

# Taking Full Advantage of Very Low Dropout Linear Regulators

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## Introduction

Linear regulators are generally considered inefficient step-down DC/DC converters, but low dropout linear regulators (LDOs) can be a good fit in many handheld battery applications where low power and efficient power conversion are critical. The lower the dropout voltage, the more efficient the LDO solution. Generally, LDOs with a very small dropout voltage come at the expense of increased package size and higher quiescent current. The LTC3035 overcomes these tradeoffs by offering a very low dropout voltage without sacrificing small solution size or low power.

The LTC3035 is a micropower, VLDO™ (very low dropout) linear regulator, which operates from input voltages between 1.7V and 5.5V. The device is capable of supplying 300mA of continuous output current with an ultra-low dropout voltage of 45mV typical (see Figure 1). The output voltage is externally adjustable over a wide voltage range, spanning between 0.4V and 3.6V.

The LTC3035 is ideal for battery-powered applications where low power, low dropout, low noise, and small solution size are essential. Under no-load conditions, the chip draws only

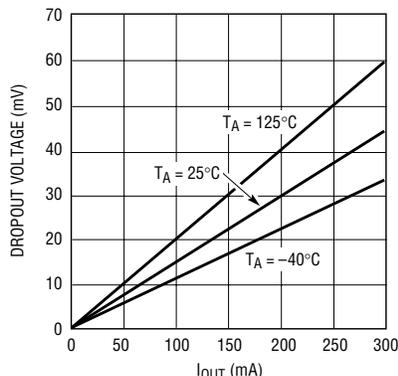


Figure 1. Typical dropout voltage versus load current

100µA from the  $V_{IN}$  supply, and drops to 1µA when in shutdown. The LDO is stable for all ceramic capacitors down to 1µF. Other features include output short-circuit protection, reverse output current protection, and thermal overload protection, all available in a tiny 3mm × 2mm DFN package.

## Low Dropout from an NMOS Pass Device

Conventional LDOs integrate a P-type transistor (either PNP or PMOS) as the power pass device to deliver current from the input supply to its output. The LTC3035, instead, incorporates an NMOS transistor as its pass element

in a source-follower configuration. This architecture allows for several performance advantages over conventional P-type LDOs, such as greater  $V_{IN}$  power supply rejection, lower dropout voltage, and better transient response characteristics, while maintaining a smaller solution size.

Using an NMOS pass device is not entirely transparent. In order to achieve low dropout performance using an NMOS pass device, the LDO circuitry must be capable of driving the NMOS gate above the  $V_{IN}$  supply. This implies that a separate higher voltage supply is necessary to power the LDO circuitry. For many applications, the luxury of an extra higher supply is simply unavailable. The LTC3035 overcomes this problem by including a built-in charge pump that generates a higher BIAS supply from the  $V_{IN}$  input to power its LDO circuitry. The charge pump requires only a 0.1µF flying capacitor and a 1µF bypass capacitor for operation. The value of the generated BIAS supply is adaptively controlled to provide sufficient gate drive over the full  $V_{IN}$  operating range, optimizing the current carrying capabilities and dropout characteristics of the VLDO regulator.

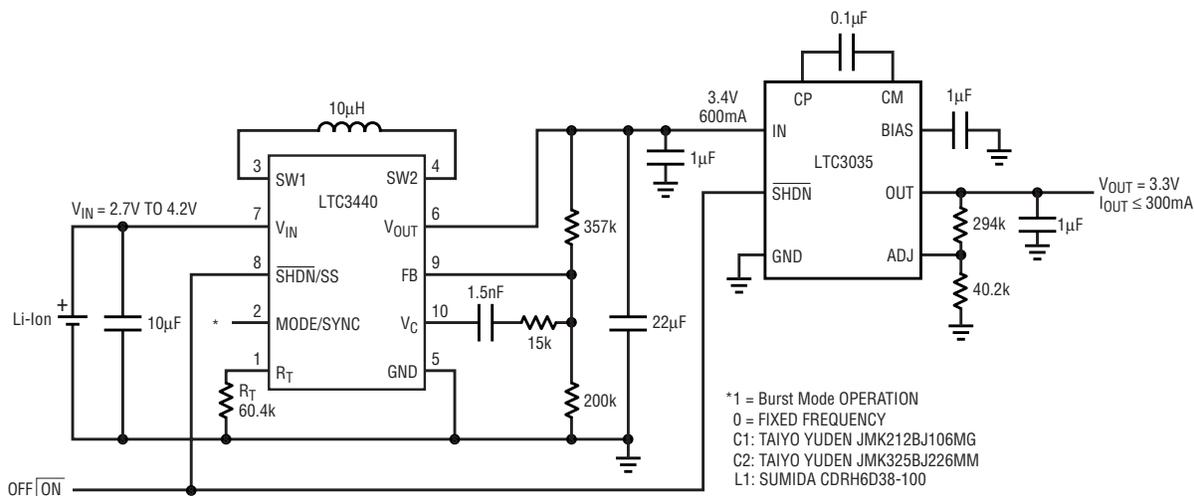
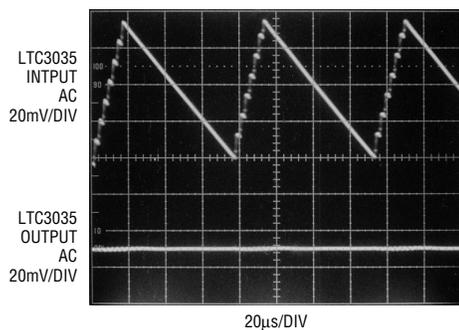


