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APPLICATION NOTE

Power Supply Solutions for Flash Memory

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POWER SUPPLY SOLUTIONS FOR FLASH MEMORY

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1.0 INTRODUCTION

Intel flash memory is rapidly being incorporated into a wide range of applications, adding enhanced capability to existing "traditional" memory markets, and creating new markets that exploit its benefits. Sometimes the design platforms may not possess the low powered 12V supply for writing flash memory. The system design engineer then needs to identify a power conversion solution with features and capabilities matching the needs of the application. For example, portable equipment requires a power supply converter that minimizes size and weight, maximizes efficiency to extend battery life, and can be switched into a standby mode to conserve power.

The following pages present some state of the art DC-DC converter solutions. These new solutions are smaller and more efficient than those typically seen in the past. Each of these solutions optimizes a subset of all possible power converter features. The choice of an optimal solution for a given application will be a tradeoff between several attributes. The solutions shown should meet the conversion needs of the majority of applications involving flash memory. Specifically, the solutions that follow encompass the following five categories:

- 5V to 12V conversion
- 3V (2 alkaline/NiCd cells) to 12V conversion
- 3V (2 Alkaline/NiCd cells) to 5V conversion
- Downconverting to 12V from a higher voltage
- Converting 12V unregulated to 12V regulated

More than one solution is presented within each of these categories. These different solutions have distinct optimal features/advantages. The optimal attributes of each solution are outlined. In addition, the appendix contains a survey of all solutions presented here, and provides a basis for comparing their features. The reader should reference it to choose an optimal solution for his/her application.

NOTE:
Solutions were selected from products offered by over thirty DC-DC converter vendors. Since this industry develops many new solutions each year, Intel recommends that designers contact vendors for latest products. Intel will continue to work with the industry to develop optimum solutions for power conversion. Intel Corporation assumes no responsibility for circuitry other than circuitry embodied in Intel products. No other circuit patent licenses are implied.

2.0 INTEL FLASH MEMORY POWER REQUIREMENTS

Intel flash memory is powered by two sources; a 5V V_{CC} line and a 12V V_{PP} line. V_{CC} is the primary power source and the only power source needed to read the memory. V_{PP} is required when writing or erasing the memory.

V_{CC} Characteristics

V_{CC} supplies power to the flash device during all operational modes. Maximum V_{CC} current is demanded by the device during the read operation. The data sheets for specific Intel flash memory devices should be consulted to determine the maximum read current (I_{CC}) for the device. If multiple components are read simultaneously, the V_{CC} current requirement increases proportionately. V_{CC} tolerance must be maintained to within specification limits at all times for proper functioning of the device.

V_{PP} Characteristics

The supplemental V_{PP} source provides the higher voltages needed to carry out the erase, erase verify, program, and program verify operations. Maximum V_{PP} current is typically demanded during the program and erase modes. The data sheets for specific Intel Flash Memory devices should be consulted to determine the V_{PP} voltage and maximum V_{PP} write/erase current (I_{PP}) for the device. If multiple components are programmed/erased simultaneously, the current requirement increases proportionately. V_{PP} must be maintained to within specification limits at all times during device program, and erase. The tolerance specification on V_{PP} must be strictly maintained. Over-voltage can damage the device, and under-voltage can decrease specified device reliability. Although the V_{PP} supply must meet these worst case specifications, power usage will typically be much lower. The lower typical values seen in the data sheets should be used in calculating typical battery life.

2.1 Supplies for Battery Powered Applications

In applications where batteries are the primary source of power, the power supplies providing V_{CC} and V_{PP} need to be selected very carefully. Optimized operating efficiency of these supplies is important to extend battery life. Another attractive feature is the capability of these supplies to be switched into a very low power shutdown mode. It is important to minimize this shutdown current consumption as well since flash memory V_{PP} generators will often be in this state for extended periods of time. Moreover, since these supplies are used in equipment that is physically small and space-constrained, size and height of the supply need to be minimized.

Where two alkaline/NiCd batteries are used as the primary source of power, the primary voltage varies depending on the type and the state of discharge of the batteries. For example, alkaline batteries start life off at 1.5V, but may still retain a significant amount of energy when the voltage falls to 1.0V with use, and will work all the way down to 0.8V. On the other hand, NiCd cells maintain a near constant voltage of 1.25V throughout most of their discharge cycle, and work down to 1.0V. A solution that derives V_{CC} or V_{PP} from 2 AA batteries must hence be capable of doing so from an input voltage that lies in the range of 1.6V to 3.0V.

It is best to directly convert the primary battery voltage into the various voltages needed throughout the system. A step conversion (e.g. a 3V to 5V converter for V_{CC}, followed by a 5V to 12V converter for V_{PP}) is not recommended, since the inefficiency involved in each conversion step combines into one large inefficiency for the sum 3V to 12V conversion. Section 4 presents appropriate 3V battery to 12V converter solutions. Most of the solutions presented in this application note, while specifically designed for battery powered applications, are also viewed as ideal for other applications that incorporate flash memory.

2.2 Choice of a DC-DC Converter

The solution to finding the right power supply for flash memory lies in picking the right DC-DC converter for the job. Three broad categories of DC-DC converters available in the market today can be applied towards this purpose. These are the low power hybrid DC-DC converter module (or modular solution), the low power discrete switching regulator IC solution, and the low power discrete charge-pump solution.

The Modular Solution

The modular solution generally consists of a push-pull (Royer type) oscillator built around an isolation transformer, and in some cases followed by a linear regulator; all of which is encapsulated within a module. This hybrid module includes all components that are required by the DC-DC converter, and so no additional design effort is needed. The input and output voltages are fixed, and the input and output are almost always isolated via the isolation transformer. The main advantage of these solutions is that no design effort and/or external components are involved. They simply plug into a socket on a PC board. Disadvantages include lower efficiency (generally 60%), larger size/height (in most cases), and higher cost (generally 3x to 10x the cost of discrete solutions).

It would seem that the integration inherent in these solutions contributes towards system reliability, however the type and quality of the discrete components used internal to these hybrid devices is open to question. The isolation offered between the input and output is viewed as overkill for flash applications, since the total power required is typically less than 1W. Note also that the isolation transformer is often the main reason for the lower efficiencies.

The Discrete Switching Regulator Solution

The discrete switching regulator IC solution consists of a DC-DC converter IC (containing a switching regulator controller and an output power switch), along with a few discrete external components (inductor, diode, capacitors, resistors, etc.). The layout of the power supply system in this case is mostly left up to the user. However, application notes and data sheets explain the design process, and provide recommended circuits for commonly used solutions. The design can be tailored to deliver different output voltages and current levels depending on the characteristics of the input voltage and the external components.

Some vendors offer fixed output voltage versions, further simplifying the design process. The newer generation of high frequency low power switching regulator ICs are specifically targeted at battery powered operation, and most can be switched into a low quiescent current shutdown mode to extend battery life. These have typical efficiencies in the 75% to 90% range. Furthermore, the higher switching frequencies of these new parts (typically 100 KHz to 200 KHz) allow the use of smaller external components, which are available in surface mount varieties. As a consequence, these newer solutions are overall much smaller than what was typically seen just a year ago.

The Discrete Charge-Pump Solution

The discrete charge-pump solution is similar to the discrete switching regulator IC solution in that it also consists of a DC-DC converter IC and a few discrete external components (capacitors). The charge-pump, however, operates in a significantly different fashion (see Appendix E), and as a result does not require inductors and diodes as a discrete switching regulator solution does, which means that a charge-pump solution is generally smaller and cheaper. On the down side, charge-pump solutions generally have lower efficiencies and lower output current capabilities than discrete switching regulator solutions.

Attributes of a DC-DC Converter

Several attributes of a power supply converter must be evaluated and prioritized when choosing the best solution for a given application. These attributes include:

- Input Voltage Range
- Output Voltage and Tolerance
- Output Current Capability
- Efficiency of Conversion
- Printed Circuit Area
- Height
- Total Cost
- Shutdown Capability
- Quiescent Current Consumed in Shutdown Mode
- Rise Time from Shutdown
- Surface Mountability

2.3 Summary

The reader is referred to Appendix B, which provides a survey of all the solutions that are presented in this application note, in order to compare their attributes.

This application note primarily presents state of the art discrete switching regulator IC solutions (and one charge-pump solution) which have been carefully designed for operation with flash memory. Included along with schematics are component values and sources/contacts for obtaining components. Actual layouts have also been included where possible. These are provided in Appendix F.

NOTE:
External components recommended in the designs should be used. These components (inductors, capacitors, resistors) were chosen based on recommendations by the converter IC vendors and provide the necessary quality for a clean design. Alternate "equivalent" parts should be chosen with care as their resistive and inductive elements can affect the operation of the solution. Please contact the respective converter IC companies for assistance if you select an alternate value/source for passive components.

3.0 V_{PP} SOLUTIONS: CONVERTING UP FROM 5V

Most computer systems have available a 5V V_{CC} line that is used for the majority of system power. Frequently, this 5V supply is used to generate 12V for flash memory. This section presents some of the new state of the art solutions that can achieve this function. These are all discrete switching regulators that optimize different attributes, mentioned along with the main features section of each example. Refer to Appendix B for a more detailed comparison of the attributes of these solutions.

3.1 Maxim Integrated Products—MAX734: V_{PP} @ 120 mA

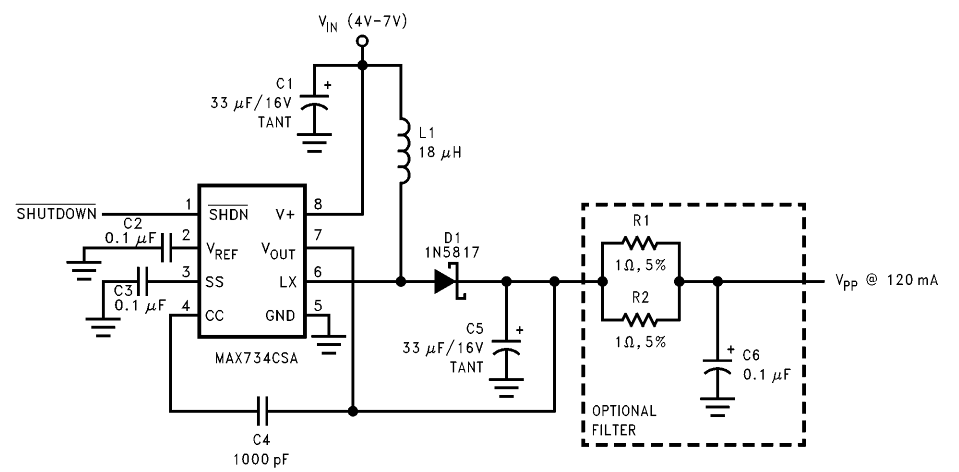


Figure 3-1. Maxim MAX734 5V to 12V Converter

Optimal Attributes

- High Efficiency
- Low Shutdown Current
- Small Size: 0.3 sq. in. Total Board Area (Single Sided)
- All Surface Mount

Main Features

- Input Voltage Range: 4V to 7V
- Output Voltage: 12V ±5%
- Output Current Capability: Up to 120 mA @ V_{IN} = 5V
- Typical Efficiency: 83%@ I_{LOAD} = 120 mA, V_{IN} = 5V
- 170 KHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 70 µA typical
- Low Operating Quiescent Current: 1.3 mA typical
- Rise Time from Shutdown: 1.5 ms typical
- Soft-start Capability

The MAX734 is a 12V-output step-up converter which uses 6 small external surface mount components to implement a small 5V to 12V converter solution. It is available in a small 8-pin surface mount package. The MAX734 design as shown is capable of providing up to 120 mA of V_{PP} current at an efficiency of 83%. The supply can be switched into a shutdown mode where the output voltage falls to approximately V_{IN} − 100 mV and the quiescent input current falls to below 70 µA. The rise time from shutdown mode is typically 1.5 ms. The MAX734 also has a Soft-start feature which allows the designer to limit surge currents at start-up by adding a capacitor between the MAX734's SS pin and ground. The high switching frequency of the MAX734 allows the use of very small external capacitors and contributes to the small size of the supply circuit. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance and a surface mount evaluation board are available from Maxim.

