



April 2007

FAN2106 — TinyBuck™ 6A, 24V Input Integrated Synchronous Buck Regulator

Features

- Over 95% efficiency
- Internal power MOSFETs:
High-side $R_{DS(ON)} = 30m\Omega$
Low-side $R_{DS(ON)} = 14m\Omega$
- Integrated low-side Schottky diode
- Programmable frequency operation
- Power-good signal
- Wide input range: 3.0V to 24V
- Output voltage range: 0.8V to 90% V_{IN}
- Input under-voltage lockout (UVLO)
- Programmable over-current protection
- Under-voltage, over-voltage, and thermal protection
- Selectable light-load power-saving mode
- 5x6mm, 25-pin, 3-pad MLP

Applications

- Thin and light Notebook PCs
- Graphics cards
- Battery-powered equipment
- Set-top box
- Point-of-load regulation

Description

The FAN2106 TinyBuck™ is an easy-to-use, cost and space-efficient, synchronous buck solution. It enables designers to solve high current requirements in a small area with minimal external components.

External programming of clock frequency, current limit, and loop response allows for optimization and flexibility selecting output filter components and transient response.

The summing current mode modulator uses lossless current sensing for current feedback and over-current, and includes voltage feedforward.

Fairchild's advanced BiCMOS power process, combined with a thermally efficient MLP package, provides low- $R_{DS(ON)}$ internal MOSFETs and the ability to dissipate high power in a small package.

Under-voltage, thermal shutdown, and power-good are blanked at start-up, but protect the device from damage during fault conditions.

Ordering Information

Part Number	Operating Temperature Range	Pb-Free	Package	Packing Method
FAN2106MPX	-10°C to 85°C	Yes	Molded Leadless Package (MLP) 5x6mm	Tape and Reel
FAN2106EMPX	-40°C to 85°C	Yes	Molded Leadless Package (MLP) 5x6mm	Tape and Reel