Figure 2. A high-efficiency and low-noise lithium-ion to 3.3V solution

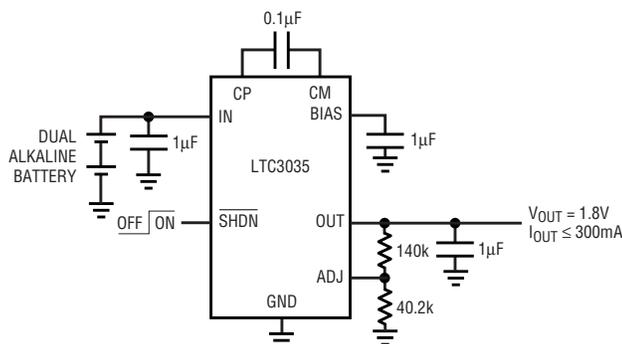


**Figure 3. Input and output waveforms to the LTC3035 in the Li-Ion to 3.3V application, showing its excellent ripple rejection ( $I_{OUT} = 25mA$ , LTC3440 in Burst Mode®)**

### High Efficiency, Low Noise Li-Ion to 3.3V

Figure 2 shows a high efficiency and low noise lithium-ion to 3.3V solution. The LTC3440, a buck-boost converter, converts the Li-Ion battery voltage to an efficient intermediate voltage (3.4V) at the input of the VLDO. The LTC3035 then regulates this intermediate voltage down to 3.3V, providing a lower noise output voltage. Figure 3 shows the input and output waveforms of the LTC3035 at 25mA of output current, illustrating its excellent power supply rejection characteristics for a lower noise solution.

For optimum total efficiency, the input to output voltage differential across the LDO should be as small as possible, since the magnitude of the dissipated power equals the product of the voltage differential and the output current. Because of the LTC3035's



**Figure 4. A very low dropout dual-alkaline to 1.8V application**

very low dropout voltage, its input voltage can be programmed to only 100mV above the 3.3V output and still maintain regulation at 300mA. Conventional LDOs with higher dropout voltages force greater input and output voltage differentials, effectively reducing efficiency by the same ratio.

### Double Alkaline to 1.8V LDO

Handheld applications using two alkaline batteries in series demand low power solutions that use as much of the battery's operating voltage range as possible. In Figure 4, two series alkaline batteries are regulated down to provide a 1.8V supply taking advantage of the LTC3035's excellent dropout characteristics.

The dropout voltage and maximum output current capabilities of typical low power LDOs using P-type transistors suffer as the input voltage supply decreases, since the power transistor's overdrive reduces. With input and

output voltages near 1.8V, conventional low power LDOs may have dropout voltages over 200mV, if they can deliver 300mA of output current at all. Using the LTC3035, the battery voltage can discharge much further to only about 50mV above the 1.8V output before the LDO begins to drop out at 300mA. Allowing the battery to discharge longer essentially extends the battery life for the application when compared to solutions that use higher dropout LDOs.

### Conclusion

The very low dropout characteristics of the LTC3035 can be exploited in battery-powered applications to obtain higher efficiency and increased battery life. Its very low dropout voltage, excellent power supply rejection, low-quiescent current, and small solution size make the LTC3035 an ideal choice for many low power, handheld battery applications.

LT3470, continued from page 34

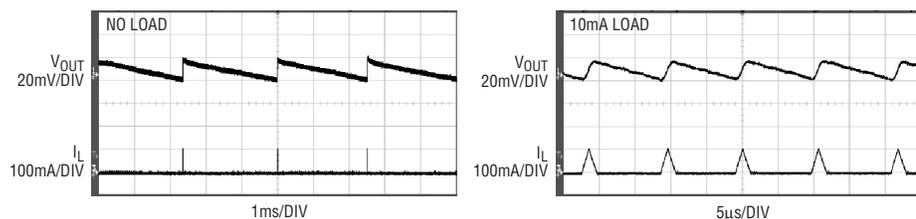
The fast cycle-by-cycle current limit of the LT3470 keeps the switch and inductor currents under control at all times. In addition, the LT3470 uses hysteretic mode control where the switching frequency automatically adjusts to accommodate variations in

$V_{IN}$  and  $V_{OUT}$ . This means that the part switches at a slower frequency when the output is in short circuit or when  $V_{IN}/V_{OUT}$  ratio is high. This ensures that the LT3470 can handle a short circuit at the output even if  $V_{IN} = 40V$  and the inductor value is small. It

is, however, important to choose an inductor that does not saturate excessively at currents below 400mA to guarantee short circuit protection.

### Conclusion

The LT3470 is a small buck regulator with a unique combination of features that make it a great choice in applications requiring small size, high efficiency across a wide range of currents, and low output ripple. It can deliver up to 200mA from inputs as high as 40V using only an inductor, four small ceramic capacitors, and two resistors while consuming only 26µA during no load operation.



**Figure 3. Operating waveforms show the output voltage ripple remains at 10mV in BurstMode operation, while requiring only a 22µF ceramic output capacitor.**