

## 1.5MHz, 1A, High-Efficiency PWM Synchronous Step-Down Converter

### Description

The FP6360 is a high efficiency, low-noise, DC-DC step-down pulse width modulated (PWM) converter. The 100% duty cycle feature provides low dropout operation, extending battery life in portable systems. The switching frequency can be controlled by the external resistor.

The internal synchronous switch increases efficiency and eliminates the need for an external Schottky diode. Shutdown mode places the device in standby, reducing quiescent supply current to less than 1μA.

The current limit protection and on-chip thermal shutdown features provide protection against any combination of overload or ambient temperature.

### Features

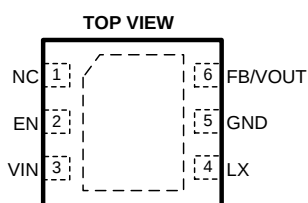
- Synchronous Rectification: Approach 95% Efficiency
- 2.5V to 5.5V Input Voltage Range
- Real Shutdown Isolated Load from Battery
- Internal Compensation without External Capacitors and Resistors
- No Schottky Diode Required
- Low Dropout Operation: 100% Duty Cycle
- Fixed Frequency Operation at 1.5MHz
- Very Low Shutdown Current at 0.1μA
- RoHS Compliant

### Applications

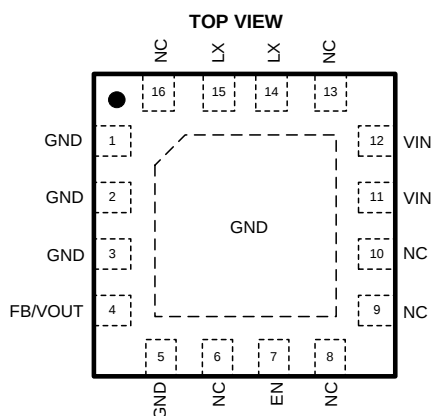
- Cellular Phone
- Handheld Instrument
- Wireless LAN
- MP3 Portable Audio Player
- Battery Operated Device

### Pin Assignments

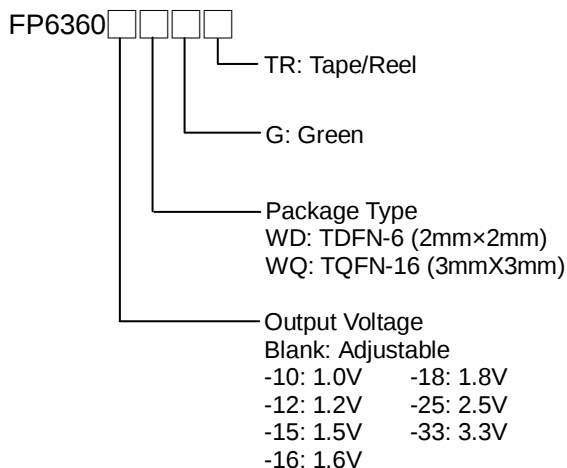
#### WD Package TDFN-6 (2mmx2mm)



#### WQ Package TQFN-16 (3mmX3mm)



### Ordering Information



#### TDFN-6(2mmx2mm) Marking

| Part Number  | Product Code | Part Number  | Product Code |
|--------------|--------------|--------------|--------------|
| FP6360-10WDG | X3=          | FP6360-18WDG | X7=          |
| FP6360-12WDG | X4=          | FP6360-25WDG | X8=          |
| FP6360-15WDG | X5=          | FP6360-33WDG | X9=          |
| FP6360-16WDG | X6=          | FP6360WDG    | Y1=          |