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Typical Application Diagram

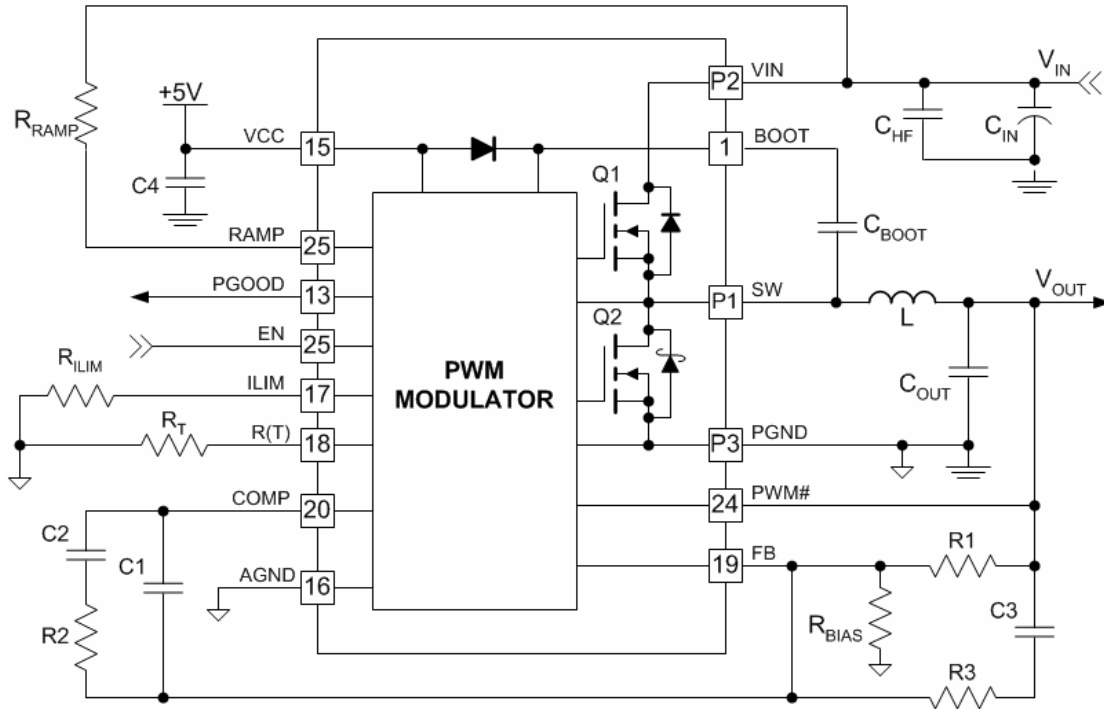


Figure 1. Typical Application

Block Diagram

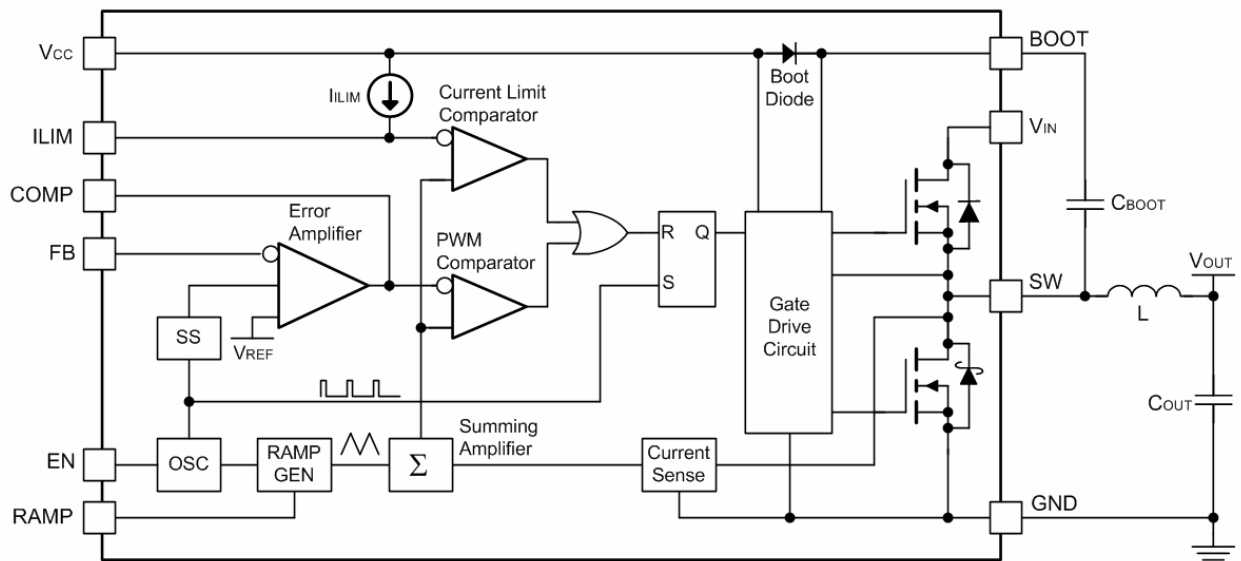


Figure 2. Block Diagram

Pin Assignments

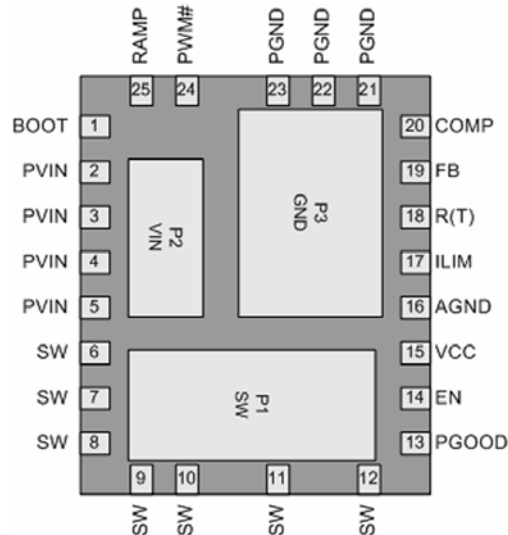


Figure 3. MLP 5x6mm Pin Configuration (PCB Layout View)