Table 3-1. Parts List for the MAX734 5V to 12V Converter

Ref	Part #	Value/Type	Source	Cost*
U1	MAX734CSA	SMPS IC	Maxim (408) 737-7600	$1.83
C1, C5	267M1602-336-MR-720	33 μF/16V Tantalum	Matsuo (714) 969-2491	$0.48
C2	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
C3 (opt)	GRM40Z5U103M050AD	0.01 μF	Murata Erie (404) 436-1300	$0.03
C4	GRM40Z5U102M050AD	0.001 μF	Murata Erie (404) 436-1300	$0.03
C6 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	EC15QS02L	1N5817 Diode	Nihon (805) 867-2555	$0.30
L1	CD43−180	18 μH	Sumida (708) 956-0666	$0.55
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$3.35

* Cost estimates based on published 10K unit pricing at the time this application note was written.

3.2 Maxim Integrated Products—MAX761: V_{PP} @ 150 mA

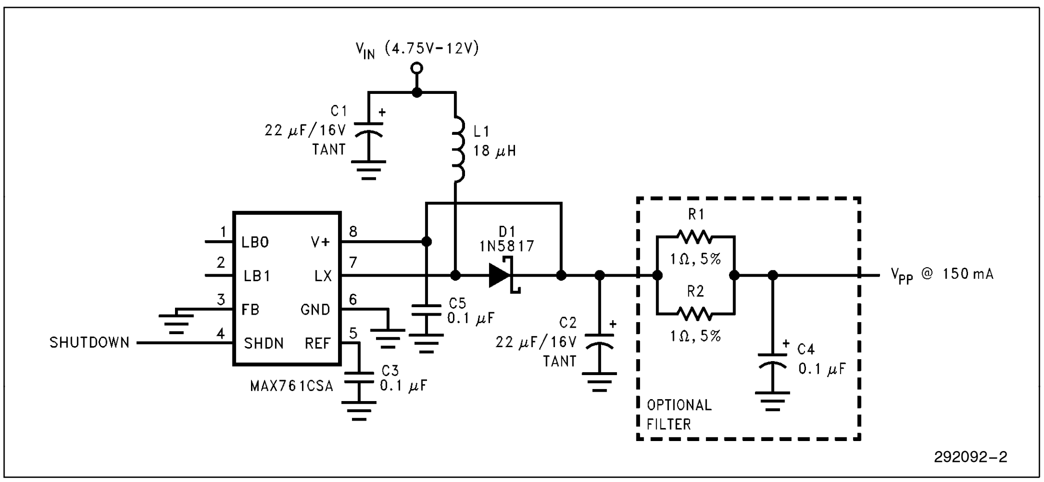


Figure 3-2. Maxim MAX761 5V to 12V Converter

Optimal Attributes

- High Efficiency
- Lowest Shutdown Current
- Low Quiescent Supply Current
- All Surface Mount

Main Features

- Input Voltage Range: 4.75V to 12V
- Output Voltage: 12V ±4%
- Output Current Capability: Up to 150 mA @ V_{IN} = 5V
- Typical Efficiency: 86% @ I_{LOAD} = 150 mA, V_{IN} = 5V
- 300 KHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 5 μA max
- Low Operating Quiescent Current: 250 μA typical
- Rise Time from Shutdown: 1 ms typical

The MAX761 is a 12V-output step-up converter which uses pulse-frequency-modulated (PFM) control to offer high efficiency over a wide range of loads. It is available in a small 8-pin surface mount package and uses only 6 small external surface mount components to provide a 12V ±5% supply. The MAX761 design as shown is capable of providing up to 150 mA of V_{PP} current at an efficiency of 86%. The supply can be switched into a shutdown mode where the output voltage falls to approximately V_{IN} and the quiescent supply current falls to below 5 μA. The rise time from shutdown mode is typically 1 ms. The high switching frequency of the MAX761 allows the use of very small external capacitors and contributes to the small size of the supply circuit. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance and a surface mount evaluation board are available from Maxim.

Table 3-2. Parts List for the MAX761 5V to 12V Converter

Ref	Part #	Value/Type	Source	Cost*
U1	MAX761CSA	SMPS IC	Maxim (408) 737-7600	$2.02
C1, C2	267M1602-226-MR-720	22 μF/16V Tantalum	Matsuo (714) 969-2491	$0.48
C3, C5	GRM40Z5U104M050AD	0.1μF	Murata Erie (404) 436-1300	$0.05
C4 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	EC10QS02L	1N5817 Diode	Nihon (805) 867-2555	$0.22
L1	CD43-180MC	18 μH	Sumida (708) 956-0666	$0.53
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$3.38

* Cost estimates based on published 10K unit pricing at the time this application note was written.

3.3 Maxim Integrated Products—MAX662: V_{PP} @ 30 mA

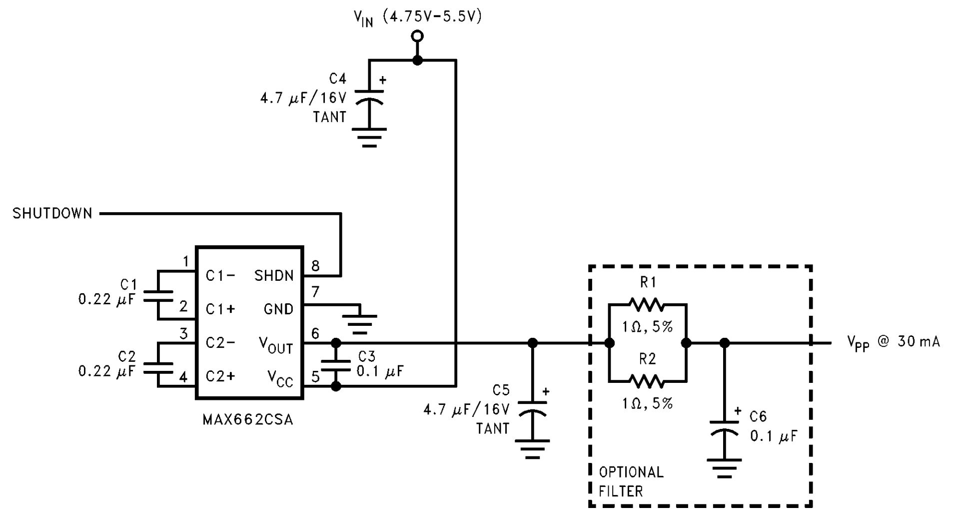


Figure 3-3. Maxim MAX662 5V to 12V Converter

Optimal Attributes

- Lowest Cost
- Low Shutdown Current
- Low Quiescent Supply Current
- Fast Rise Time from Shutdown
- No Inductors Necessary
- Small Size: 0.2 sq. in. Total Board Area (Single Sided)
- All Surface Mount

Main Features

- Input Voltage Range: 4.75V to 5.5V
- Output Voltage: 12V ±5%
- Output Current Capability: Up to 30 mA @ V_{IN} = 5V
- Typical Efficiency: 74% @ I_{LOAD} = 30 mA, V_{IN} = 5V
- 400 KHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 70 µA typical
- Low Operating Quiescent Current: 320 µA typical
- Rise Time from Shutdown: 600 µs typical

The MAX662 is a 12V-output boost converter. It uses internal charge pumps and 5 small external surface mount capacitors to generate V_{PP}, with no need for inductors. It is available in a small 8-pin narrow surface mount package. The MAX662 design as shown is capable of providing up to 30 mA of V_{PP} current at an efficiency of 74%. The supply can be switched into a shutdown mode where the output voltage falls to V_{IN} and the quiescent supply current falls to below 70 µA. The rise time from shutdown mode is typically 600 µs. The high switching frequency of the MAX662 allows the use of very small external capacitors and contributes to the small size of the supply circuit. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance and a surface mount evaluation board are available from Maxim.

Table 3-3. Parts List for the MAX662 5V to 12V Converter

Ref	Part #	Value/Type	Source	Cost*
U1	MAX662CSA	SMPS IC	Maxim (408) 737-7600	$1.69
C1, C2	GRM40Y5V224Z025AD	0.22 μF	Murata Erie (404) 436-1300	$0.15
C3	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
C4, C5	267M1602-475-MR-533	4.7 μF/16V Tantalum	Matsuo (714) 969-2491	$0.21
C6 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$2.18

* Cost estimates based on published 10K unit pricing at the time this application note was written.

3.4 Linear Technology LT1109-12: V_{PP} @ 60 mA

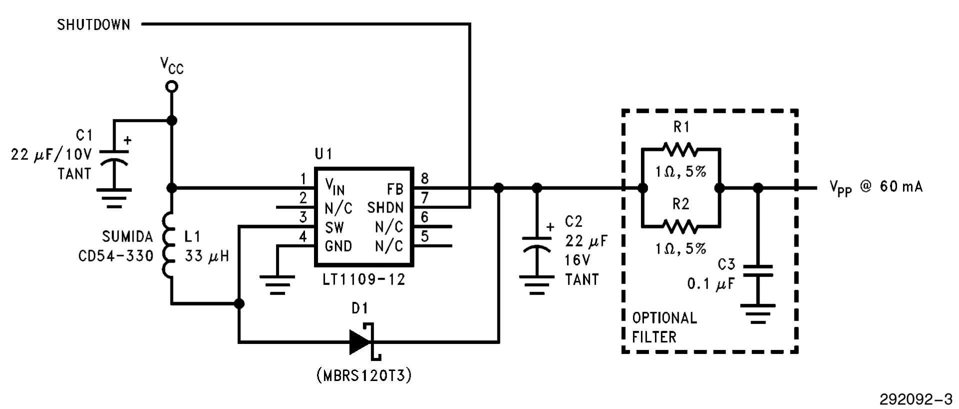


Figure 3.4 Linear Technology LT1109-12 5V to 12V Converter

Optimal Attributes

- Low Quiescent Supply Current
- Small Size
- All Surface Mount

Main Features

- Input Voltage Range: 4.5V to 5.5V
- Output Voltage: 12V ±5%
- Output Current Capability: Up to 60 mA, @ V_{IN} = 5V
- Typical Efficiency: 84% @ I_{LOAD} = 60 mA, V_{IN} = 5V
- 120 KHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 320 μA typical
- Low Operating Quiescent Current: 320 μA typical
- Rise Time from Shutdown: 800 μs typical

The LT1109-12 is a fixed 12V-output part which is well suited to flash memory applications. It is available in a small 8-pin surface mount package and uses only 4 small external components to implement a very small size 5V to 12V converter solution. The LT1109-12 design as shown is capable of providing up to 60 mA of V_{PP} current at an efficiency of 84%. The supply can be switched into a shutdown mode where the output voltage falls to approximately V_{IN}−550 mV. Quiescent supply current at shutdown remains at approximately 320 μA. The rise time from shutdown mode is typically 800 μs. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance is available from Linear Technology Corporation.

Table 3-4. Parts List for the LT1109-12 5V to 12V Converter

Ref	Part#	Value/Type	Source	Cost*
U1	LT1109CS8-12	SMPS IC	Linear Tech (408) 432-1900	$2.16
C1	267M1002-226-MR-720	22 μF/10V Tantalum	Matsuo (714) 969-2491	$0.16
C2	267M2502-106-MR-720	10 μF/25V Tantalum	Matsuo (714) 969-2491	$0.24
C3 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	MBRS120T3	Schottky Diode	Motorola (800) 521-6274	$0.37
L1	CD54-330LC	3 μH	Sumida (708) 956-0666	$0.55
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$3.56

* Cost estimates based on published 10K unit pricing at the time this application note was written.