Figure 1. Pin Assignment of FP6360

## Typical Application Circuit

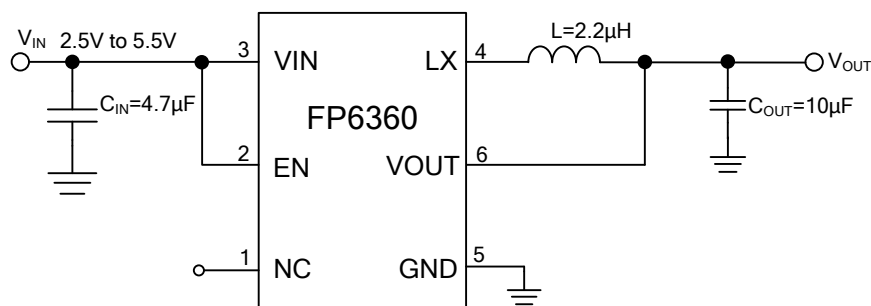


Figure 2. Typical application circuit of fixed voltage version

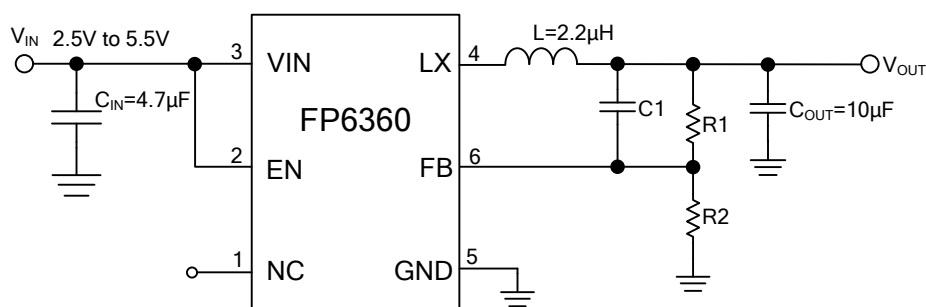


Figure 3. Typical application circuit of adjustable voltage version

## Functional Pin Description

| Pin Name | Pin Function                                                                                                                                   |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------|
| NC       | No Connection (Floating or connect to GND).                                                                                                    |
| EN       | Enable Pin. Logic high enables the converter, and logic low forces the device into shutdown mode to reduce the supply current to less than 1µA |
| GND      | Ground                                                                                                                                         |
| LX       | Inductor connection to the drains of the internal power MOSFETs                                                                                |
| VIN      | Supply Voltage Input. Input range is from 2.5V to 5.5V. Bypass with a 10µF capacitor                                                           |
| FB/VOUT  | Feedback Input/Output Voltage Pin.                                                                                                             |

## Block Diagram

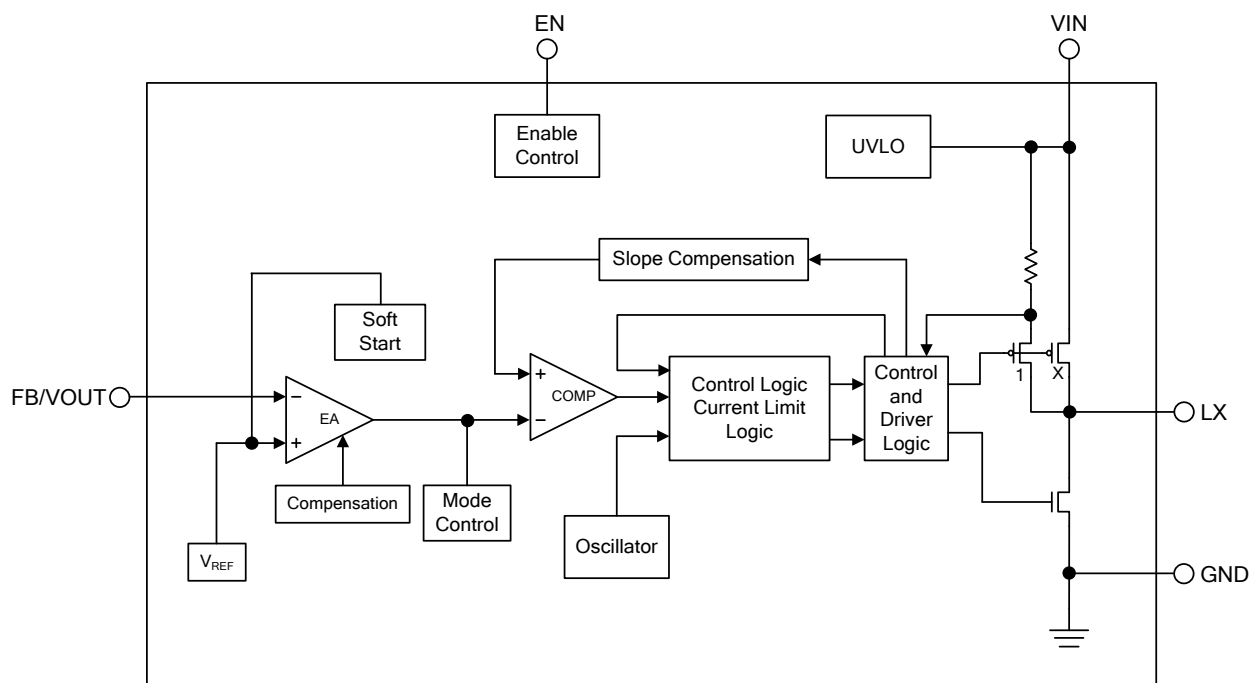


Figure 4. Block Diagram of FP6360

## Absolute Maximum Ratings

- VIN to GND ----- -0.3V to +6V
- LX to GND ----- -0.3V to (VIN+0.3)
- EN, FB/VOUT to GND ----- -0.3V to VIN
- Power Dissipation @25°C, (PD)
  - TDFN-6 (2mm×2mm) ----- +1.25W
  - TQFN-16 (3mm×3mm) ----- +1.54W
- Package Thermal Resistance, ( $\theta_{JA}$ )
  - TDFN-6 (2mm×2mm) ----- +80°C/W
  - TQFN-16 (3mm×3mm) ----- +65°C/W
- Package Thermal Resistance, ( $\theta_{JC}$ )
  - TDFN-6 (2mm×2mm) ----- 56°C/W
- Maximum Junction Temperature (TJ) ----- +150°C
- Storage Temperature (TSTG) ----- -65°C to +150°C
- Lead Temperature (Soldering, 10sec.) ----- +260°C

Note 1 : Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device.

