Application Note 107

July 2006

Extending the Input Voltage Range of PowerPath Circuits for Automotive and Industrial Applications

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INTRODUCTION

The voltage range of Linear Technology's PowerPath® circuits can be easily extended with just a few components, thus allowing them to meet the needs of virtually all applications. This application note presents solutions for circuits that must withstand large negative voltages, a reverse adapter input for example, and circuits that must withstand large positive inputs, such as automotive load-dump.

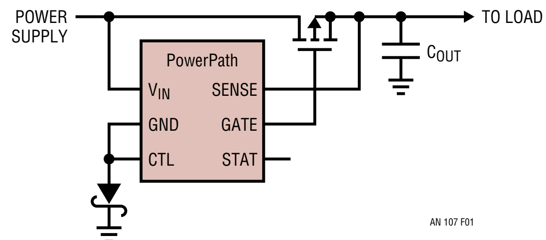

Figure 1. Circuit Capable of Operating with a Large Negative Input Supply

EXTENDING THE VOLTAGE RANGE

Any of Linear's PowerPath controller circuits can benefit from an extended voltage range, even those that already have wide operating and absolute maximum voltage ranges. For instance, the LTC4412HV and LTC4414 will each withstand voltages from –14V to 40V, which can be extended further using the techniques described here. Likewise, the LTC4412's range of –14V to 28V can be extended. The voltage ranges of monolithic PowerPath solutions such as the LTC4411, which ranges from –0.3V to 6V, can also be extended, though not as far.

There are two different approaches to extending the voltage range of the PowerPath circuits. The first addresses the negative input voltage requirements with the addition of a Schottky diode. This change assures that the external P-channel pass transistor is held in the off state as the input goes below ground. The second approach allows the ICs to operate both above the specified voltage range and below ground. The external circuit count is still compact, requiring only three additional components.

CIRCUIT FOR LARGE NEGATIVE INPUT VOLTAGES

Refer to Figure 1 for a description of the circuit. The ground and control pins of the PowerPath IC are tied through a Schottky diode to the system ground. When the power supply goes below ground, the diode is reverse biased, blocking the negative supply path to ground. The maximum negative voltage for the circuit is limited by the maximum allowed voltage difference between the Sense pin and the V_{IN} pin. In the case of both the LTC4412HV and LTC4414, this difference is 40V, so the negative voltage limit is –40V. Likewise, LTC4411 is limited to –6V. These values both assume the SENSE Pin (load side) is 0V. Because the LTC4412HV and LTC4414 are capable of withstanding –14V with no diode present, the reverse breakdown voltage of the Schottky diode must exceed 26V to achieve the –40V capability at the input (40V – 14V = 26V).

During normal operation, when the input supply is positive, the voltage at the ground pin is equal to the forward voltage of the Schottky or approximately 0.2V. In turn, this additional voltage on the ground pin raises the minimum operating supply of the circuit by approximately 0.2V. The control signal input threshold increases by the same amount.

When the input supply goes more negative than the normal operating range of the part (–14V on the LTC4412 and LTC4414), the ground pin begins to go negative. The IC continues to hold the P-channel FET off as the power supply goes further below ground until the maximum V_{SENSE} minus V_{IN} voltage is reached (–40V on the LTC4412 and LTC4414 and –6V on the LTC4411).

The control and status pins also go negative under this large negative supply condition. Refer to Figure 2 for a circuit that allows control of the PowerPath IC during normal operation. A 100k series resistor must be added between the micro-

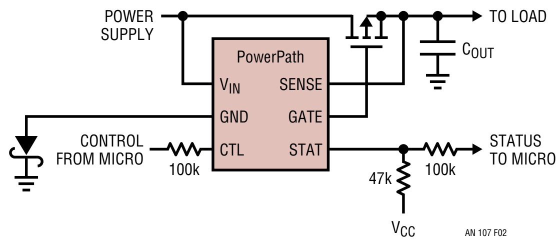

Figure 2. PowerPath Circuit Capable of Operating with a Large Negative Supply with Control and Status Available.

processor output and the control input. The series resistor allows the control pin to go below ground without causing excessive current in the microprocessor or other device controlling the part. The status pin also goes below ground under a negative input supply, requiring a 100k resistor in series between the status pin and the microprocessor input. Again, the resistor is added to protect the microprocessor from the negative input signal. Realistically, V_{CC} is not valid if the input power supply is negative, so the part operates for all valid supply conditions. The 100k series resistors have minimal impact on the control threshold or Status output. Both signals have a nominal ground reference at the V_F of the Schottky diode or approximately 0.2V. This is the largest deviation from nominal and should not present a problem in most systems.

CIRCUIT FOR LARGE POSITIVE INPUT VOLTAGES

Refer to Figure 3 for a description of the circuit. The IC ground and control pins of the PowerPath circuit are wired together and grounded through a resistor. They are also connected through a Zener diode to the input power supply. The breakdown voltage on the Zener must be less than the breakdown voltage of the IC: that is, a 5V Zener for the LTC4411, and a 36V Zener for both the LTC4412HV and the LTC4414.

When a large positive voltage is applied to the system, the

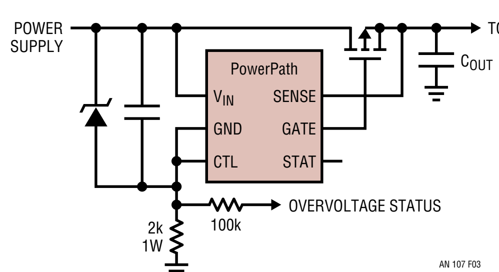

Figure 3. PowerPath Circuit Capable of Operating with a Large Positive Input Supply

Zener diode clamps the voltage between the V_{IN} and ground pins of the IC. The voltage on the resistor connected to system ground rises. The quiescent current of the PowerPath products are typically under 50µA, thus a 2k resistor causes the nominal voltage on the ground line to rise only 0.1V. This increases the minimum operating voltage by the voltage drop across the resistor or approximately 0.1V. The ground resistor must have a high enough power rating (V^2/R) for the circuit. For example, the LTC4412HV with a 36V Zener and an 80V input, produces 44V across the resistor. The resistor power rating is equal to $(44V)^2/2k$ or approximately 1W. If 80V only occurs during a transient, the power rating of the resistor can be reduced.

The ground pin of the PowerPath IC is positive when the input supply exceeds the Zener clamp voltage. This ground signal can be run through a 100k resistor to a microprocessor input to provide a control signal to the system. The voltage on the Overvoltage Status pin can be quite large, injecting too much current into the microprocessor input pin. A Schottky diode can be added between the 100k resistor and system supply to clamp the signal, if required.

When the input supply is a diode voltage below ground, the Zener diode conducts. This pulls the ground resistor terminal to within a diode of the negative power supply. The part sees virtually no external voltage between the ground and input pins. The maximum negative supply is limited by the maximum voltage difference between V_{IN} and the Sense pin. On the LTC4412HV and the LTC4414, the limit is 40V.

The LTC4411 has a negative absolute maximum voltage of –0.3V. The forward voltage of the Zener diode may be too large to assure minimal current in the IC under the negative supply condition. If the current is too large, a Schottky diode can be placed in parallel with the Zener diode. The reverse breakdown of the Schottky must be greater than the Zener breakdown of 5V. The forward voltage of the Schottky is less than 0.3V assuring no excessive current in the IC. Again, the maximum negative voltage allowed is the maximum differential between IN and OUT or 6V.

CONCLUSION

The circuit techniques presented here extend the supply voltage ranges of Linear Technology's PowerPath products, thereby extending their applicability beyond their data sheet voltage range.

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