding can be derived from the LTC1142's 3.3V section or from an LTC1148-3.3 part. The 3.3V duty cycle is more than adequate to support 12V currents. Figure 8 shows this circuit. In this case a transformer with a turns ratio of 1:3.6 replaces the 3.3V section inductor. In the previous circuit, power is drawn directly from the batteries through D1, when the switching regulator (LTC1142 or LTC1148-5) is in Burst Mode operation and the VPP pins require 3.3V or 5V. For these lower input voltages this technique is invalid as the input will fall below the LT1312 linear regulator's dropout voltage. To correct for this situation, the switch Q3 forces the switching regulator into continuous mode operation whenever 3.3V, 5V or 12V is selected.

## Equipment with Existing 5V or 12V Supplies

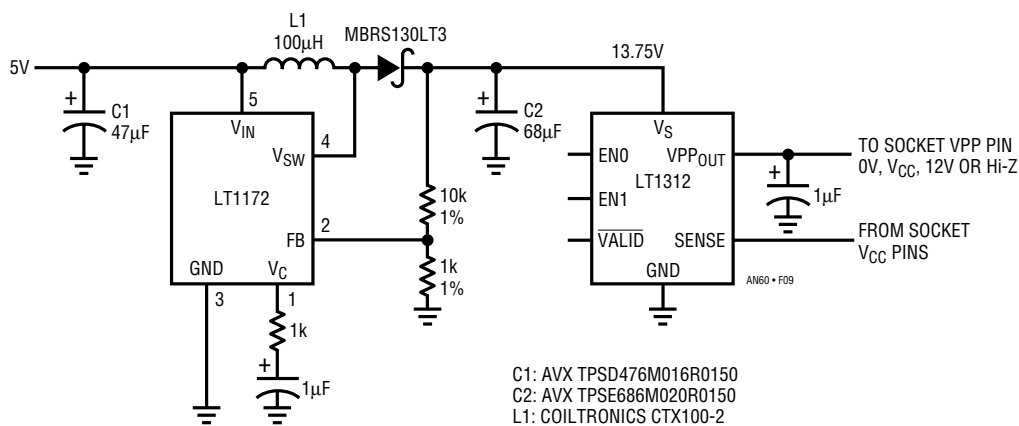
The previous circuits were solutions for portable equipment that require multiple supplies from battery power. For line-powered equipment or products that already have 5V available, the designer need only to generate a rough supply to utilize the LT1312. Figure 9 shows how to use the LT1172 as a boost regulator to convert the 5V input to 13.75V for use by the LT1312.

Some equipment such as PCs will have an existing 12V supply. More often than not this supply is noisy and not well regulated to the  $12V \pm 5\%$  flash memory specification. Figure 10 shows a solution utilizing the LT1111 boost regulator to deliver a 13.75V for input to the LT1312.

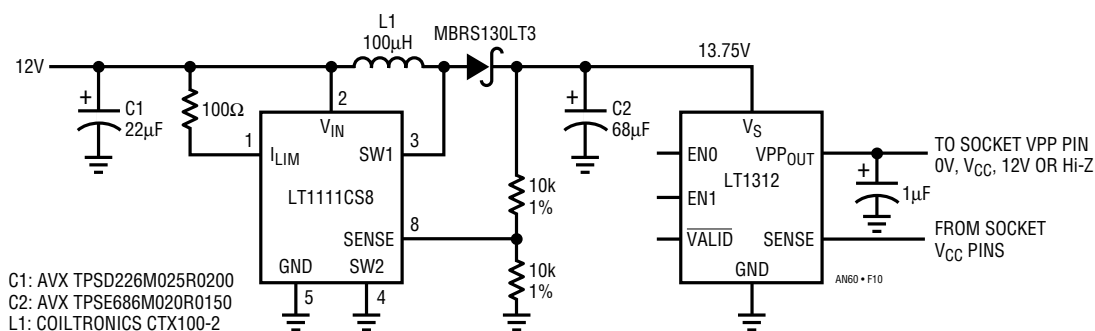
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### Figure 8. Deriving 14V Power from a 3.3V Auxiliary Winding



**Figure 9. Local 5V to 13.75V Boost Regulator for Use with the LT1312**



**Figure 10. Local 12V to 13.75V Boost Regulator for Use with the LT1312**

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## Dual Socket Design with the LTC1471 and LT1313

For applications requiring two PC card sockets the designer can use the dual versions of the LTC1470 and the LT1312. The LTC1471 dual  $V_{CC}$  switch matrix has the same performance characteristics as the LTC1470 and comes in the narrow body 16-pin SOIC. The LT1313 dual VPP regulator driver shares the same performance characteristics as the single version, the LT1312, and is also packaged in the narrow body 16-pin SOIC. Figure 11 shows a typical two-socket application using the LTC1471 for  $V_{CC}$  switching and the LT1313 regulating an overwinding to derive the VPP voltages. Performance is the same as if the single version were used but with some board space and cost savings realized.