3.5 Linear Technology LT1301: V_{PP} @ 200 mA

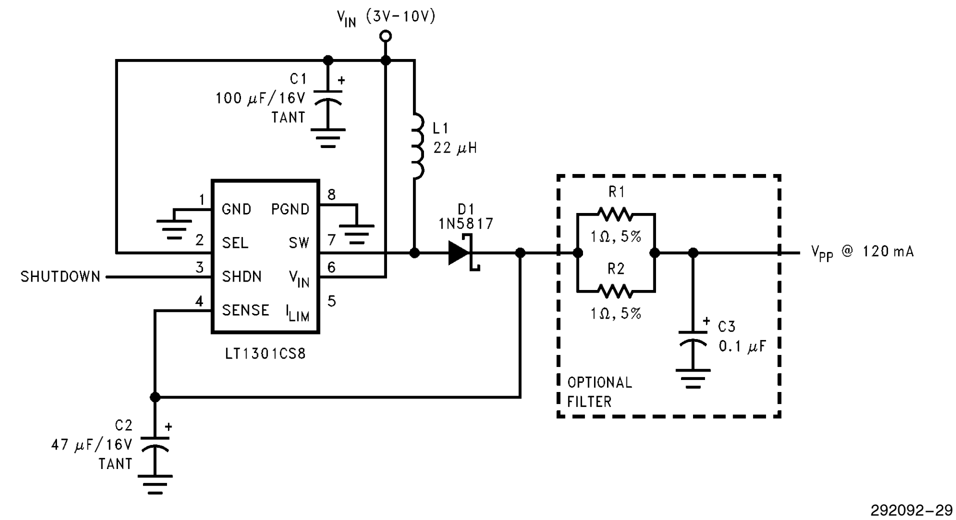


Figure 3-5. Linear Technology LT1301 5V to 12V Converter

Optimal Attributes

- High Efficiency
- High Output Current Capability
- Low Shutdown Current
- Low Quiescent Supply Current
- Small Size

Main Features

- Input Voltage Range: 3V to 10V
- Output Voltage: 12V ±5%
- Output Current Capability: Over 200 mA @ V_{IN} = 5V
- Typical Efficiency: 88% @ I_{LOAD} = 200 mA, V_{IN} = 5V
- 155 KHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 15 μA max
- Low Operating Quiescent Current: 120 μA typical
- Rise Time from Shutdown: 1.2 ms typical

The LT1301 is a micropower step-up DC-DC converter. It is available in a small 8-pin surface mount package and uses only 4 small external surface mount components. The LT1301 design as shown is capable of providing over 200 mA of V_{PP} current at an efficiency of 88%. The supply can be switched into a shutdown mode where the output voltage falls to approximately V_{IN} − 550 mV and the quiescent supply current falls to below 15 μA. The LT1301 also has an input which selects between a 5V and 12V output, for flexibility in migration to Smart Voltage flash memory. The high switching frequency of the MAX761 allows the use of very small external capacitors and contributes to the small size of the supply circuit. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance is available from Linear Technology Corporation.

Table 3-5. Parts List for the LT1301 5V to 12V Converter

Ref	Part #	Value/Type	Source	Cost*
U1	LT1301CS8	SMPS IC	Linear Tech (408) 432-1900	$2.40
C1	267M1002-107-MR-720	100 μF/10V Tantalum	Matsuo (714) 969-2491	$0.35
C2	267M1602-476-MR-720	4 μF/16V Tantalum	Matsuo (714) 969-2491	$0.35
C3 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	EC10QS02L	1N5817 Diode	Nihon (805) 867-2555	$0.22
L1	CD75-220KC	22 μH	Sumida (708) 956-0666	$0.63
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$4.03

* Cost estimates based on published 10K unit pricing at the time this application note was written.

3.6 Motorola MC34063A: V_{PP} @ 120 mA

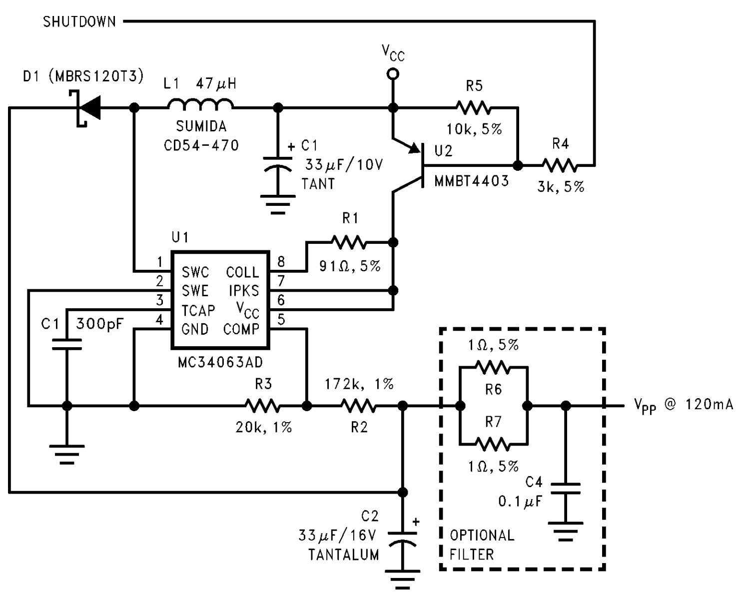


Figure 3-6. Motorola MC34063A 5V to 12V Converter

Optimal Attributes

- Low Cost
- Low Shutdown Current
- All Surface Mount

Main Features

- Input Voltage Range: 4.5V to 5.5V
- Output Voltage: 12V ±5%
- Output Current Capability: Up to 120 mA @ V_{IN} = 5V
- Typical Efficiency: 80% @ I_{LOAD} = 120 mA, V_{IN} = 5V
- 100 KHz Switching Frequency
- Shutdown Feature using External Components
- Low Quiescent Current at Shutdown: 25 μA typical
- Rise Time from Shutdown: 2 ms typical

The MC34063A solution presented uses 11 small sized external components to implement a low cost surface mount 5V to 12V converter solution. Three external components (U2, R4, R5) are used to shut down supply to the part when V_{PP} is not needed. These could be eliminated to further lower the cost if power consumption is not important. The quiescent current in shutdown state is 25 μA. The output voltage in shutdown is approximately V_{IN}−550 mV. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance is available from Motorola.

Table 3-6. Parts List for the MC34063A 5V to 12V Converter

Ref	Part #	Value/Type	Source	Cost*
U1	MC34063A	SMPS IC	Motorola (800) 521-6274	$0.85
U2	MMBT4403LT1	PNP Transistor	Motorola (800) 521-6274	$0.10
C1	267M1002-336-MR-720	33 μF/10V Tantalum	Matsuo (714) 969-2491	$0.24
C2	267M1602-336-MR-720	33 μF/16V Tantalum	Matsuo (714) 969-2491	$0.24
C3	GRM40X7R330M050AD	330 pF	Murata Erie (404) 436-1300	$0.08
C4 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	MBRS120T3	Schottky Diode	Motorola (800) 521-6274	$0.37
L1	CD54-470LC	47 μH	Sumida (708) 956-0666	$0.55
R1	9C08052A9100JLR	91Ω, 5%	Philips (817) 325-7871	$0.02
R2	9B08053A1723FCB	172 KΩ, 1%	Philips (817) 325-7871	$0.03
R3	9B08053A2002FCB	20 KΩ, 1%	Philips (817) 325-7871	$0.03
R4	9C08052A3001JLR	3 KΩ, 5%	Philips (817) 325-7871	$0.02
R5	9C08052A1002JLR	10 KΩ, 5%	Philips (817) 325-7871	$0.02
R6, R7 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$2.63

* Cost estimates based on published 10K unit pricing at the time this application note was written.

4.0 V_{PP} SOLUTIONS: CONVERTING UP FROM 2 NiCd/ALKALINE CELLS

Palmtop computers that use 2 alkaline/NiCd batteries require that the system work even when the battery voltage is down near 1.8V. Currently there exist two good solutions that achieve a 12V output with inputs as low as 1.8V, and yet supply at least 30 mA of current. These are the LT1301 from Linear Technology Corporation, and the MAX761 from Maxim Integrated Products.

4.1 Maxim Integrated Products—MAX761: V_{PP} @ 75 mA

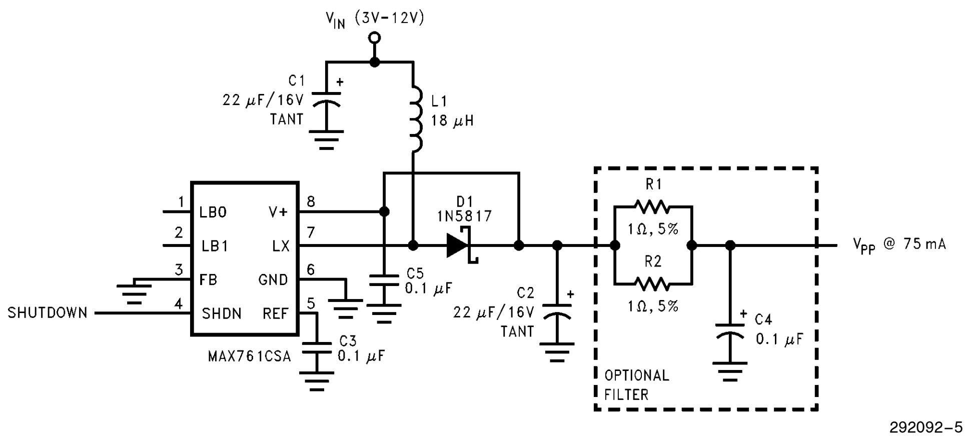


Figure 4-1. Maxim MAX761 3V to 12V Converter

Optimal Attributes

- High Efficiency
- Lowest Shutdown Current
- Low Quiescent Supply Current
- All Surface Mount

Main Features

- Input Voltage Range: 1.7V to 12V
- Output Voltage: 12V ±5%
- Output Current Capability: Up to 75 mA @ V_{IN} = 3.3V
- Typical Efficiency: 79% @ I_{LOAD} = 75 mA, V_{IN} = 3.3V
- 300 KHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 5 µA max
- Low Operating Quiescent Current: 500 µA typical
- Rise Time from Shutdown: 1 ms typical

The MAX761 is a 12V-output step-up converter which uses pulse-frequency-modulated (PFM) control to offer high efficiency over a wide range of loads. It is available in a small 8-pin surface mount package and uses only 6 small external surface mount components to provide a 12V ±5% supply. This design is identical to the 5V to 12V converter design shown in Section 3.2, but with different characteristics when operating with a 3.3V input. The MAX761 design as shown is capable of providing up to 75 mA of V_{PP} current at an efficiency of 79% with a V_{IN} of 3.3V. The supply can be switched into a shutdown mode where the output voltage falls to approximately V_{IN} and the quiescent supply current falls to below 5 µA. The rise time from shutdown mode is typically 1 ms. The high switching frequency of the MAX761 allows the use of very small external capacitors and contributes to the small size of the supply circuit. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance and a surface mount evaluation board are available from Maxim.

Table 4-1. Parts List for the MAX761 3.3V to 12C Converter

Ref	Part#	Value/Type	Source	Cost*
U1	MAX761CSA	SMPS IC	Maxim (408) 737-7600	$2.02
C1, C2	267M1602-226-MR-720	22 μF/16V Tantalum	Matsuo (714) 969-2491	$0.48
C3, C5	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
C4 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	EC10QS02L	1N5817 Diode	Nihon (805) 867-2555	$0.22
L1	CD43-180MC	18 μH	Sumida (708) 956-0666	$0.53
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$3.38

* Cost estimates based on published 10K unit pricing at the time this application note was written.