## Recommended Operating Conditions

- Supply Voltage (VIN) ----- +2.5V to +5.5V
- Operation Temperature Range (TOPR) ----- -40°C to +85°C

## Electrical Characteristics

( $V_{IN}=3.6V$ ,  $EN=V_{IN}$ ,  $T_A=25^{\circ}C$ , unless otherwise specified)

| Parameter                              | Symbol            | Conditions                                       | Min.  | Typ. | Max.  | Unit        |
|----------------------------------------|-------------------|--------------------------------------------------|-------|------|-------|-------------|
| Operating Input Voltage                | $V_{IN}$          |                                                  | 2.5   |      | 5.5   | V           |
| Quiescent Current                      | $I_Q$             | $V_{FB}=0.63V$ or $V_{OUT}=105\%$ ,<br>$I_O=0mA$ |       | 50   | 70    | $\mu A$     |
| Shutdown Current                       | $I_{SD}$          | $EN=GND$                                         |       | 0.1  | 1     |             |
| EN High-Level Input Voltage            | $V_{IH}$          |                                                  | 1.3   |      |       | V           |
| EN Low-Level Input Voltage             | $V_{IL}$          |                                                  |       |      | 0.4   | V           |
| EN Input Leakage Current               | $I_{LKG}$         | $EN=GND$ or $V_{IN}$                             |       | 0.01 | 1     | $\mu A$     |
| N-Channel MOSFET On-Resistance (Note2) | $R_{DS(ON)}$      | $I_{LX} = 100mA$                                 |       | 250  | 300   | $m\Omega$   |
| P-Channel MOSFET On-Resistance (Note2) | $R_{DS(ON)}$      | $I_{LX} = 100mA$                                 |       | 280  | 330   | $m\Omega$   |
| Oscillator Frequency                   | $f_s$             |                                                  |       | 1500 |       | kHz         |
| P-Channel Current Limit (Note2)        | $I_{LIM}$         | $V_{FB}=0.5V$                                    | 1.4   | 1.5  |       | A           |
| Under Voltage Lock Out Voltage         | UVLO              |                                                  |       | 1.8  |       | V           |
| UVLO Hysteresis                        | $V_{HYS}$         |                                                  |       | 0.1  |       | V           |
| FB Input Leakage Current               | $I_{FB}$          | $V_{FB}=V_{IN}$                                  |       | 0.01 | 1     | $\mu A$     |
| LX Leakage Current                     |                   | $V_{IN}=3.6V$ , $V_{LX}=0V$ or $V_{LX}=3.6V$     | -1    |      | 1     | $\mu A$     |
| Reference Voltage                      | $V_{REF}$         |                                                  | 0.588 | 0.6  | 0.612 | V           |
| Output Voltage Accuracy (Fix)          | $\Delta V_{OUT}$  |                                                  | -2    |      | +2    | %           |
| Line Regulation                        | $\Delta V_{LINE}$ | $V_{IN}=V_O+0.5V$ to $5.5V$ ; $I_O = 10mA$       |       | 0.05 |       | %/V         |
| Load Regulation                        | $\Delta V_{LOAD}$ | $I_O = 10mA$ to $1A$                             |       | 0.8  |       | %/A         |
| Thermal Shutdown Temperature (Note2)   | $T_{SD}$          |                                                  |       | 160  |       | $^{\circ}C$ |
|                                        | $\Delta T_{SD}$   | Hysteresis                                       |       | 20   |       | $^{\circ}C$ |

Note 2 : Guarantee by design.