## LTC1314: $V_{CC}$ Switch Driver and VPP Switch Matrix

Figure 12 shows another approach that is very space and power efficient. Here the LTC1314 PCMCIA switch matrix, used in conjunction with the LT1301 DC/DC converter, provides complete power management for a PCMCIA card socket. The LTC1314 and LT1301 combination provide a highly efficient, minimal parts count solution. This circuit is especially good for designers who are adding a PCMCIA socket to existing systems that currently have only 5V or 3.3V available. Table 1 shows the truth table for the LTC1314. The LTC1314's logic interface allows direct connection to active high  $V_{CC}$  or active low  $V_{CC}$  type controllers eliminating the need for additional glue logic.

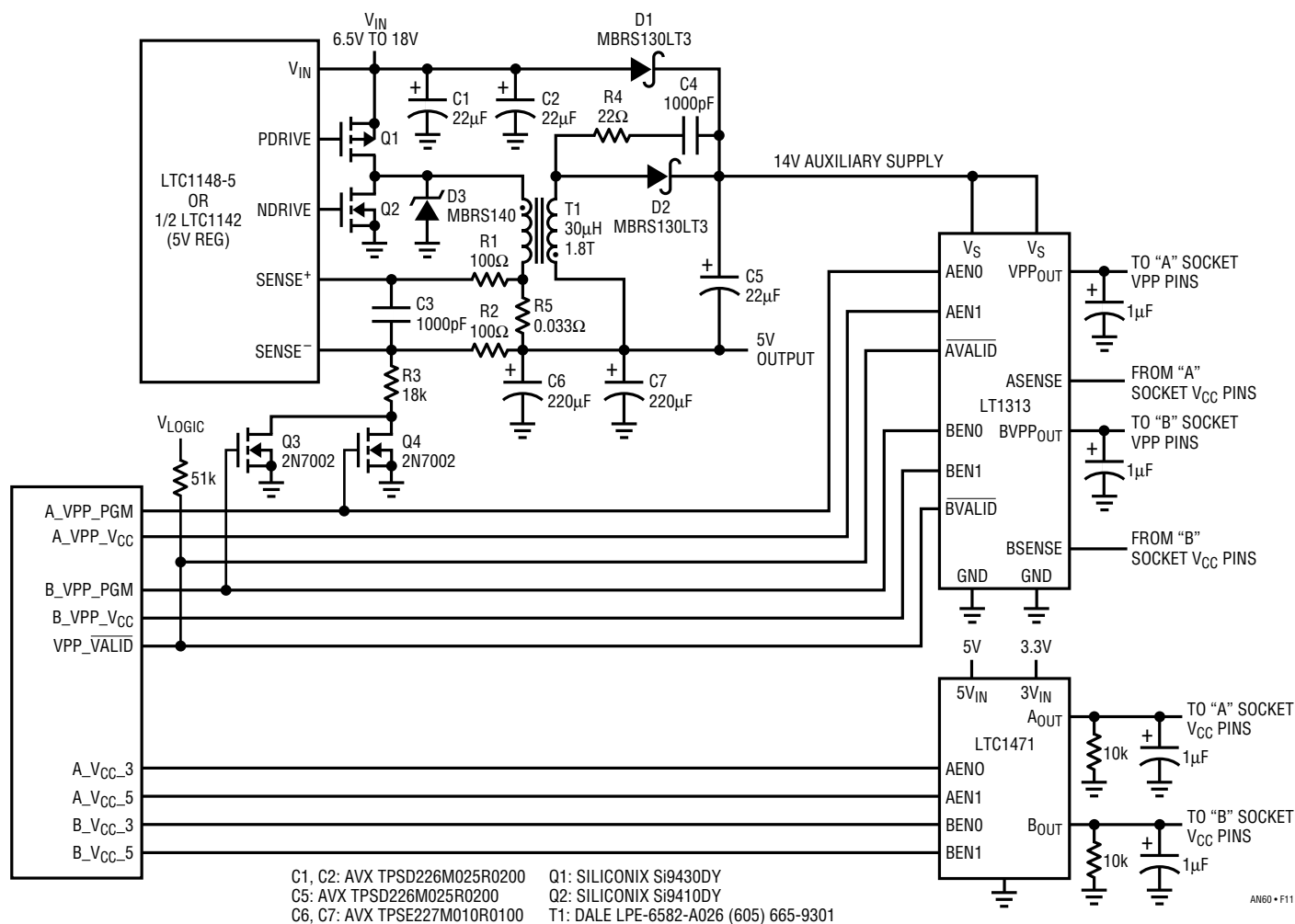
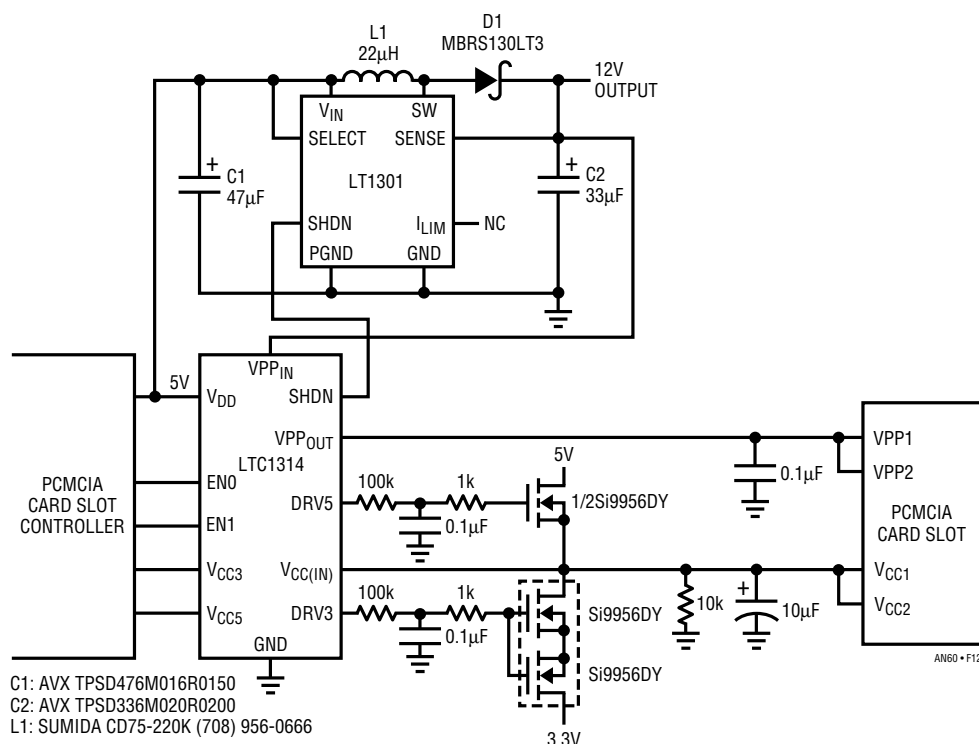