4.2 Linear Technology LT1301: V_{PP} @ 120 mA

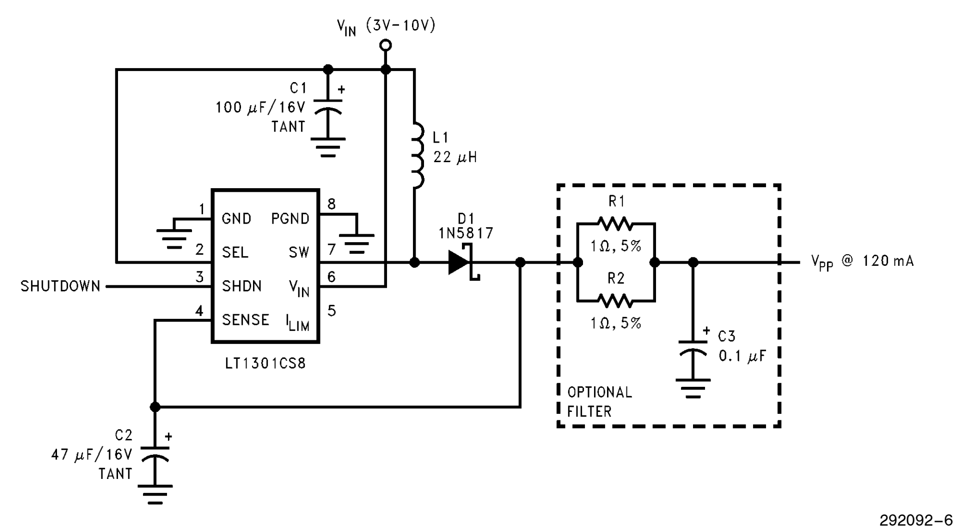


Figure 4-2. Linear Technology LT1301 3V to 12V Converter

Optimal Attributes
- High Efficiency
- High Output Current Capability
- Low Shutdown Current
- Low Quiescent Supply Current
- Small Size

Main Features
- Input Voltage Range: 1.8V to 10V
- Output Voltage: 12V ± 5%
- Output Current Capability: Up to 120 mA @ V_{IN} = 3.3V
- Typical Efficiency: 86% @ I_{LOAD} = 120 mA, V_{IN} = 3.3V
- 155 KHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 15 μA max
- Low Operating Quiescent Current: 120 μA typical
- Rise Time from Shutdown: 1.2 ms typical

The LT1301 is a micropower step-up DC-DC converter. It is available in a small 8-pin surface mount package and uses only 4 small external surface mount components. This design is identical to the 5V to 12V converter design shown in Section 3.5, but with different characteristics when operating with a 3.3V input. The LT1301 design as shown is capable of providing 120 mA of V_{PP} current at an efficiency of 86%. The supply can be switched into a shutdown mode where the output voltage falls to approximately V_{IN} − 550 mV and the quiescent supply current falls to below 15 μA. The LT1301 also has an input which selects between a 5V and 12V output, for flexibility in migration to a Smart Voltage flash memory. The high switching frequency of the MAX761 allows the use of very small external capacitors and contributes to the small size of the supply circuit. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance is available from Linear Technology Corporation.

Table 4-2. Parts List for the LT1301 3.3V to 12V Converter

Ref	Part#	Value/Type	Source	Cost*
U1	LT1301CS8	SMPS IC	Linear Tech (408) 432-1900	$2.40
C1	267M1002-107-MR-720	100 μF/10V Tantalum	Matsuo (714) 969-2491	$0.35
C2	267M1602-476-MR-720	47 μF/16V Tantalum	Matsuo (714) 969-2491	$0.35
C3 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	EC10QS02L	1N5817 Diode	Nihon (805) 867-2555	$0.22
L1	CD75-220KC	22 μH	Sumida (708) 956-0666	$0.63
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$4.03

* Cost estimates based on published 10K unit pricing at the time this application note was written.

5.0 V_{CC} SOLUTIONS: CONVERTING UP FROM TWO NiCd/ALKALINE CELLS

Palmtop and hand-held computers that use two AA size NiCd or alkaline batteries need a converter solution to provide the V_{CC} supply for the system as well as flash memory. Two good solutions are offered currently for this purpose, the MAX756 from Maxim Integrated Products and the LT1301 from Linear Technology Corporation.

5.1 Maxim Integrated Products—MAX756: V_{CC} @ 400 mA

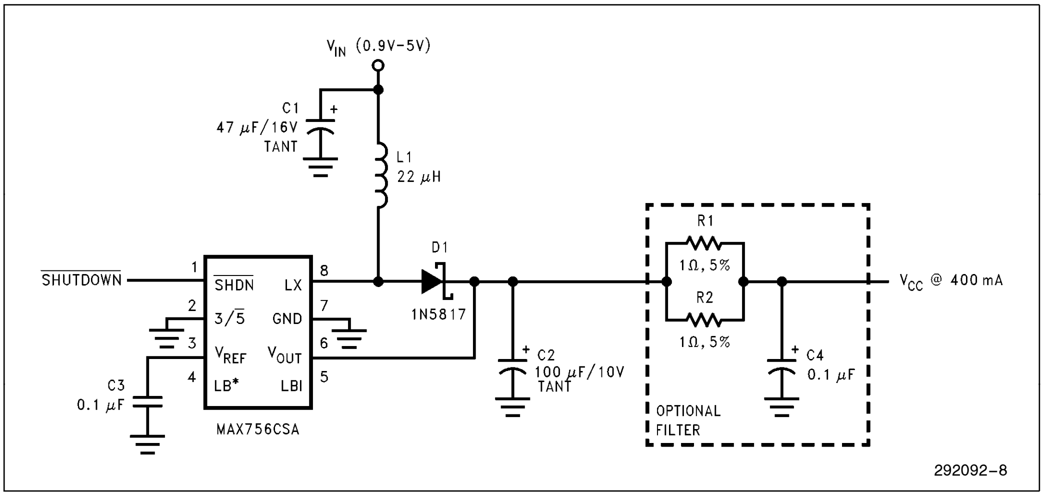


Figure 5-1. Maxim MAX756 3V to 5V Converter

Optimal Attributes

- High Output Current Capability
- Low Quiescent Supply Current
- Low Shutdown Current
- High Efficiency

Main Features

- Input Voltage Range: 0.9V to 5V
- Output Voltage: 5V ±4%
- Output Current Capability: Up to 400 mA @ V_{IN} = 3V
- Typical Efficiency: 87% @ I_{LOAD} = 200 mA, V_{IN} = 3.3V
- 0.5 MHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 20 μA max
- Low Operating Quiescent Current: 140 μA typical
- Rise Time from Shutdown: 2 ms typical

The MAX756 is a high-current solution for obtaining V_{CC} from a pair of NiCd/alkaline cells. The supply can be switched into a shutdown mode where the output voltage falls to approximately V_{IN} and the quiescent supply current falls to below 20 μA. The high switching frequency of the MAX756 allows the use of very small external capacitors and inductors and contributes to the small size of the supply circuit. Series inductance in the filter capacitor and diode switching transients may cause high-frequency noise which appears as sharp voltage spikes in the output. Such spikes can be eliminated by practicing good PC-board layout or by using the optional filter circuit shown in the design. Applications assistance and an evaluation kit are available from Maxim.

Table 5-1. Parts List for the MAX756 3V to 5V Converter

Ref	Part #	Value/Type	Source	Cost*
U1	MAX756	SMPS IC	Maxim (408) 737-7600	$1.97
C1	267M1002-107-MR-720	100 μF/10V Tantalum	Matsuo (714) 969-2491	$0.35
C2	267M1602-476-MR-720	47 μF/16V Tantalum	Matsuo (714) 969-2491	$0.35
C3	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
C4 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	EC10QS02L	1N5817 Diode	Nihon (805) 867-2555	$0.22
L1	CD54-220KC	22 μH	Sumida (708) 956-0666	$0.55
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$3.57

* Cost estimates based on published 10K unit pricing at the time this application note was written.

5.2 Linear Technology LT1301: V_{CC} @ 120 mA

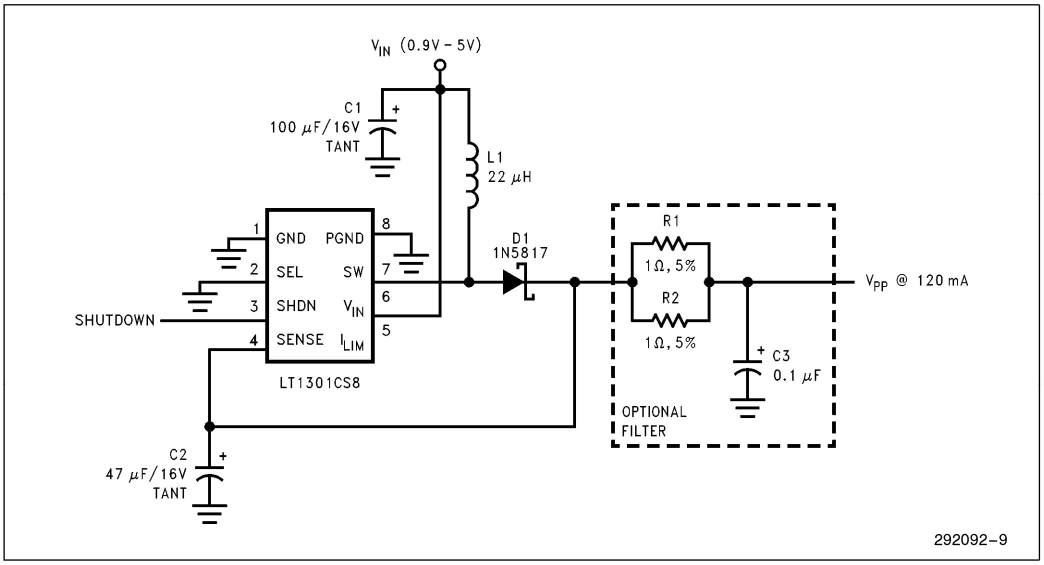


Figure 5-2. Linear Technology LT1301 3V to 5V Converter

Optimal Attributes

- Low Shutdown Current
- Low Quiescent Supply Current
- Small Size

Main Features

- Input Voltage Range: 1.8V to 5V
- Output Voltage: 5V ±5%
- Output Current Capability: Up to 120 mA @ V_{IN} = 3.3V
- Typical Efficiency: 86% @ I_{LOAD} = 120 mA, V_{IN} = 3.3V
- 155 KHz Switching Frequency
- Shutdown Feature on Chip
- Low Quiescent Current at Shutdown: 15 µA max
- Low Operating Quiescent Current: 120 µA typical
- Rise Time from Shutdown: 1.2 ms typical

The LT1301 3V-to-5V converter design is the same as the LT1301 12V converter designs shown in sections 3.4 and 4.2, with the output selected as 5V instead of 12V using the select pin.

Table 5-2. Parts List for the LT1301 3.3V to 5V Converter

Ref	Part #	Value/Type	Source	Cost*
U1	LT1301CS8	SMPS IC	Linear Tech (408) 432-1900	$2.40
C1	267M1002-107-MR-720	100 μF/10V Tantalum	Matsuo (714) 969-2491	$0.35
C2	267M1602-476-MR-720	47 μF/16V Tantalum	Matsuo (714) 969-2491	$0.35
C3 (opt)	GRM40Z5U104M050AD	0.1 μF	Murata Erie (404) 436-1300	$0.05
D1	EC10QS02L	1N5817 Diode	Nihon (805) 867-2555	$0.22
L1	CD75-220KC	22 μH	Sumida (708) 956-0666	$0.63
R1, R2 (opt)	9C08052A1R00JLR	1Ω, 5%	Philips (817) 325-7871	$0.03
			Total Cost	$4.03

* Cost estimates based on published 1OK unit pricing at the time this application note was written

6.0 DOWN-CONVERTING TO 12V

The ability to down-convert to 12V from a higher voltage is often needed (as in the telecommunications environment). This section presents some good solutions for obtaining V_{PP} from a higher voltage.