## Typical Performance Curves

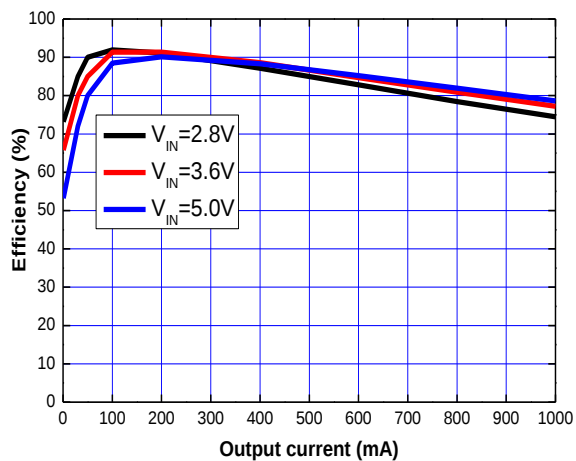


Figure 5. Efficiency vs. Load Current

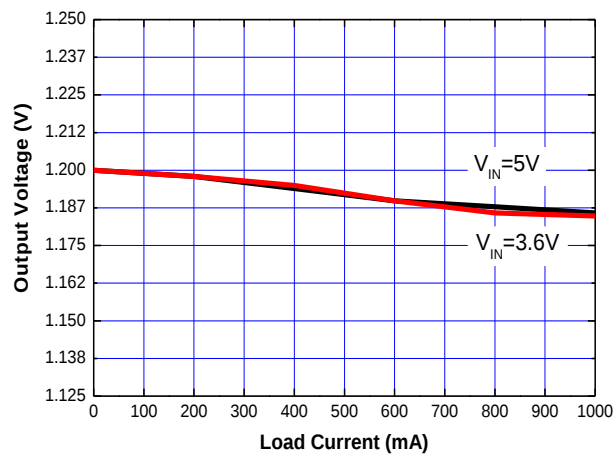


Figure 6. Output Voltage vs. Output Current

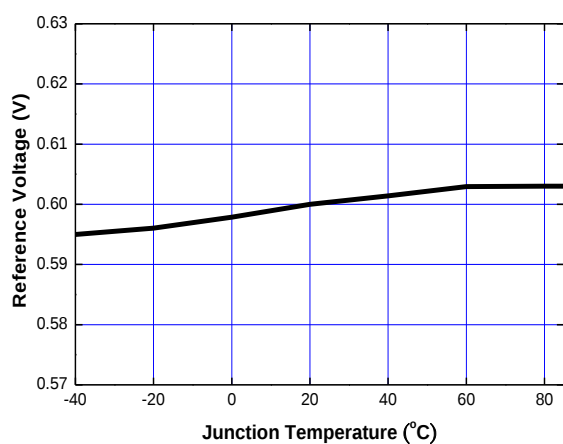


Figure 7. Reference Voltage vs. Junction Temperature

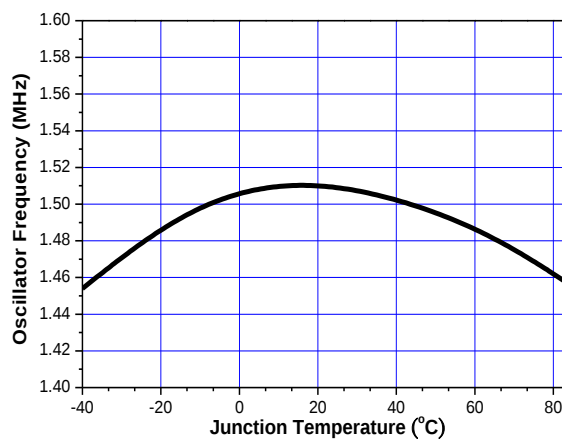


Figure 8. Frequency vs. Junction Temperature

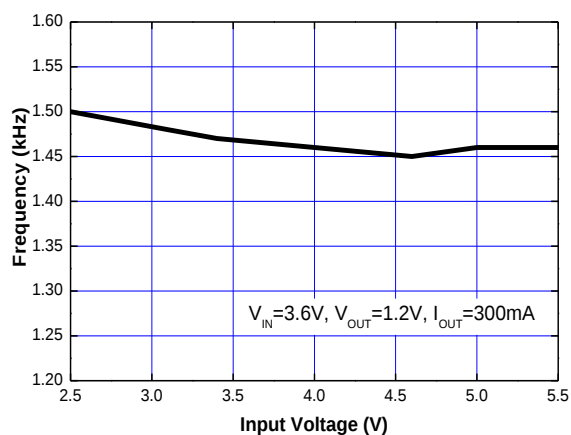


Figure 9. Frequency vs. Input Voltage

## Typical Performance Curves (Continued)

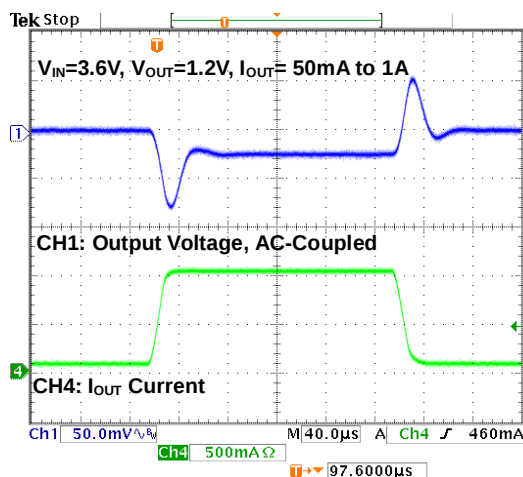


Figure 10. Load Transient Response

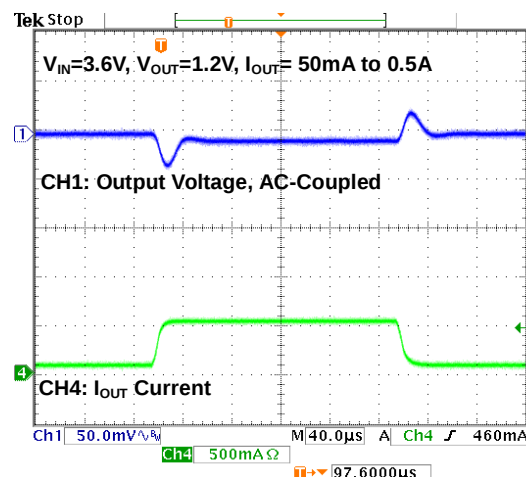


Figure 11. Load Transient Response

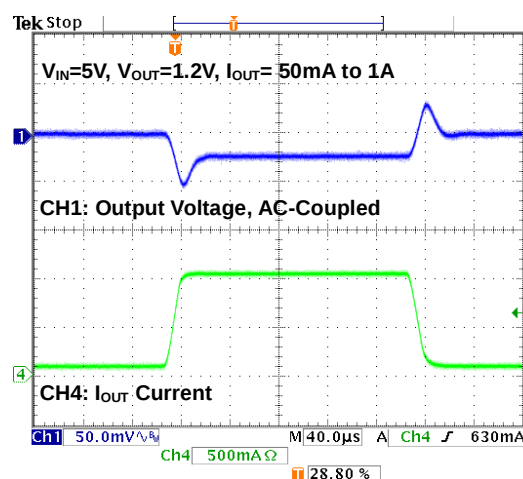


Figure 12. Load Transient Response

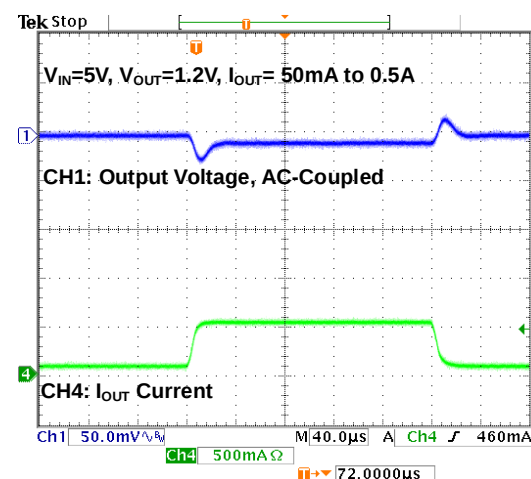


Figure 13. Load Transient Response

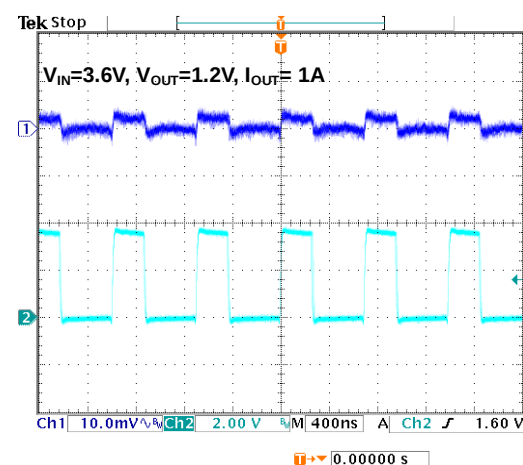


Figure 14. Output Ripple Voltage

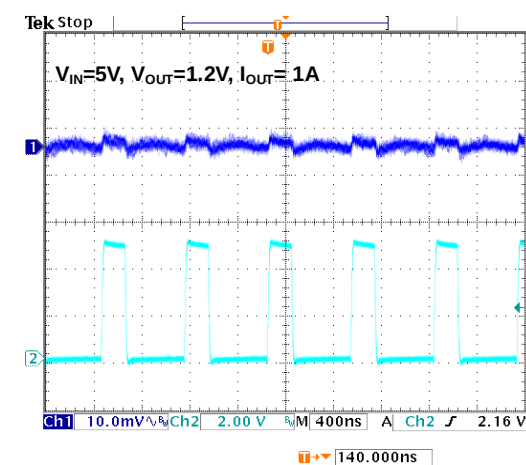


Figure 15. Output Ripple Voltage

## Typical Performance Curves (Continued)

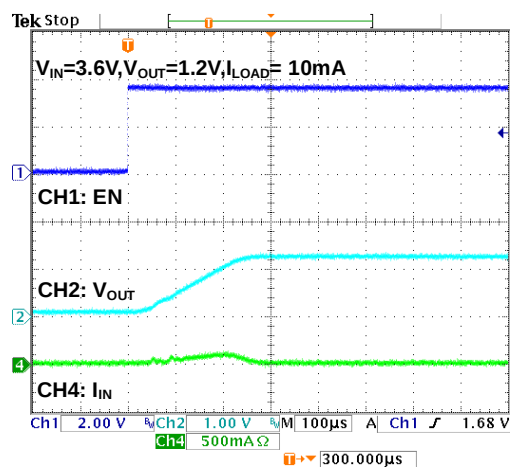


Figure 16. Start-up Waveform

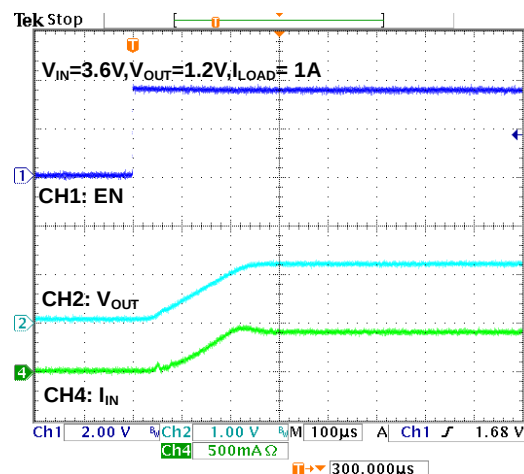


Figure 17. Start-up Waveform

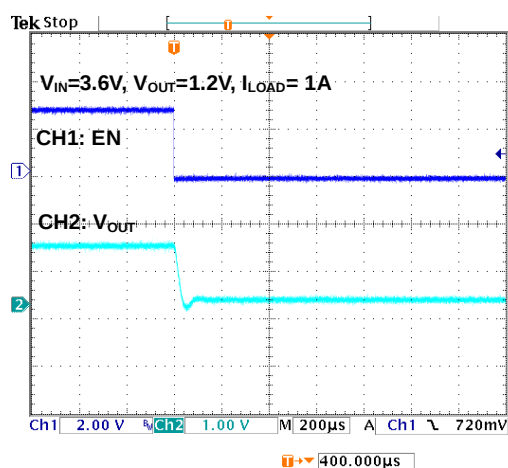


Figure 18. Power Off from EN