Figure 11. Typical Two-Socket Application with the LTC1471 and LT1313





### Figure 12. LTC1314 and LT1301 Configuration

### Table 1. LTC1314 Truth Table

EN0	EN1	V <sub>CC3</sub>	V <sub>CC5</sub>	VPP <sub>OUT</sub>	DRV3	DRV5
0	0	X	X	GND	X	X
0	1	X	X	V <sub>CC(IN)</sub>	X	X
1	0	X	X	VPP <sub>IN</sub>	X	X
1	1	X	X	Hi-Z	X	X
X	X	1	0	X	1	0
X	X	0	1	X	0	1
X	X	0	0	X	0	0
X	X	1	1	X	0	0

X = Don't care.

The LTC1314 drives three N-channel MOSFETs that provide  $V_{CC}$  pin power switching. On-chip charge pumps provide the necessary voltage to fully enhance the switches. With the charge pumps on-chip the MOSFET drive is available without the need for a 12V supply. This method of  $V_{CC}$  switching allows the use of fully enhanced N-channel MOSFETs for low on resistance and low cost. The LTC1314 provides a natural break-before-make action and smooth transitions due to the asymmetrical turn-on and turn-off of the MOSFETs.

The 3.3V  $V_{CC}$  switch must use two MOSFETs due to the parasitic body diode of the MOSFET. The on resistance of the 3.3V channel is still below  $0.18\Omega$ , adequate for any realistic current level. Different MOSFETs can be used for lower resistance. To limit the inrush current when charging capacitive loads, an RC network is inserted between the LTC1314 and the MOSFET's gate. This will slow the rise time down to a couple of milliseconds. Inrush current is limited only by slowing down the rise time. With a  $150\mu\text{F}$  input capacitor and the 2ms rise time, the inrush current is limited to just 275mA.