6.1 Maxim Integrated Products MAX667

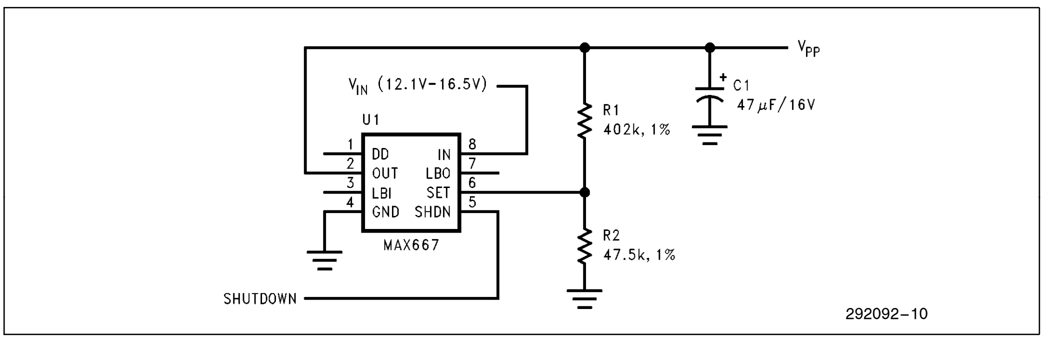


Figure 6-1. Maxim MAX667 12V Linear Voltage Regulator

Optimal Attributes

- Small Size
- Ultra Low Shutdown Current
- All Surface Mount
- Very Low Dropout

Main Features

- Input Voltage Range: 12.1V to 16.5V
- Output Voltage: 12V ±5%
- Output Current Capability: Up to 120 mA
- Typical Efficiency: 70%
- Shutdown Mode On Chip
- Low Quiescent Current at Shutdown: 0.2 μA Typical
- Rise Time from Shutdown: Less than 0.1 ms Typical

Table 6-1. Parts List for the MAX667 12V Step Down Converter

Ref	Part #	Value/Type	Source	Cost*
U1	MAX667CSA	SMPS IC- SO8 Package	Maxim (408) 737-7600	$1.99
C1	267M1602-476-MR-720	7 μF/16V Tantalum	Matsuo (714) 969-2491	$0.35
R1	9C08053A4023JLR	402 KΩ, 1%	Philips (817) 325-7871	$0.03
R2	9C08053A4752JLR	47.5 KΩ,1%	Philips	$0.03
			Total Cost	$2.39

*Cost estimates based on published 10K unit pricing at the time this application note was written.

6.2 Linear Technology Corporation LT1111-12

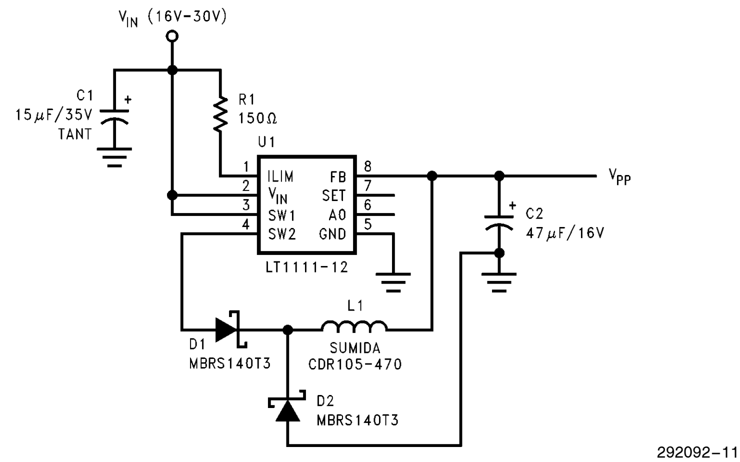


Figure 6-2. Linear Technology LT1111-12 Step Down Switcher

Optimal Attributes

- High Efficiency
- All Surface Mount

Main Features

- Input Voltage Range: 16V to 30V
- Output Voltage: 12V ±5%
- Output Current Capability: Up to 120 mA
- Typical Efficiency: 80%

Table 6-2. Parts List for the LT1111-12 12V Step Down Converter

Ref	Part #	Value/Type	Source	Cost*
U1	LT1111-12	SMPS IC- SO8 Package	Linear Tech (408) 432-1900	$2.20
C1	267M3502-225-MR-720	2.2 μF/35V Tantalum	Matsuo (714) 969-2491	$0.28
C2	267M1602-476-MR-720	47 μF/16V Tantalum	Matsuo (714) 969-2491	$0.35
R1	9C08052A1500JLR	150Ω, 5%	Philips (817) 325-7871	$0.02
L1	CDR105-470	47 μH	Sumida (708) 956-0666	$0.38
D1, D2	MBRS140T3	Schottky Diode	Motorola (800) 521-6274	$0.74
			Total Cost	$3.97

*Cost estimates based on published 10K unit pricing at the time this application note was written.

6.3 National Semiconductor LM2940CT-12

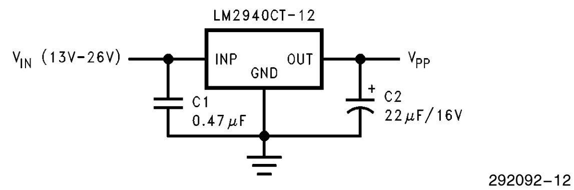


Figure 6-3. National LM2940CT-12 12V Linear Regulator

Optimal Attributes

- Lowest Cost

Main Features

- Input Voltage Range: 13V to 26V
- Output Voltage: 12V ±3%
- Output Current Capability: 1A

The LM2940CT-12 is a low drop-out linear regulator from National Semiconductor. This is a good low cost fixed 12V output solution. The part is offered in a standard TO-220 plastic package. The input capacitor is required only if the regulator is located far away from the input power supply filter, and the output capacitor must be at least 22 μF in order to maintain stability.

Table 6-3. Parts List for the LM2940CT-12 Step Down Converter

Ref	Part #	Value/Type	Source	Cost*
U1	LM2940CT-12	Voltage Reg TO-220	National (408) 721-5000	$0.95
C1	GRM43-2Z5U474M050AD	0.47 μF/50V	Murata Erie (404) 436-1300	$0.07
C2	267M1602-226-MR-720	22 μF/16V Tantalum	Matsuo (714) 969-2491	$0.24
			Total Cost	$1.26

*Cost estimates based on published 10K unit pricing at the time this application note was written.

7.0 OBTAINING V_{PP} FROM 12V UNREGULATED

In systems like the desktop computer, a 12V supply exists but may not be regulated to ±5%. If this voltage is used as the V_{PP} source for flash memory, it may well degrade the write/erase performance of the memory, or adversely affect its reliability. Fortunately, in most of the situations where a 12V unregulated (or not regulated to within 5%) supply exists, a 5V supply also exists in the system (the desktop computer is a good example). It is recommended in such cases that the existing 5V supply be used to obtain the 12V ±5% rail. This approach is more economical, more efficient, and provides space savings over a buck-boost topology that takes unregulated 12V and regulates it to ±5%.

In the rare case where a 5V supply is not present, modular solutions exist that will regulate the unregulated 12V supply to ±5%. However, these are bulky and expensive. Moreover, many of them require that a minimum load be maintained in order to stay in regulation. One such solution in presented in Appendix A.

8.0 SUMMARY

For battery powered applications, the author views the discrete switching regulator IC solution or charge pump solution as a better choice than the modular solution. The lower cost, higher efficiency, and smaller size/height associated with discrete solutions justify the small additional design effort required to incorporate them in flash memory applications. In applications where the primary source of power is a wall power outlet, or in applications where the flash memory will be written to infrequently, efficiency and quiescent current take on secondary importance. In such cases, it may be acceptable to use a 12V regulated (to within ±5%) tap from the system supply. Alternatively, the ability to easily design-in modular solutions may outweigh the disadvantages of lower efficiency and increased cost. For those users wishing to incorporate modular solutions, Appendix A provides some of the lower cost solutions from this industry segment.

APPENDIX A
MODULAR SOLUTIONS

Modular solutions may work well in non-battery powered situations where the efficiency of the power supply converter is not critical. These are also advantageous in that they usually do not need any external components and there is no converter design involved. However, the type and quality of the discrete components used in these hybrid solutions is open to question. This is not true in the case of the discrete converter designs presented in the earlier sections, where the quality of the components used are under the control of the system design engineer. Hence, even though modular solutions offer the convenience of a single package and ease of testability, the quality/reliability of comparably priced modular solutions may be questionable.

Some modular solutions suited to flash memory applications are presented below, with a brief description of each. Sources for obtaining these are listed in Appendix B.

International Power/Newport Components NMF0512S

The NMF0512S is a 5V to 12V hybrid power module that has an output current capability of 80 mA. Output tolerance is ±5%. It is equipped with a shutdown pin which can be used to switch V_{PP} off. However, power dissipated in the shutdown mode is relatively high (about 100 mW). The part is small in size and measures 0.76 in. (19.5 mm) x 0.4 in. (9.8 mm) x 0.4 in. (9.8 mm), and costs about $7.90 in 10K quantities (at the time this application note was written). Typical efficiency of conversion is 62%.

Xentek NPSC-0512S

The Xentek NPSC-0512S is a 1W power module that converts 5V to V_{PP} and will source up to 80 mA of continuous current. However, it uses two external filter capacitors—one at the input and one at the output. The input filter capacitor is 47 μF/10V, and the output filter capacitor is 100 μF/16V. Size of the solution (converter alone) is 0.87 in. (22 mm) x 0.39 in. (10 mm) x 0.79 in. (20 mm). The NPSC-0512S does not have a shutdown mode. The part costs around $5.00 in 10K quantities (at the time this application note was written). Typical efficiency of conversion is 60%.

Shindengen America Inc. HDF-0512D

The HDF-0512D module from Shindengen will convert unregulated 12V to 12V ±5%. This part is a dual output part (±12V), but only the +12V line is used. The conversion efficiency is high (75% typical), and the part will provide a regulated V_{PP} voltage from input voltages as low as 8V, and as high as 16.5V. A minimum load of 5 mA needs to be maintained to guarantee regulation. Size of the solution is 1.75 in. (44 mm) x 0.43 in. (11 mm) x 0.8 in. (20 mm). Cost is approximately $10.00 in quantities of 10K (at the time this application note was written).

Valor PM6064

The PM6064 is a 5V to 12V module that will source up to 60 mA of current. Output tolerance is ±5%. It has an enable pin which allows V_{PP} to be switched off. The supply current when V_{PP} is disabled is less than 20 μA. The part's dimensions are 0.78 in. (19.8mm) x 0.58 in. (14.7mm) x 0.35 in. (8.9mm). The part costs $3.00 in 10K quantities. Typical efficiency of conversion is high, relative to other modular solutions, at 74%.

APPENDIX B
SURVEY OF SOLUTIONS PRESENTED

REF #	VENDOR NAME	PART #	INPUT V (Volts)	OUTPUT V (Volts)	OUTPUT C (mA)	EFFIC (%)	EXT COMP (Note 1)	100% SMD?	COST (Note 2)	PC AREA (Note 3)	HEIGHT (in.)	SHDN ?	ISHDN (Note 4)	R Time (Note 5)	Temp
3.1	Maxim	MAX734	4V–7V	12V, 5%	120 mA	83%	6;D,L,4C	YES	$3.35	0.3	0.18	YES	70 μA	1.5 ms	0°C, 70°C
3.2	Maxim	MAX761	4.75V–12V	12V, 4%	150 mA	86%	6;D,L,4C	YES	$3.38	0.3	0.12	YES	5 μA	1 ms	0°C, 70°C
3.3	Maxim	MAX662	4.75V–5.5V	12V, 5%	30 mA	74%	5;5C	YES	$2.18	0.2	0.07	YES	70 μA	0.6 ms	0°C, 70°C
3.4	Linear Tech	LT1109–12	5V, 10%	12V, 5%	60 mA	84%	4;D,L,2C	YES	$3.56	0.38	0.18	YES	320 μA	0.8 ms	0°C, 70°C
3.5	Linear Tech	LT1301	3V–10V	12V, 5%	200 mA	88%	4;D,L,2C	YES	$4.03	0.38	0.14	YES	15 μA	1.2 ms	0°C, 70°C
3.6	Motorola	MC34063A	5V, 10%	12V, 5%	120 mA	75%	11;D;L;T;3C;5R	YES	$2.63	0.49	0.18	YES	25 μA	2 ms	0°C, 70°C
4.1	Maxim	MAX761	1.7V–12V	12V, 5%	75 mA	79%	6;D,L,4C	YES	$3.38	0.3	0.12	YES	5 μA	1 ms	0°C, 70°C
4.2	Linear Tech	LT1301	3V–10V	12V, 5%	120 mA	86%	4;D,L,2C	YES	$4.03	0.38	0.14	YES	15 μA	1.2 ms	0°C, 70°C
5.1	Maxim	MAX756	0.9V–5V	5V, 4%	400 mA	87%	5;D,L,3C	YES	$3.57	0.4	0.2	YES	20 μA	2 ms	0°C, 70°C
5.2	Linear Tech	LT1301	1.8V–5V	5V, 5%	120 mA	86%	4;D,L,2C	YES	$4.03	0.38	0.14	YES	15 μA	1.2 ms	0°C, 70°C
6.1	Maxim	MAX667	12.1V–16.5V	12V, 5%	250 mA	70%	3;2R,1C	YES	$2.39	0.25	0.15	YES	0.2 μA	0.1 ms	0°C, 70°C
6.2	Linear Tech	LT1111–12	16V–30V	12V, 5%	120 mA	80%	6;2D,L,2C,R	YES	$3.97	0.78	0.2	NO	N/A	N/A	0°C, 70°C
6.3	National	LM2940CT–12	13V–26V	12V, 3%	1 Amp	$12V/V_{IN}$	2;2C	NO	$1.26	0.5	0.18	NO	N/A	N/A	0°C, 70°C
A.1	International Power	NMF0512S	5V, 10%	12V, 5%	80 mA	62%	0	NO	$7.90	0.3	0.40	YES	20 mA	10 μs	0°C, 70°C
A.2	Shindengen	HDF1212D	8V–16.5V	12V, 5%	120 mA	77%	0	NO	$10.00	0.76	0.80	NO	N/A	N/A	−40°C, 70°C
A.3	Xentek	NPSC–0512S	5V, 10%	12V, 5%	80 mA	60%	2;2C	NO	$5.50	0.34	0.79	NO	N/A	N/A	−10°C, 70°C
A.4	Valor	PM6064	5V, 10%	12V, 5%	60 mA	74%	0	NO	$3.00	0.9	0.35	YES	20 μA		−10°C, 70°C