## Application Information

### Inductor Selection

A 2.2μH to 4.7μH is recommended for general use. The value of inductor depends on the operating frequency. Higher frequency allows smaller inductor and capacitor but increases internal switching loss. Two inductor parameters should be considered, current rating and DCR. The inductor with the lowest DCR is chosen for the highest efficiency.

The inductor value can be calculated as:

$$L \geq \frac{V_{OUT}}{f \times \Delta I_L} \left( 1 - \frac{V_{OUT}}{V_{IN}} \right)$$

$\Delta I_L$ : inductor ripple current, which is defined as:

$$\Delta I_L = V_O \left[ \left( 1 - \frac{V_O}{V_I} \right) / (L \cdot f) \right] \quad (\text{General Setting})$$

$$\approx 0.1 \times 2 \times I_{O-MAX}$$

The inductor should be rated for the maximum output current ( $I_{O-MAX}$ ) plus the inductor ripple current ( $\Delta I_L$ ) to avoid saturation. The maximum inductor current ( $I_{L-MAX}$ ) is given by:

$$I_{L-MAX} = I_{O-MAX} + \frac{\Delta I_L}{2}$$

### Capacitor Selection

The small size of ceramic capacitors are ideal for FP6360 applications. X5R and X7R types are recommended because they retain their capacitance over wider voltage and temperature ranges than other types, such as Y5V or Z5U. A 4.7μF input capacitor and a 10μF output capacitor are sufficient for most FP6360 applications.