The VPP switching is accomplished by a combination of the LTC1314 and LT1301 DC/DC converter. The LT1301 DC/DC converter is in shutdown mode, consuming only 10µA, to conserve power until the VPP pins require 12V. When VPP pins require 12V, the LT1301 is activated and the LTC1314's internal switches will route the VPP<sub>IN</sub> pin to the VPP<sub>OUT</sub> pin. The LT1301 is capable of delivering 12V at 120mA maintaining high efficiency as shown in Figure 13. As shown in Figure 14, the LTC1314's break-before-make and slope-controlled switching will ensure that the

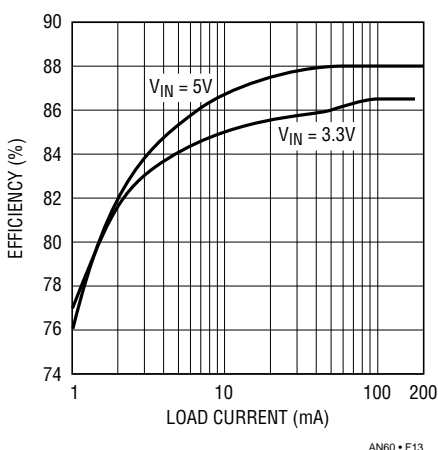


Figure 13. 12V Efficiency of LT1301

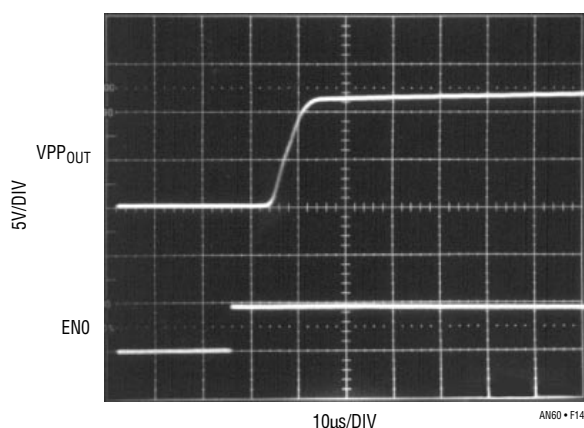


Figure 14. LTC1314/LT1301 VPP Switching Waveform

output voltage transition will be smooth, of moderate slope, and without overshoot. This is critical for flash memory products to prevent damaging parts from overshoot and ringing exceeding the 14V part limit.

The LTC1314's  $VPP_{IN}$  pin may be connected directly to a stable 12V supply. However, this should be done with caution. The 12V supply available with most computer systems has an excessive voltage tolerance and is accompanied by significant digital switching noise. The specification for flash memory requires  $12V \pm 5\%$ . Voltages greater than 14V will result in damaged memory

devices. When using a general purpose 12V supply, make certain that you meet these criteria to ensure a safe, robust system.

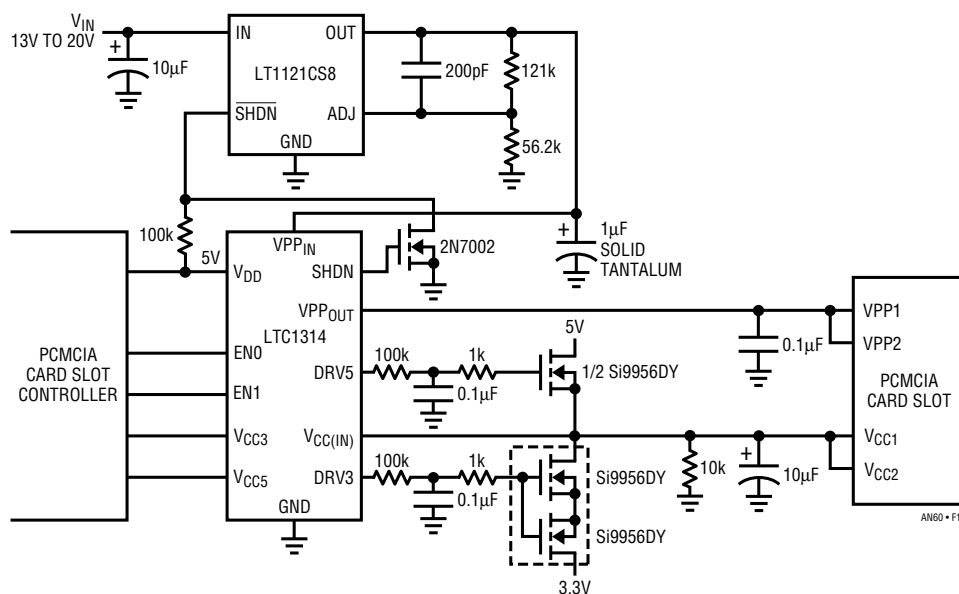
The major characteristics of the previous designs that are missing are current limiting and thermal shutdown. The low cost approach does not have these features and is susceptible to short-circuit connections at the pins and excessive inrush current if extremely large capacitive loads are experienced. This may be acceptable in some systems if the main supply is carefully current limited to maintain operation or if some other form of protection is added. Care should be exercised when allowing exposed external pin connections to go without short-circuit protection.