Pin Definitions

Pin	Name	Description
P1, 6-12	SW	Switching Node.
P2, 2-5	PVIN	Power Input Voltage. Connect to the main input power source.
P3, 21-23	PGND	Power Ground. Power return and Q2 source.
1	BOOT	High-Side Drive BOOT Voltage. Connect through capacitor (C_{BOOT}) to SW. The IC includes an internal synchronous bootstrap diode to recharge the capacitor on this pin to V_{CC} when SW is LOW.
13	PGOOD	Power-Good Flag. An open-drain output that pulls LOW when FB is outside a $\pm 10\%$ range of the reference when EN is HIGH. PGOOD does not assert HIGH until the fault latch is enabled.
14	EN	ENABLE. Enables operation when pulled to logic HIGH or left open. Toggling EN resets the regulator after a latched fault condition. This input has an internal pull-up when the IC is functioning normally. When a latched fault occurs, EN is discharged by a current sink.
15	VCC	Input Bias Supply for IC. The IC's logic and analog circuitry are powered from this pin.
16	AGND	Analog Ground. The signal ground for the IC. All internal control voltages are referred to this pin. Tie this pin to the ground island/plane through the lowest impedance connection.
17	ILIM	Current Limit. A resistor (R_{ILIM}) from this pin to AGND can be used to program the current-limit trip threshold lower than the default setting.
18	R(T)	Oscillator Frequency. A resistor (R_T) from this pin to AGND sets the PWM switching frequency.
19	FB	Output Voltage Feedback. Connect through a resistor divider to the output voltage.
20	COMP	Compensation. Error amplifier output. Connect the external compensation network between this pin and FB.
24	PWM# / VOUT	Forced PWM / VOUT. Connect to VOUT to enable light-load, power-saving mode of operation. Connect to GND or leave open for PWM mode.
25	RAMP	Ramp Amplitude. A resistor (R_{RAMP}) connected from this pin to PVIN sets the ramp amplitude and provides voltage feedforward functionality.

Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Parameter	Conditions	Min.	Max.	Unit
PVIN to PGND			28	V
VCC to AGND	AGND = PGND		6	V
BOOT to PGND			35	V
BOOT to SW		-0.3	6	V
SW to PGND	Continuous	-0.5	24	V
	Transient (t < 20nsec, F ≤ 600KHz)	-5	30	V
All other pins		-0.3	V _{CC} +0.3	V

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to absolute maximum ratings.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V _{CC}	Bias Voltage	VCC to AGND	4.5	5.0	5.5	V
V _{IN}	Supply Voltage	PVIN to PGND	3		24	V
T _A	Ambient Temperature	FAN2106M	-10		85	°C
		FAN2106EM	-40		85	°C
T _J	Junction Temperature				125	°C

Thermal Information

Symbol	Parameter	Min.	Typ.	Max.	Unit
T _{STG}	Storage Temperature	-65		150	°C
T _L	Lead Soldering Temperature, 10 seconds			300	°C
T _{VP}	Vapor Phase, 60 seconds			215	°C
T _I	Infrared, 15 seconds			220	°C
θ _{JC}	Thermal Resistance: Junction-to-Case	P1 (Q2)		4	°C/W
		P2 (Q1)		7	°C/W
		P3		4	°C/W
θ _{J-PCB}	Thermal Resistance: Junction-to-Mounting Surface		35 ⁽¹⁾		°C/W
P _D	Power Dissipation, T _A = 25°C			2.8 ⁽¹⁾	W

Note:

1. Typical thermal resistance when mounted on a four-layer, two-ounce PCB, as shown in Figure 25. Actual results are dependent on mounting method and surface related to the design.

Electrical Specifications

Recommended operating conditions are the result of using the circuit shown in Figure 1 unless otherwise noted.