NOTES:

1. # External components. D: Diode, L: Inductor, C: Capacitor, R: Resistor, T: Transistor
2. Cost. Cost estimates assume 10K quantities
3. PC Area. PC Area is conservatively estimated as 2.0X (area of all components). Where actual layouts are presented, the lower value is given. Note that this estimate is for a single sided board, and area can be reduced considerably if both sides of the board are utilized.
4. I Shdn. Current consumed by supply at shutdown. Output settles to V_{CC} at shutdown, so some additional flash V_{PP} leakage/standby will exist.
5. R Time. Rise time from shutdown state. Erase/Writes should not be attempted till V_{PP} level has risen to valid level after shutdown is disabled.

APPENDIX C
SOURCES/CONTACTS FOR RECOMMENDED DC-DC CONVERTERS

Linear Technology Corporation

Recommended Products:

— LT1109-12 (DC-DC Converter IC)

— LT1111-12 (DC-DC Converter IC)

— LT1301 (DC-DC Converter IC)

In U.S.A.:
1630 McCarthy Blvd.
Milpitas, CA 95035-7487
Tel: (408) 432-1900
Fax: (408) 432-0507

In Europe (U.K.):
111 Windmill Road
Sunbury
Middlesex TW16 7EF
U.K.
Tel (44)(932) 765688
Fax (44)(932) 781936

In Asia (Japan):
4F Ichihashi Bldg
1-8-4 Kudankita Chiyoda-ku
Tokyo 102 Japan
Tel (81) (03) 3237-7891
Fax (81) (03) 3237-8010

Maxim Integrated Products

Recommended Products:

— MAX662 (DC-DC Converter IC)

— MAX667 (DC-DC Converter IC)

— MAX734 (DC-DC Converter IC)

— MAX756 (DC-DC Converter IC)

— MAX761 (DC-DC Converter IC)

In U.S.A.:
120 San Gabriel Drive
Sunnyvale, CA 94086
Tel (408) 737-7600
Fax (408) 737-7194

In Europe (U.K.):
Maxim Integrated Products (UK), Ltd.
Tel: (44) (734) 845255

In Asia (Japan):
Maxim Japan Co., Ltd.
Tel: 81 (03) 3232-6141

Motorola Semiconductor Inc.

Recommended Product:

— MC34063AD (DC-DC Converter IC)

In U.S.A.:
616 West 24th Street
Tempe, AZ 85282
Tel: (800) 521-6274

In Europe (U.K.):
Tel: (44) (296) 395-252

In Asia (Japan):
Tel: (81) (3) 440-3311

National Semiconductor

Recommended Product:

— LM2940CT-12 (Voltage Regulator IC)

In the U.S.:
2900 Semiconductor Drive
P.O. Box 58090
Santa Clara, CA 95052
Tel: (408) 721-5000

In Europe:
National Semiconductor (UK) Ltd.
The Maple, Kembrey Park
Swindon, Wiltshire SN26UT
U.K.
Tel: (07-93) 614141
Fax: (07-93) 697522

In Asia:
National Semiconductor Japan Ltd.
Sanseido Bldg. 5F
4-15 Nishi Shinjuku
Shinjuku-ku
Tokyo 160 Japan
Tel: (81) (3) 299-7001
Fax: (81) (3) 299-7000

Newport Components/ International Power

Recommended Product:

— NMF0512S (5V–12V Converter Module)

In U.S.A.:
International Power Sources
200 Butterfield Drive
Ashland, MA 01721
Tel: (508) 881-7434
Fax: (508) 879-8669

In Europe:
Newport Components
4 Tanners Drive
Blakelands North
Milton Keynes MK14 5NA
Tel: (0908) 615232
Fax: (0908) 617545

Shindengen Electric Co. Ltd.

Recommended Product:

— HDF0512D (12V unreg. to 12V reg. converter module)

In the U.S.:
2649 Townsgate Road #200
Westlake Village, CA 91361
Tel: (800) 634-3654
Fax: (805) 373-3710

In Europe:
Shindengen Magnaquest U.K. Ltd.
Unit 13, River Road,
Barking Business Park,
33 River Road, Barking,
Essex 1G11 ODA
Tel: (44) (81) 591-8703
Fax: (44) (81) 591-8792

In Asia:
2-1,2-Chome Ohtemachi
Chiyoda-ku
Tokyo 100
Japan
Tel: (81) (3) 279-4431
Fax: (81) (3) 279-6478

Valor Electronics, Inc.

Recommended Product:

— PM6064

In U.S.A.:
9715 Business Park Avenue
San Diego, CA 92131-1642
Tel: (619) 537-2500
Fax: (619) 537-2525

In Europe:
Valor Electronics GmbH
Steinstraße 68
81667 Munchen
Germany
Tel: (49) (89) 480-2823
Fax: (49) (89) 484-743

In Asia:
Valor Electronics, Ltd.
Room 510, 5th Floor
1 Kornhill Road, Kornhill Metro Tower
Quarry Bay, Hong Kong
Tel: (852) 513-8210
Fax: (852) 513-8214

Xentek Inc.

Recommended Product:

— NPSC0512S (5V–12V Converter Module)

In U.S.A.:
760 Shadowridge Drive
Vista, CA 92083
Tel: (619) 727-0940
Fax: (619) 727-8926

In Europe (Germany):
Xentek, Inc.
c/o Taiyo Yuden GMBH.
Obermaierstrasse 10,
D-8500 Nurnberg 10
Federal Republic of Germany
Tel: (49) (911) 350-8400
Fax: (49) (911) 350-8460

In Asia (Japan):
Xentek, Inc,
c/o Taiyo Yuden., Ltd.
6-16-20, Ueno, Taito-ku
Tokyo 110
Japan
Tel: (81) (3) 3837-6547
Fax: (81) (3) 3835-4752

APPENDIX D
CONTACTS FOR DISCRETE COMPONENTS

Matsuo Electric Co., Ltd.

Matsuo's 267 series surface mount tantalum chip capacitors are recommended by Maxim and Linear Technology for input and output filter capacitors on their DC-DC converters. Part #s are included on the parts list that accompanies most solutions. If alternate "equivalents" are required, choose high reliability, low ESR (Equivalent Series Resistance) and low ESL (Equivalent Series Inductance) type tantalums, which help in keeping output ripple and switching noise to a minimum.

In U.S.A.:
2134 Main St., Ste. 200
Huntington Beach , CA 92648
Tel: (714) 969-2491
Fax: (714) 960-6492

In Europe:
Steucon - Center II Mergenthalleralle 77
D-6236 Eschben/Ts.
Federal Republic of Germany
Tel: 6196-470-361
Fax: 6196-470-360

In Asia:
Oak Esaka Bldg.
10-28 Hiroshiba-Cho
Suita-shi
Osaka 564
Tel: (06) 337-6450
Fax: (06) 337-6456

Sumida Electric Co. Ltd.

Sumida CD series surface mount inductors are recommended by Maxim, Linear Technology for their miniature size and relatively low cost. These are well suited to low power DC-DC converter applications. Contact Sumida Electric directly for procuring these. The part #s are included in the parts list that accompanies most solutions. In applications where noise (EMI) is a concern, shielded varieties are also offered by Sumida.

In U.S.A.:
637 East Golf Road
Suite 209
Arlington Heights, IL 60005
Tel: (708) 956-0666
Fax: (708) 956-0702

In Asia:
4-8 Kanamachi 2-chome,
Katsushika-ku,
Tokyo 125
Japan
Tel: (81) (03) 3607-5111
Fax: (81) (03) 3607-5428

Coiltronix Inc.

Coiltronix is recommended as a good alternate source for surface mount inductors. The CTX series offered by Coiltronix is well suited to DC-DC converter applications. These are shielded, and have a toroidal core. However, they are bigger in size and currently much more expensive (7X to 8X) than the Sumida varieties recommended in the solutions herein. The equivalent part numbers are:

Sumida CD54-470 → Coiltronix CTX50-1
Sumida CD54-180 → Coiltronix CTX20-1
Sumida CD54-220 → Coiltronix CTX20-1
Sumida CD75-470 → Coiltronix CTX50-2
Sumida CDR105-470 → Coiltronix CTX50-2

In U.S.A.:
Coiltronix Inc.
984 S.W. 13th Court
Pompano Beach, FL 33069
Tel: (305) 781-8900
Fax: (305) 782-4163

In U.K.:
Microelectronics Technology Ltd.
Great Haseley Trading Estate
Great Haseley
Oxfordshire OX9 7PF
U.K.
Tel: (08) 44 278781
Fax: (08) 44 278746

In Asia:
Serial System Mktg.
Poh Leng Bldg., #02-01
21 Moonstone Lane
Singapore 1232
Tel: 2938830
Fax: 2912673

Coilcraft

Coilcraft is also recommended as a good alternate source for surface mount inductors. The N2724-A shielded series is well suited to DC-DC converter applications. These are bigger and currently more expensive (2x to 3x) than the Sumida inductors recommended in the solutions. Contact Coilcraft directly for any applications assistance or for procurement of these parts. The equivalent part numbers are:

Sumida CD54-470 → Coilcraft N2724-A 47 μH
Sumida CD54-180 → Coilcraft N2724-A 18 μH
Sumida CDR105-470 → Coilcraft N2724-A 47 μH

In the US:
1102 Silver Lake Road
Cary , IL 60013
Tel: (708) 639-6400
Fax: (708) 639-1469

In Europe:
21 Napier Place
Wardpark North
Cumbernauld
Scotland G68 0LL
Tel: 0236 730595
Fax: 0236 730627

In Asia:
Block 101, Boon Keng Road
#06-13/20
Kallang Basin Industrial Estate
Singapore 1233
Tel: 2966933
Fax: 2964463

Philips Components

Philips Components is recommended as a good source for surface mount (SMD) resistors (standard 9C series, and 9B (MELF) series). Part #s are included in the parts list that accompanies most of the solutions in the application note. Many alternate sources exist.

In the US:
2001 W. Blue Heron Blvd.
P.O. Box 10330
Riviera Beach, FL 33404
Tel: (407) 881-3200
Fax: (407) 881-3304

In Europe:
Philips Components Ltd.
Mullard House
Torrington Place
London WC1E 7HD
Tel: (44) 71 580 6633
Fax: (44) 71 636 0394

In Asia:
Philips K.K.
Philips Bldg. 13-37
Kohnan 2-chome
Minato-Ku Tokyo 108
Tel: (81) 3 740-5028
Fax: (81) 3 740-5035

Siliconix-Logic Level PFETs

Siliconix offers low-"on" resistance logic level PFETs (Si9400, and Si9405) that can be used for switching a DC-DC converter into a shutdown state by using these switches on the high side of the input to the converter (see Appendix E).