## The LTC1314 with Higher Voltage Supplies Available

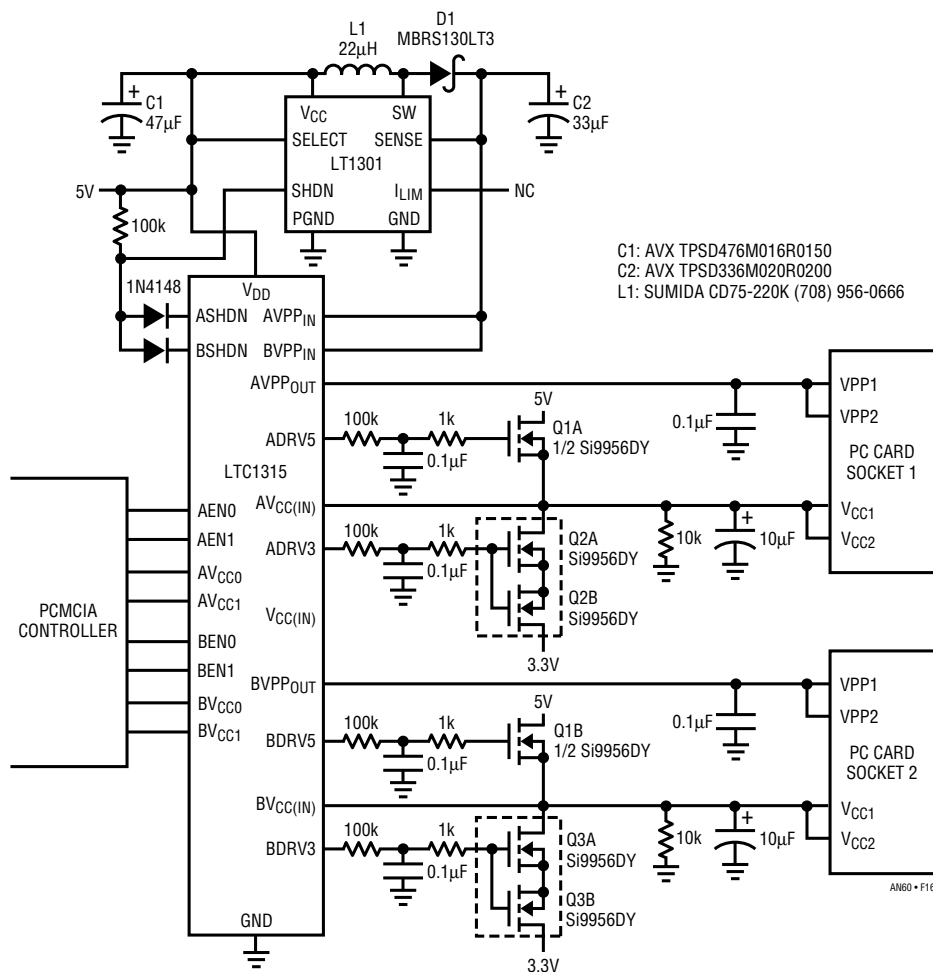
Often systems have an available supply voltage greater than 12V. The LTC1314 can be used in conjunction with the LT1121 linear regulator to supply the PC card socket with all necessary voltages. Figure 15 shows this circuit. The LTC1314 will enable the LT1121 linear regulator only when 12V is required at the VPP pin. In all other modes the LT1121 is in shutdown mode and consumes only  $16\mu A$ . This LT1121 also provides thermal and current limiting features to increase the robustness of the socket. This configuration can be used in conjunction with the LTC1142 auxiliary winding techniques shown earlier to provide a current limited, protected solution.

## LTC1315 Dual Switch Driver and VPP Switch Matrix

For applications requiring two PC card sockets the LTC1315 provides a single package switch matrix solution. The LTC1315 is a dual version of the LTC1314 with two complete "A" and "B" sections and operates in a similar fashion. Figure 16 shows a typical circuit utilizing the LT1301 to derive 12V from the 5V line. For maximum efficiency, the ASHDN and BSHDN signals are diode OR'd to enable the LT1301 only when 12V VPP is required.