Parameter	Conditions	Min.	Typ.	Max.	Unit
Power Supplies					
V _{CC} Current	SW = Open, FB = 0.7V, V _{CC} = 5V, F _{SW} = 600KHz		8	12	mA
	Shutdown: EN=0, V _{CC} = 5V		7	10	μA
	Power Saving Mode, V _{CC} = 5V, F _{MIN}		2.2	4.5	mA
V _{CC} UVLO Threshold	Rising V _{CC}	4.1	4.3	4.5	V
	Hysteresis		300		mV
Power Output Section					
N-Channel (Q1) R _{DS(ON)}	V _{CC} = 5V, 25°C		30	35	mΩ
N-Channel (Q2) R _{DS(ON)}	V _{CC} = 5V, 25°C		14	16	mΩ
Oscillator					
Frequency	R _T = 50KΩ	255	300	345	KHz
	R _T = 24KΩ	540	600	660	KHz
Minimum On-Time ⁽²⁾			50	65	nsec
Ramp Amplitude, pk-pk	16V _{IN} , 1.8V _{OUT} , R _T = 30KΩ, R _{RAMP} = 200KΩ		0.53		V
Minimum Off-Time ⁽²⁾			100	150	nsec
Reference					
Reference Voltage (V _{FB})	FAN2106M, 25°C	794	800	806	mV
	FAN2106EM, 25°C	795	800	805	mV
Error Amplifier					
DC Gain ⁽²⁾	V _{CC} = 5V	80	85		dB
Gain Bandwidth Product ⁽²⁾	V _{CC} = 5V	12	15		MHz
Output Voltage (V _{COMP})	V _{CC} = 5V	0.4		3.2	V
Output Current, Sourcing	V _{CC} = 5V, V _{COMP} = 2.2V	1.5	2.2		mA
Output Current, Sinking	V _{CC} = 5V, V _{COMP} = 1.2V	0.8	1.2		mA
FB Bias Current	V _{FB} = 0.8V, 25°C	-850	-650	-450	nA
Protection and Shutdown					
Current Limit	R _{LIM} open	6	8	10	A
I _{LIM} Current		-11	-10	-9	μA
Over-Temperature Shutdown	Die temperature		150		°C
Over-Temperature Hysteresis	Die temperature		25		°C
Over-Voltage Threshold	2 consecutive clock cycles	110	115	120	%V _{OUT}
Under-Voltage Shutdown	16 consecutive clock cycles	68	73	78	%V _{OUT}
Fault Discharge Threshold	Measured at FB pin		250		mV
Fault Discharge Hysteresis	Measured at FB pin (V _{FB} ~500mV)		250		mV

Note:

2. Specifications guaranteed by design and characterization; not production tested.

Electrical Specifications (Continued)

Recommended operating conditions are the result of using the circuit shown in Figure 1 unless otherwise noted.

Parameter	Conditions	Min.	Typ.	Max.	Unit
Soft-Start					
EN to V _{OUT} Regulation (T _{0.8})	Frequency = 600KHz		3.0		msec
EN to Fault Enable/SSOK (T _{1.0})	Frequency = 600KHz		3.3		msec
Control Functions					
EN Threshold, Rising			1.35	2.0	V
EN Hysteresis			250		mV
EN Pull-Up Resistance			800		K Ω
EN Discharge Current	Auto-restart mode		1		μ A
FB OK Drive Resistance				800	Ω
PGOOD Threshold	FB < V _{REF}	-14	-11	-8	%V _{FB}
	FB > V _{REF}	107	110	113	%V _{FB}
PGOOD Output Low	I _{OUT} \leq 2mA			0.4	V
PGOOD Output High	V _{PGOOD} = 5V			1	μ A
PWM# Threshold			0.6	0.8	V
PWM# Input Current	V _{PWM#} = 0.4V		1.0	1.2	μ A