In the US:
2201 Laurelwood Road
P.O. Box 54951
Santa Clara, CA 95056-9951
Tel: (408) 988-8000
Fax: (408) 727-5414

In Europe:
Weir House
Overbridge Square, Hambridge Lane
Newbury, Berks RG14 5UX
Tel: (0635) 30905
Fax: (0635) 34805

In Asia:
Room 709, Chinachem Golden Plaza
77 Mody Road
TST East Kowloon
Tel: (852) 724-3377
Fax: (852) 311-7909

APPENDIX E
OTHER DESIGN CONSIDERATIONS

V_{PP} Valid Handshake Logic

It is often desirable to have, along with the V_{PP} solution, a handshake signal (using extra hardware) that is asserted as long as the voltage level on V_{PP} is valid. The following schematic illustrates a good way of achieving this. This handshake signal could be used to determine when it is suitable to perform writes/erases on the flash device. The circuit shown uses a precision zener voltage reference and a comparator, along with bias resistors, to monitor the voltage level on V_{PP}. The point at which the comparator trips must be set after careful consideration of the variation in the reference voltage and the tolerances on the bias resistors. The worst case conditions on these variations must guarantee that the handshake signal is asserted when V_{PP} is at its worst case lower-end level (11.4V). Care must be taken to use the exact same components as specified in order to maintain the tight tolerance on the trip level of the output signal.

Obtaining Shutdown Using Logic Level PFETs

Low "on" resistance logic level PFETs can be used on the high side of the input to the DC-DC converters to obtain shutdown. One such part is the Si9405 from Siliconix Inc. The device is part of the "little foot" series, and is available in an SO8 (8-pin surface mount) package. The Si9405 is a logic level PFET with an "on resistance" of 0.2Ω (at a gate drive of 4.5V). It is important to have as low an "on" resistance as possible, since the peak currents and start-up currents into the supply are high. Care must be taken to ensure that the DC-DC conversion process is not affected after accounting for the drop in input voltage across the PFET.

Working of the Discrete Step Up Switching Regulator

This section presents a brief overview of the operation of discrete step up switching regulators, and presents issues that the user needs to be concerned with while designing these solutions into the system.

The four most basic elements of a discrete switching regulator power supply are:

1. The SMPS IC (which includes the switch control element and logic, along with the power switch itself),
2. An inductor for storage and transfer of energy between the input and output,
3. A switching diode to direct the inductor energy to "catch", or channel, the inductor energy to the output, and
4. An output filter capacitor.

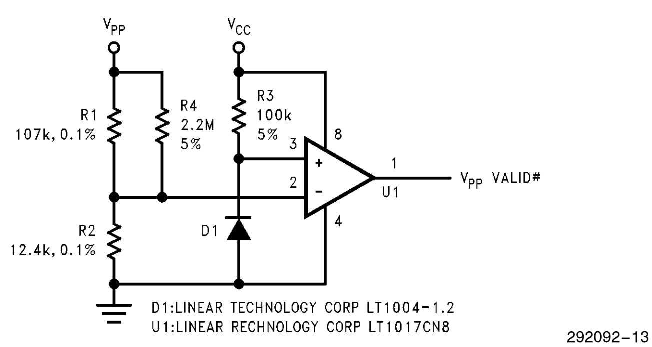


Figure E-1. V_{PP} Valid Handshake Circuit

In the boost configuration where the output voltage is greater than the input voltage, the basic switching power supply configuration is as shown in Figure E.2:

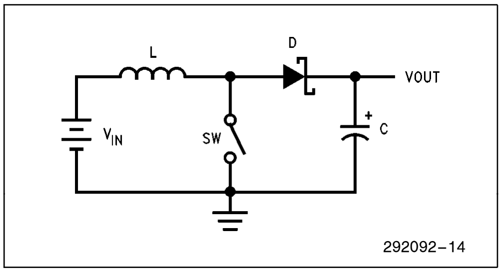


Figure E-2. Working of the Step-Up Switching Regulator

The power switch SW can be turned on and off; the control for it is derived from a feedback mechanism that senses the output voltage. While the switch is turned on, the inductor stores energy as the current flows through it from the input supply. The peak current through the inductor I_L can be approximated as ($V_{IN}/L * t_{ON}$); where t_{ON} is the on time of the switch. During this time, the energy is supplied by the input voltage, $V_L = V_{IN}$. The output is isolated from the inductor via the reverse-biased diode, and the load current is supplied by the output filter capacitor. When the switch turns off, the energy stored in the inductor appears as a rapidly increasing voltage across the inductor. As soon as this voltage reaches a value equal to the output voltage plus the voltage drop across the diode, the diode switches on and current starts to flow through the diode. This diode current supplies the load current while also at the same time charging up the output filter capacitor to the output voltage.

The switch is controlled by sensing the output voltage via a feedback mechanism—usually a pair of resistors. This sense voltage is gated via a comparator whose output acts as a control signal to an oscillator. The oscillator output controls the switch.

The power into the inductor P_L can be approximated as:

$$P_L = 0.5 * L * I_{PK}^2 * f_{OSC}$$

and the power into the load P_{LOAD} (out of the inductor) can be approximated as

$$P_{LOAD} = (V_{OUT} + V_D - V_{IN}) * I_{OUT}$$

The peak currents through the inductor is usually several times higher than the load current, is mostly of the value of the load current and builds up during time t_{ON}. On most of the solutions presented here, peak operating currents lie in the range of 500 mA to 1.2A. Though this may seem high, most of this in-rush of energy is transferred to the output, and little is lost to heat due to the efficient energy storage characteristic of inductors. Note that since the peak currents are high, the input voltage source must be capable of providing this current, and the current capability of the input source must not be calculated simply as ($V_{OUT} * I_{OUT}$)/(V_{IN} * Eff). A large bypass capacitor at the input pin of the converter is hence also necessary on all designs.

Some of the solutions presented in this application note are of the fixed duty cycle or fixed on time type (e.g. LT1109-12, MC34063A), whereas some of them vary the duty cycle depending on the load current (e.g. MAX734). These latter ones provide higher efficiencies.

Inductor Selection

The choice of an inductor is crucial to the design of the power supply system. To begin with, the inductor value must be low enough to supply the peak currents needed when the input voltage V_{IN}, as well as the on time t_{on}, are at their worst case low value. On the other hand, the inductor value must be high enough so that the peak currents at the worst case high values do not exceed the maximum peak currents that can be handled by the switch. Furthermore, once the value has been picked, the physical inductor that is chosen for the job must be able to handle these peak currents, and must not saturate. This is done by picking an inductor whose DC current rating is more than the worst case peak current that will be required by the operation of the device. The other characteristic to consider is the resistance of the inductor. In order to keep losses to a minimum, it is essential that the resistance of the coil is a minimum. Thus, it is important to use the inductors specified in the parts list that accompanies the solutions. These have been carefully chosen after reviewing the requirements. Alternate inductors may be used, as long as they are "equivalent".

EMI Concerns

Since the switching regulators presented in this application note switch at frequencies between 100 KHz and 500 KHz, there exists a potential for EMI. In cases where EMI may be a problem, shielded inductors can be used. This will reduce EMI significantly. Shielded versions of the inductors specified are readily available. Contact the vendor directly for these.

Output Switching Noise

Output switching noise has several sources. The most significant one is the IR drop through the ESR (Equivalent Series Resistance) of the output filter capacitor. This is caused by switching current pulses from the inductor. There is also noise in the form of switching spikes riding on the DC output. This is due to the output filter capacitor's ESL (Equivalent Series Inductance), current spikes in the ground trace and rectifier turn-on transients.

It is important to use low ESR and low ESL output and input filter capacitors. Proper layout is also essential in order to avoid spikes in the output. The safest solution is to use a filter circuit at the output. LC filters are not recommended, because of the transient nature of the load currents on flash devices. An RC filter is recommended on most solutions as an option. Two 1Ω resistors are used in parallel to avoid causing a significant drop across the resistance. This method is inexpensive and assures that the spikes riding on the output waveform are contained to within the 5% tolerance requirement on V_{PP}.

In addition, care must be taken to keep the leads from the output of the solution to all flash devices as short as possible. Use of a 0.1 μF capacitor at the V_{PP} pin of each flash device is highly recommended.

Working of the Discrete Charge-Pump DC-DC Converter

This section provides a brief overview of the operation of discrete charge-pump DC-DC converters.

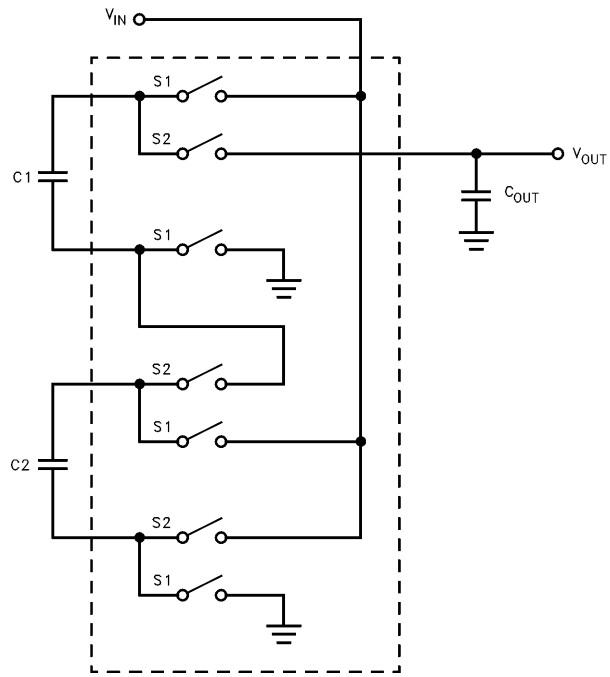
The three most basic elements of a discrete charge-pump DC-DC converter are:

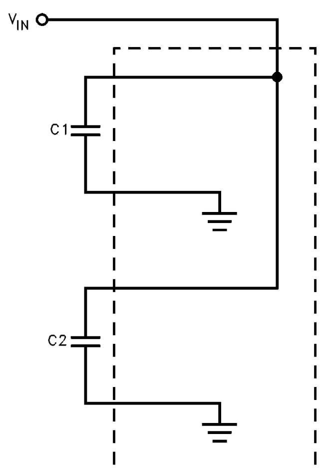
1. The charge-pump IC (which includes the internal charge-pumps as well as output regulation logic),
2. External capacitors to store energy from the input, and
3. An output filter capacitor.

The basic charge-pump power supply configuration is as shown in Figure E.3 (a).

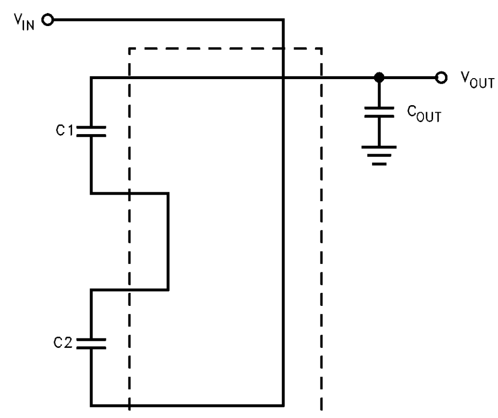
The S1 and S2 switches can be opened and closed; the control is derived from a feedback mechanism that senses the output voltage. When the S1 switches are open, the S2 switches are closed, and vice versa. When the S1 switches are closed (Figure E.3 (b)), capacitors C1 and C2 are charged to V_{IN}. When the S2 switches are closed (Figure E.3 (c)), capacitors C1 and C2 are connected in series between V_{IN} and V_{OUT}. This triples the input voltage, with the feedback scheme in the charge-pump IC adjusting the output voltage to 12V. During one cycle, energy is transferred from the input to the external charge-pump capacitors (S1 switches closed), and then from the charge-pump capacitors to the output filter capacitor and the load (S2 switches closed).

The S1 and S2 switches are controlled by sensing the output voltage via a feedback mechanism. This sense voltage is gated via a comparator whose output acts as a control signal to an oscillator. The oscillator output controls the S2 switches, and the inverted oscillator output controls the S1 switches.