### Figure 15. LTC1314 with the LT1121 Linear Regulator



**Figure 16. Typical Two-Socket Application Using the LT1315 and the LT1301**

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## THE OTHER SIDE OF THE FENCE: PC CARD ON-CARD POWER MANAGEMENT

Designers of PC cards may want to have greater control of the power management and not be at the mercy of the socket's provisions. Many sockets do not support all of the voltages that the PCMCIA standard outlines or may not be able to meet the card's current demands. In addition, not all PCMCIA sockets will incorporate smooth voltage transitions thus damaging PC cards. To assure maximum reliability and broad compatibility, the PC card designer can design the card for  $V_{CC}$  only operation. With the release of the new PCMCIA low voltage card specifications, cards requiring only 3.3V will become popular. This will often necessitate on-card 3.3V to 5V conversion and VPP generation.

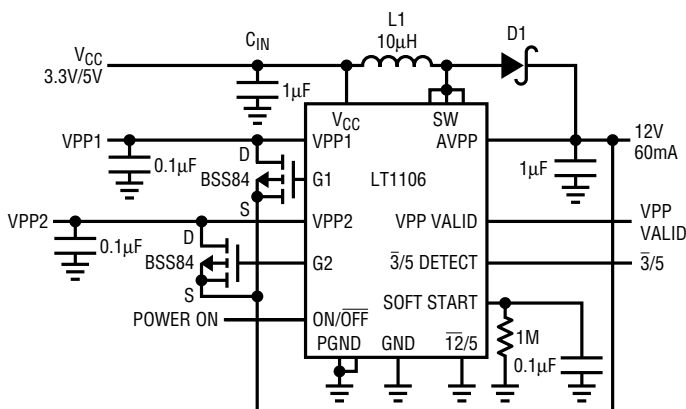
The size constraints of PC cards make on-card power management design extremely challenging. Board "Real Estate" problems are further compounded by severe height requirements. There are few components available compatible with the Type I card's 1.19mm height requirement. Type II cards are only marginally easier at 1.752mm height for center mounted cards and 2.31mm for offset mounted cards. These dimensions are for typical applications and vary depending on board thickness and card frame.

### LT1106: PC Card 3.3V/5V to 12V Converter for Flash Memory

Flash memory cards are a typical Type I and Type II PC card application. The PC card socket should provide the necessary VPP 12V programming voltage. Card designers often prefer to have this critical voltage under their own control. The LT1106 is a switching regulator in the ultra-thin 20 pin TSSOP package designed specifically for use in PC cards. Figure 17 shows a typical application of the LT1106 as a boost regulator from 3.3V or 5V to 12V at 60mA.

The LT1106 combines an efficient switching regulator with many special PCMCIA interface features. On-chip comparators sense the socket VPP pins. If 12V is present, internal drivers enhance the P-channel MOSFET switches, Q1 and Q2, and the LT1106 goes into a low power mode

(350 $\mu$ A). The LT1106 also produces a VPP valid signal when the voltage at the AVPP pin is greater than 11.5V to indicate that a valid programming voltage is available. An additional comparator output indicates whether the  $V_{CC}$  supply is 3.3V or 5V. The LT1106 is also selectable to produce 5V or 12V and has a shutdown pin to reduce supply current to only 10 $\mu$ A. The Soft Start pin controls the rise time of the output by a single resistor and capacitor.



$C_{IN}$ : TANTALUM

FOR TYPE I CARDS (1.19mm MAX HEIGHT)  
L1: COILTRONICS CTX02-11238 (407) 241-7876  
OR DALE ILS-2538-10 (605) 665-9301  
D1: PHILIPS BAT54C (4 IN PARALLEL)

FOR TYPE II CARDS (2.2mm MAX HEIGHT)  
L1: MURATA ERIE LQH3C100K04M00  
D1: PHILIPS PRL5818 OR MOTOROLA MBR0530

Figure 17. Typical LT1106 Application

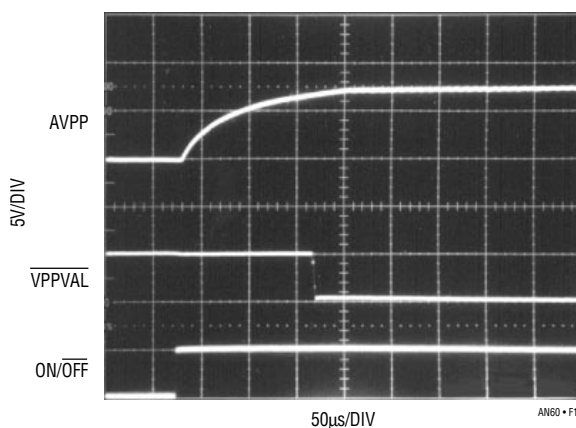


Figure 18. LT1106 VPP Switching Waveform

In Figure 18 the output voltage transition is smooth with no overshoot and ringing. This type of response assures the reliability of flash memory products.