Typical Characteristics

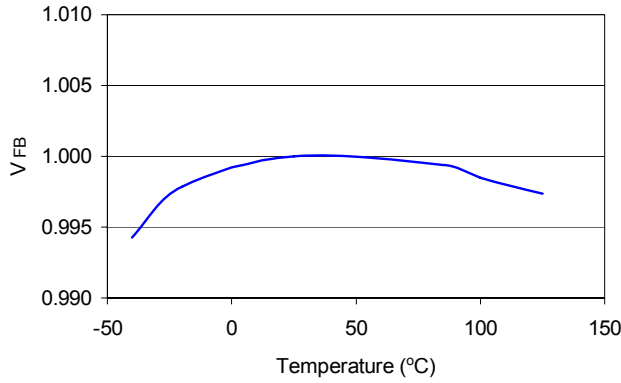


Figure 4. Reference Voltage (V_{FB}) vs. Temperature, Normalized

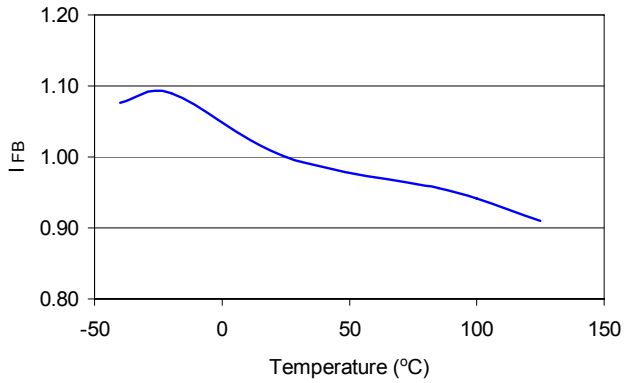


Figure 5. Reference Bias Current (I_{FB}) vs. Temperature, Normalized

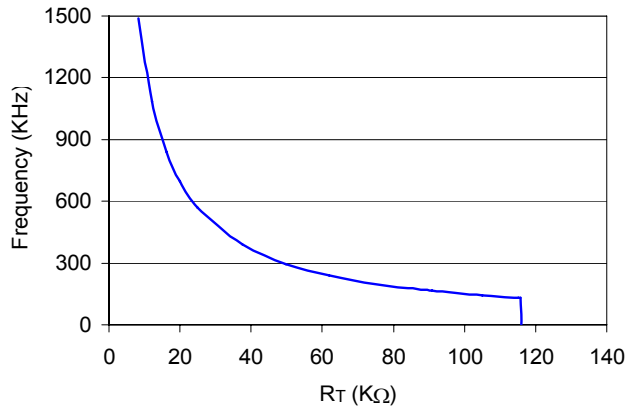


Figure 6. Frequency vs. R_T

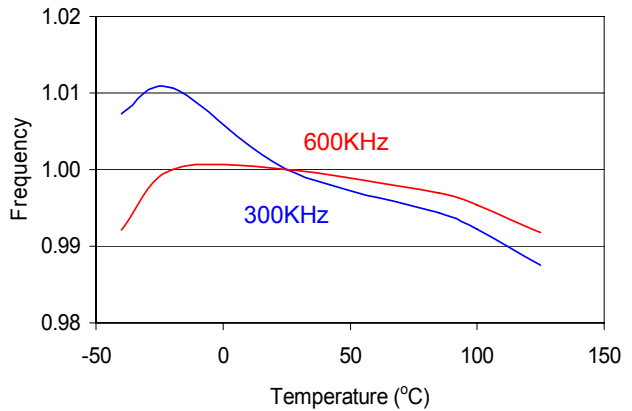


Figure 7. Frequency vs. Temperature, Normalized

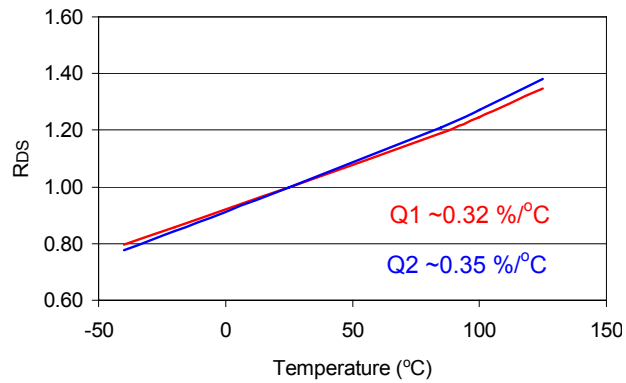


Figure 8. R_{DS} vs. Temperature, Normalized ($V_{CC} = V_{GS} = 5V$)