(b) S1 Switches Closed



(c) S2 Switches Closed

Figure E-3. Working of the Charge-Pump DC-DC Converter

APPENDIX F
PC LAYOUTS FOR SOME RECOMMENDED SOLUTIONS

Maxim Integrated Products MAX662

The double-sided layout presented below (Figure F-1) has been designed for the MAX662 5V–12V converter solution (Section 3.3). It has been designed for the parts specified in the parts list that accompanies the solution. Contact Maxim for any additional layout assistance.

Maxim Integrated Products MAX734

The double-sided layout presented below (Figure F-2) has been designed for MAX734 5V-12V converter solution (Section 3.1). It has been designed for the parts specified in the parts list that accompanies the solution. Contact Maxim for any additional layout assistance.

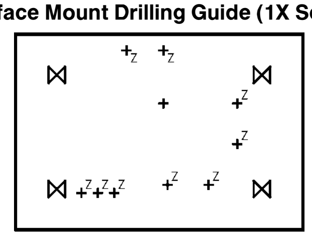
Maxim Integrated Products MAX761

The double-sided layout presented below (Figure F-3) has been designed for the MAX761 3.3V/5V–12V converter solution (Sections 3.2 and 4.1). It has been designed for the parts specified in the parts list that accompanies the solution. Contact Maxim for any additional layout assistance.

Linear Technology Corporation LT1109-12

The single-sided layout presented below (Figure F-4) can be used to implement the LT1109-12 5V–12V converter solution (Section 3.4). The layout has been designed for the parts that are specified in the parts list that accompanies the solution. Contact Linear Technology for any additional layout assistance.

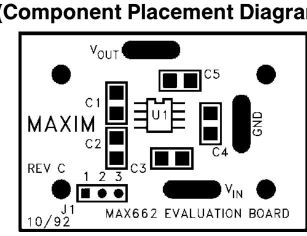
Surface Mount Drilling Guide (1X Scale)



SIZE	QTY	SYM
20	1	+
100	4	⋈
35	9	Z

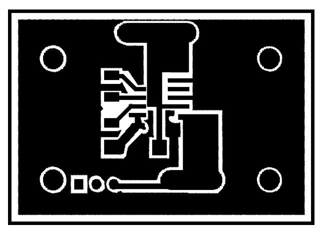
292092–15

(Component Placement Diagram)



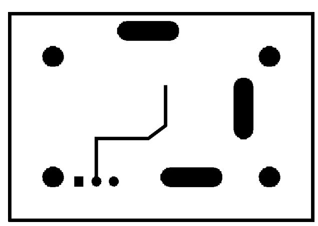
292092–16

(1X Scale Top Side Trace View)



292092–17

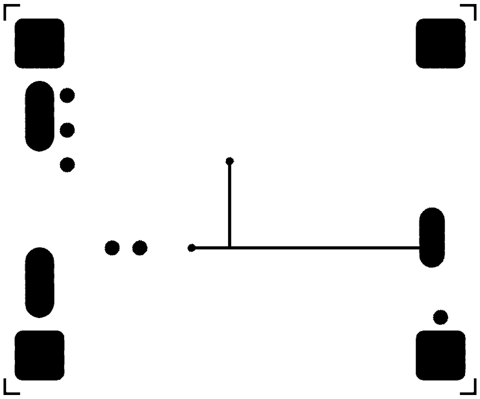
(1X Scale Bottom Side Trace View)



292092–18

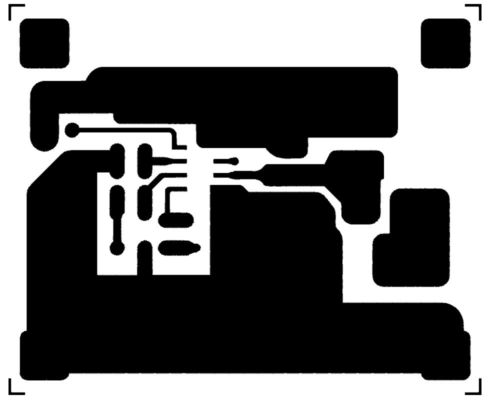
Figure F-1

(1X Scale Top Side Trace View)



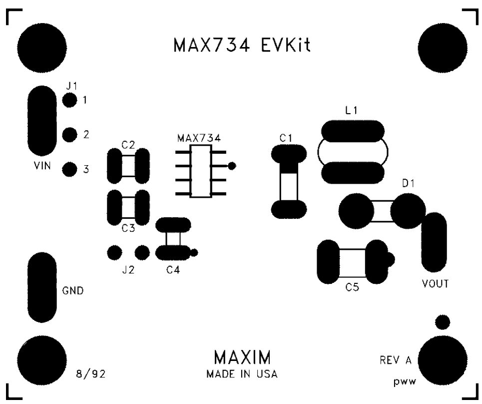
292092–19

(1X Scale Bottom Side Trace View)



292092–20

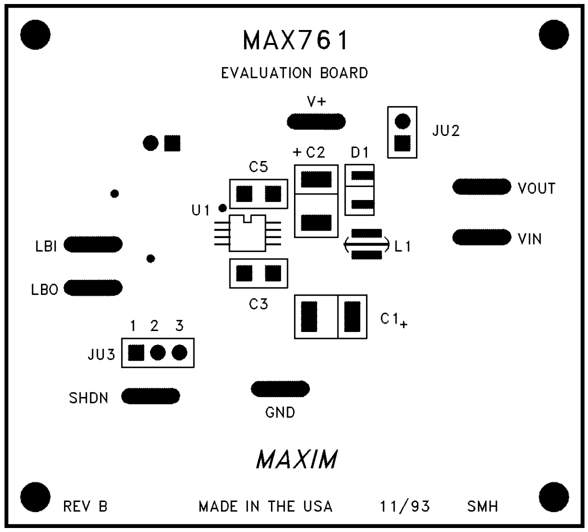
(1X Scale Component Placement Diagram)



292092–22

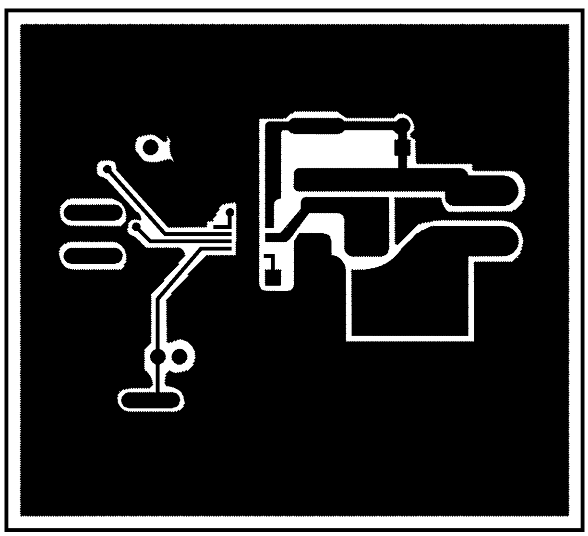
Figure F-2

(1X Scale Top Side Component Placement Diagram)



292092–33

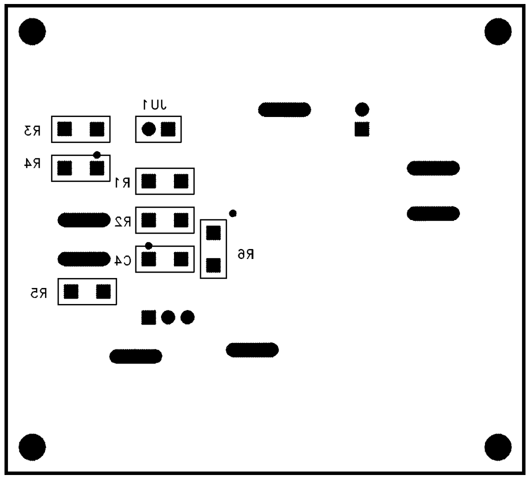
(1X Scale Top Side Trace View)



292092–35

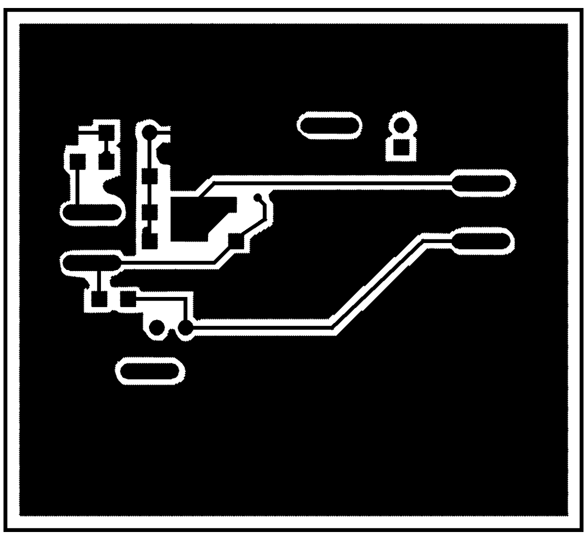
Figure F-3

(1X Scale Bottom Side Component Placement Diagram)



292092–34

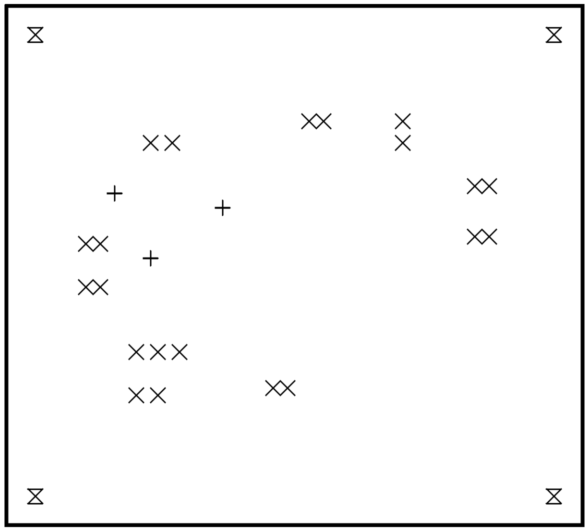
(1X Scale Bottom Side— Trace View)



292092–36

Figure F-3

(1X Scale Surface Mount Drilling Guide)



SIZE	QTY	SYM
20	3	+
37	21	×
125	4	⧖

292092–37

Figure F-3

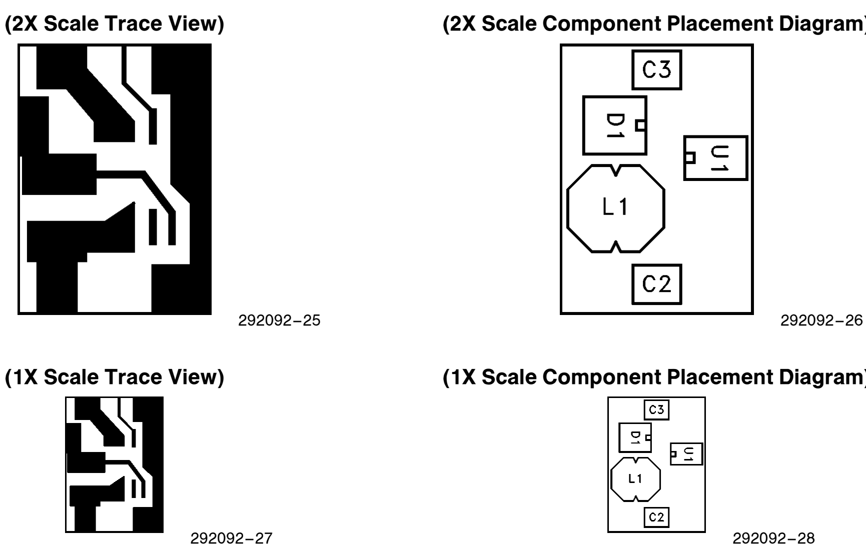


Figure F-4

Revision History

Version	Description
001	Original Version
002	Added MAX734, MAX761, MAX662, MAX756, LT1301, PM6064. Deleted MAX732, LT1110, MAX658.

INTEL CORPORATION, 2200 Mission College Blvd., Santa Clara, CA 95052; Tel. (408) 765-8080

INTEL CORPORATION (U.K.) Ltd., Swindon, United Kingdom; Tel. (0793) 696 000

INTEL JAPAN k.k., Ibaraki-ken; Tel. 029747-8511