Important performance features, in addition to the thin TSSOP package of the LT1106, make the part ideal for PC card applications. The 500kHz switching frequency allows the use of a small value, small size inductor. Small inductors in an ultra-thin form factor, critical for Type I and Type II PC card applications are achievable. The LT1106 has been designed to require only 1 $\mu$ F input and output capacitance. The LT1106 also features Burst Mode operation with efficiency as high as 85% to minimize battery drain and any on-card thermal issues.

Inductor, diode, and capacitor selection are critical to achieving good regulation and high efficiency at the output currents desired. The LT1106 circuit (Figure 17) requires a 10 $\mu$ H inductor. This inductor must not saturate at the LT1106's rated current, must have low DC resistance, and its inductance as a function of frequency must be relatively constant up to the 500kHz oscillator frequency. The combination of characteristics makes the inductor design formidable. There are several acceptable inductors listed in Figure 17.

The diode selection criteria are also difficult to meet. The diode must switch quickly, have low leakage and have a low forward voltage drop. The switching speed requirement is due primarily to the LT1106's 500kHz oscillator and the low forward voltage drop of the part is necessary to achieve good efficiency. At the time of this writing there is no diode that will satisfy this requirement in a package less than 1.19mm in height necessary for Type I cards. There are several SOT-23 packaged, fast switching diodes that can be paralleled to share the current requirements and therefore run at a lower forward voltage drop. The BAT54C Schottky diode from Philips is a dual diode in the SOT-23 package that is a solution to this problem. The circuit in Figure 17 uses four of these packages (eight diodes) in parallel to get the forward voltage drop down to 530mV at 600mA.

Capacitor selection is also critical. The capacitors must be sufficient in value with an ESR below 0.5 $\Omega$  to assure good efficiency and output ripple values. The small 1 $\mu$ F output capacitor value allows the use of ceramic capacitors. Thin surface mount ceramic capacitors are readily available. Paralleling ten 0.1 $\mu$ F capacitors, often used to decouple ICs, yields a cost effective solution.

Figure 19 shows the efficiency of the LT1106 when producing 12V at various current levels. You can see how the selection of the passive components affects the efficiency of the regulator. The dashed lines represent the 12V converter made with the ultra-thin Type I card components and shows good efficiency above 80% for most current ranges. The larger Type II components allow the same circuit topology to produce 2% to 3% better efficiency.