When selecting an output capacitor, consider the output ripple voltage and the ripple current. The ESR of capacitor is a major factor to the output ripple. For the best performance, a low ESR output capacitor is required. The ripple voltage is given by:

$$\Delta V_O = \Delta I_L \left( \text{ESR} + \frac{1}{8 \times f \times C_O} \right)$$

### Output Voltage Programming (Adjustable Voltage Version)

The output voltage of FP6360 is set by the resistor divider according to the following formula:

$$V_{OUT} = V_{FB} \times \left( 1 + \frac{R1}{R2} \right)$$

R1 is the upper resistor of the voltage divider. For transient response reasons, a small feed-forward capacitor ( $C_F$ ) is required in parallel to the upper feedback resistor, and 33pF is recommended.

### Checking Transient Response

The regulator loop response can be checked by looking at the load transient response. Switching regulators take several cycles to respond to a step in load current. When a load step occurs,  $V_{OUT}$  will be shifted immediately by an amount equal to  $(\Delta I_{LOAD} \cdot \text{ESR})$ , where ESR is the effective series resistance of  $C_{OUT}$ .  $\Delta I_{LOAD}$  will also begin to charge or discharge  $C_{OUT}$ , which generates a feedback error signal. Then the regulator loop will act to return  $V_{OUT}$  to its steady state value. During this recovery time,  $V_{OUT}$  can be monitored for overshoot or ringing that will indicate the stability problem.