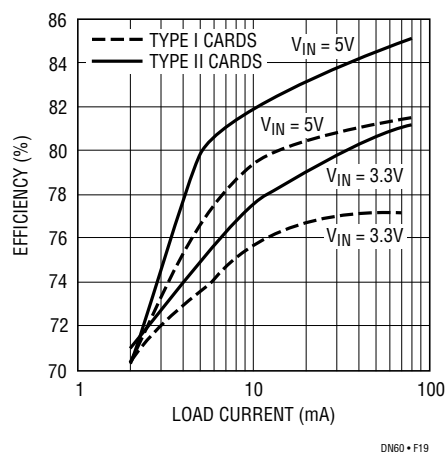


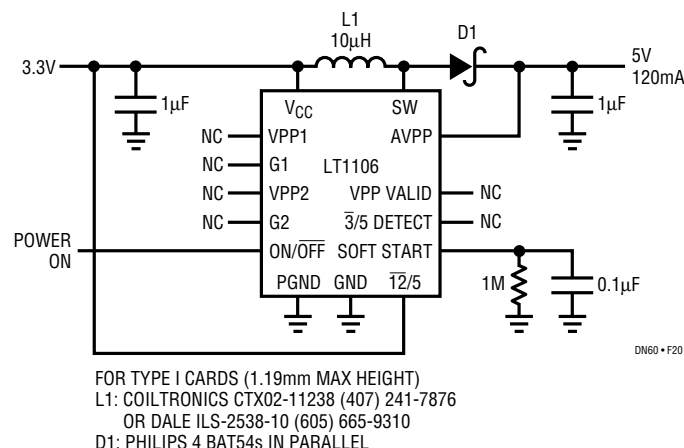
Figure 19. 12V Output Efficiency

## LT1106 3.3V to 5V DC/DC Converter for Type I Cards

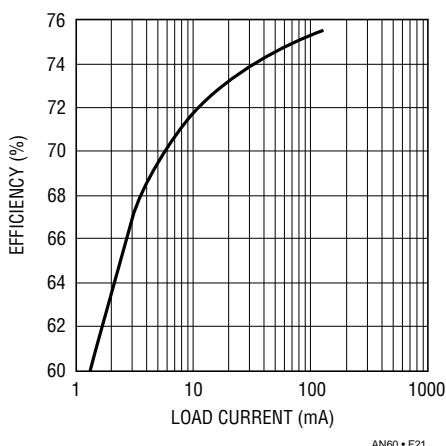
The LT1106 has an output voltage select pin for 12V output or 5V output. Connecting this pin to the 3.3V input will program the LT1106 for 5V output. Utilizing the same components as the 12V output design, this circuit will provide 5V at up to 120mA output current. For maximum efficiency, the ON/OFF control allows the device to be activated only when required. Figure 20 shows a typical

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application. The LT1106's higher frequency operation allows for smaller components making it an ideal part for on-card DC/DC regulation. The typical efficiency is plotted in Figure 21.



**Figure 20. LT1106 3.3V to 5V DC/DC Converter**

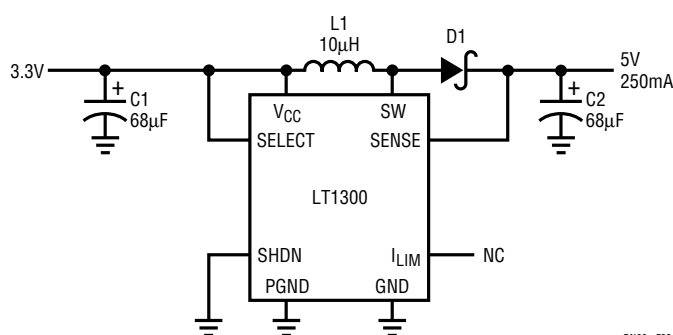


**Figure 21. LT1106 3.3V to 5V Efficiency**

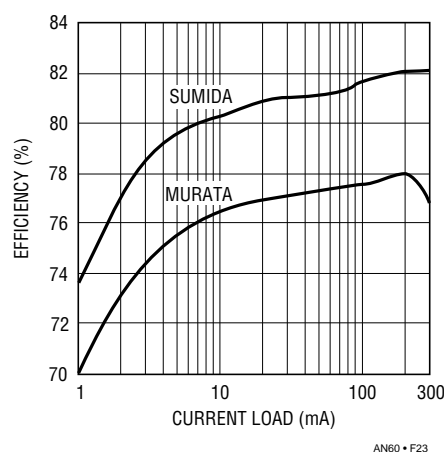
## LT1300 3.3V to 5V DC/DC Converter for Type II Cards

For PC cards requiring 3.3V to 5V conversion at more than 120mA, a design utilizing the LT1300 can provide a solution for Type II and Type III cards. While the LT1300 can deliver more current than the LT1106, it was not designed specifi-

cally for high frequency, small component operation. For this reason the inductor and capacitor values will not be as small as the LT1106 design. The LT1300's SOIC package and the use of a larger inductor with tantalum capacitors limit this design to Type II or Type III cards. Figure 22 shows a typical circuit utilizing the LT1300 to deliver 5V at 250mA from a 3.3V input. While the passive devices are not as thin as those used with the LT1106, the parts specified are much thinner than those used in conventional designs with a more standard height requirement. Figure 23 shows the typical efficiency of this design.



**Figure 22. LT1300 3.3V to 5V Converter for Type II or Type III Cards**



**Figure 23. LT1300 3.3V to 5V Efficiency**

## CONCLUSION

PCMCIA expansion sockets are becoming more popular with portable equipment. The expansion sockets are also being used in desktop systems and other systems that require easy expandability. The PCMCIA specification gives a set of guidelines that form a good starting point for the design of any portable system. There are a host of other practical design issues to consider for a robust system. The main issues are switch on-resistance, inrush current, short-circuit protection and switch output ringing during switching. The main features to look for in the switch matrix are easy interface to standard controllers, low enough on-

resistance, slowed switch rise times, and current limiting and thermal shutdown. By designing with these features the PCMCIA socket will meet the voltage requirements of all cards and will ensure a reliable system with a satisfied customer.

On-card power management can take many forms. Conversion from 3.3V or 5V to other voltages, both positive and negative, can be achieved through careful design and component selection. The specific voltage requirements will be as varied as the wide diversity of PC card products themselves. For solutions to your specific needs, call Linear Technology for applications assistance.

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