The discharged bypass capacitors are effectively put in parallel with  $C_{OUT}$ , causing a rapidly drop in  $V_{OUT}$ . No regulator can deliver enough current to prevent this problem if the load switch resistance is low and it is driven quickly. The only solution is to limit the rise time of the switch drive, so that the load rise time will be limited to approximately  $(25 \cdot C_{LOAD})$ .

### Current Mode PWM Control

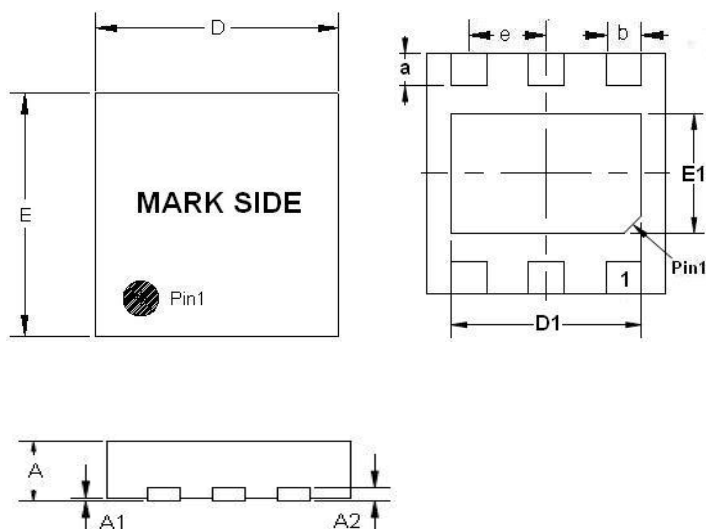
Slope compensated current mode PWM control provides stable switching, cycle-by-cycle current limit for superior load, line response, protection of the internal main switch and synchronous rectifier. The FP6360 switches at a constant frequency (1.5MHz) and regulates the output voltage. During each cycle, the PWM comparator modulates the power transferred to the load by changing the inductor peak current based on the feedback error voltage. During normal operation, the main switch is turned on for a certain time to ramp the inductor current at each rising edge of the internal oscillator, and switched off when the peak inductor current is above the error voltage. When the main switch is off, the synchronous rectifier will be turned on immediately and stay on until next cycle starts.

### Dropout Operation

The FP6360 allows the main switch to remain on for more than one switching cycle, and increases the duty cycle while the input voltage is dropping close to the output voltage. When the duty cycle reaches 100%, the main switch will be held on continuously to deliver current to the output up to the MOSFET current limit. Then the output voltage will be the input voltage minus the voltage drop across the main switch and the inductor.

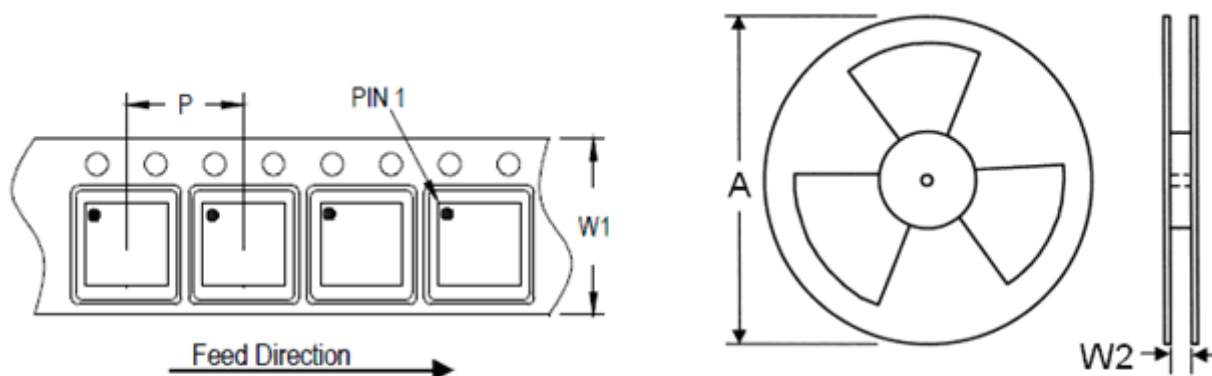
## Outline Information

TDFN-6 2mm×2mm Package (Unit: mm)



| SYMBOLS<br>UNIT | DIMENSION IN MILLIMETER |      |
|-----------------|-------------------------|------|
|                 | MIN                     | MAX  |
| A               | 0.70                    | 0.80 |
| A1              | 0.00                    | 0.05 |
| A2              | 0.19                    | 0.22 |
| D               | 1.95                    | 2.05 |
| E               | 1.95                    | 2.05 |
| a               | 0.20                    | 0.40 |
| b               | 0.25                    | 0.35 |
| e               | 0.60                    | 0.70 |
| D1              | 1.15                    | 1.65 |
| E1              | 0.55                    | 1.05 |

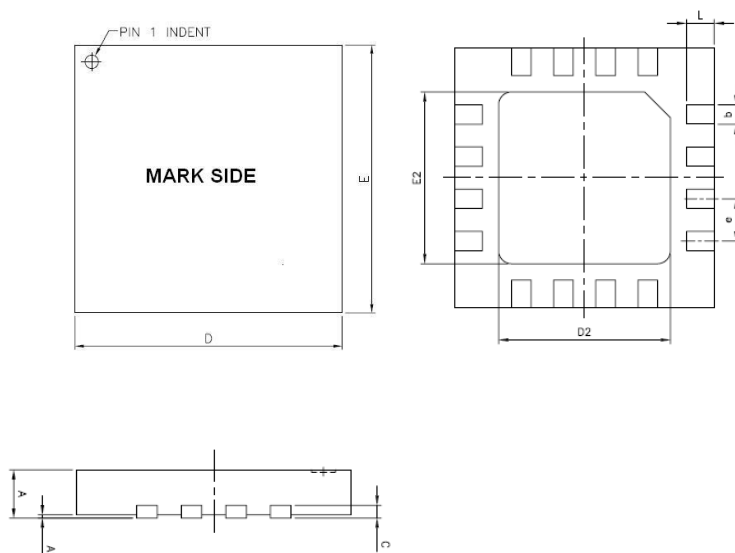
## Carrier Dimensions



| Tape Size<br>(W1) mm | Pocket Pitch<br>(P) mm | Reel Size (A) |     | Reel Width<br>(W2) mm | Empty Cavity<br>Length mm | Units per Reel |
|----------------------|------------------------|---------------|-----|-----------------------|---------------------------|----------------|
|                      |                        | in            | mm  |                       |                           |                |
| 8                    | 4                      | 7             | 180 | 8.4                   | 400~1000                  | 3,000          |

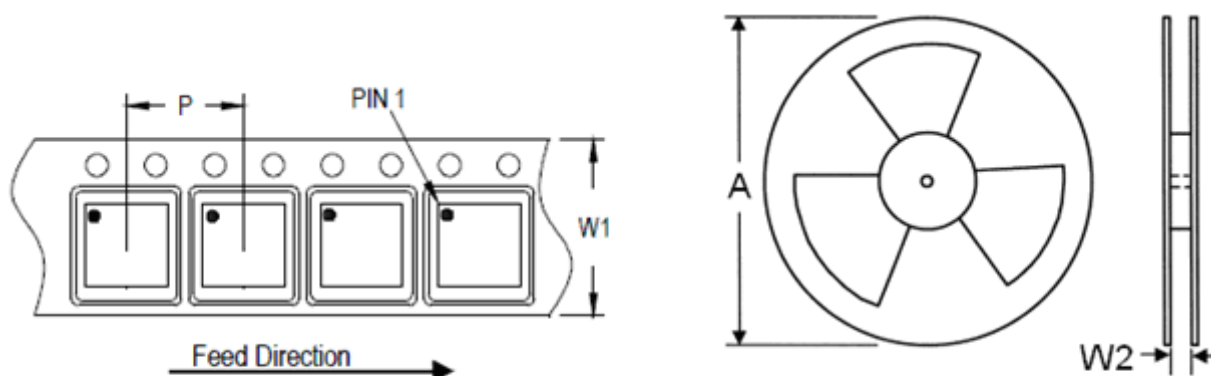
## Outline Information (Continued)

TQFN-16 3mmx3mm Package (Unit: mm)



| SYMBOLS<br>UNIT | DIMENSION IN MILLIMETER |      |
|-----------------|-------------------------|------|
|                 | MIN                     | MAX  |
| A               | 0.70                    | 0.80 |
| A1              | 0.00                    | 0.05 |
| C               | 0.19                    | 0.30 |
| E               | 2.90                    | 3.10 |
| D               | 2.90                    | 3.10 |
| L               | 0.35                    | 0.45 |
| b               | 0.18                    | 0.30 |
| e               | 0.45                    | 0.55 |
| E2              | 1.50                    | 1.80 |
| D2              | 1.50                    | 1.80 |

## Carrier Dimensions



| Tape Size<br>(W1) mm | Pocket Pitch<br>(P) mm | Reel Size (A) |     | Reel Width<br>(W2) mm | Empty Cavity<br>Length mm | Units per Reel |
|----------------------|------------------------|---------------|-----|-----------------------|---------------------------|----------------|
|                      |                        | in            | mm  |                       |                           |                |
| 12                   | 8                      | 13            | 330 | 12.4                  | 400~1000                  | 3,000          |

### Life Support Policy

Fitipower's products are not authorized for use as critical components in life support devices or other medical systems