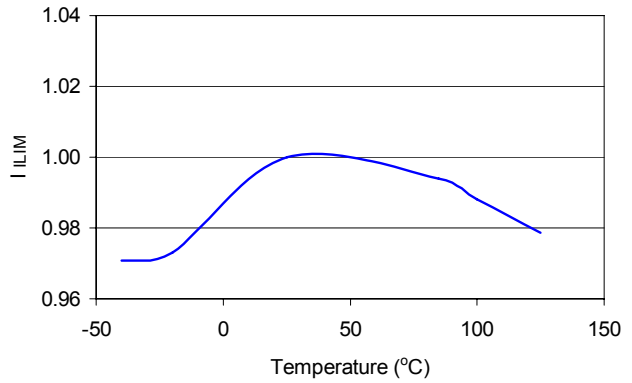


Figure 9. I_{ILIM} Current (I_{ILIM}) vs. Temperature, Normalized

Application Circuit

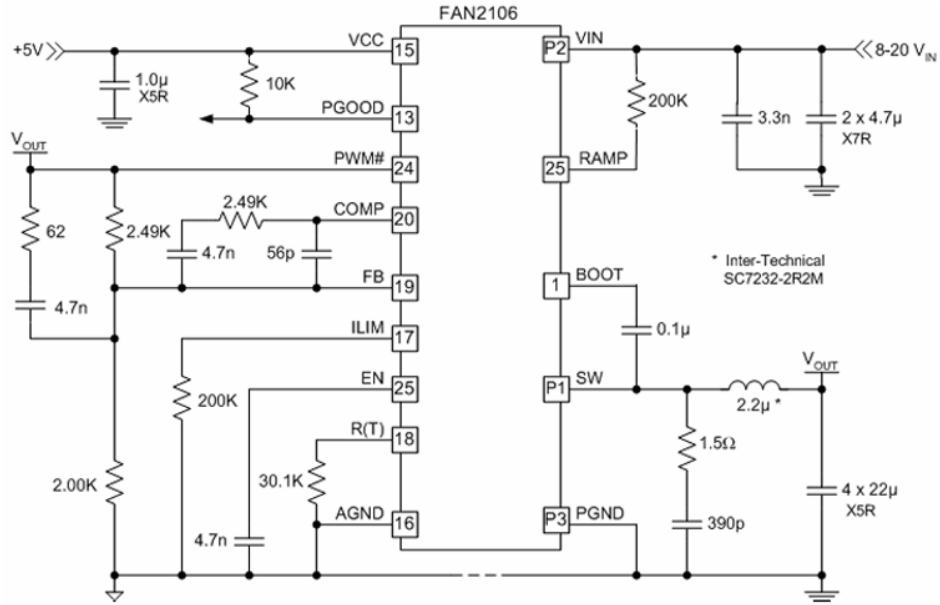


Figure 10. Application Circuit: 1.8V_{OUT}, 500KHz

Typical Performance Characteristics

Typical operating characteristics using the circuit shown in Figure 10. V_{IN}=16V, V_{CC}=5V, unless otherwise specified.

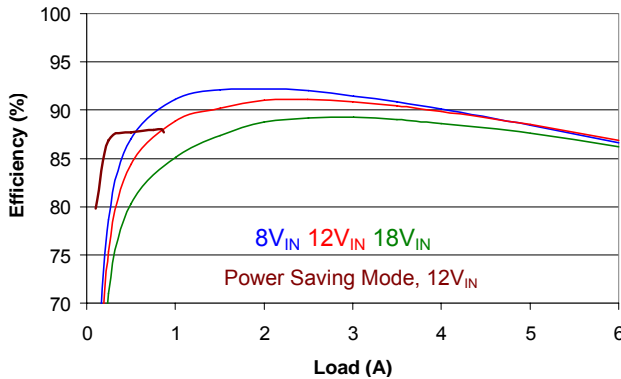


Figure 11. 1.8V_{OUT} Efficiency Over V_{IN} vs. Load

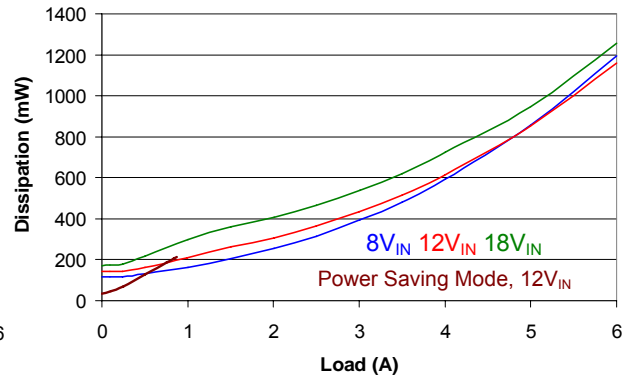


Figure 12. 1.8V_{OUT} Dissipation Over V_{IN} vs. Load

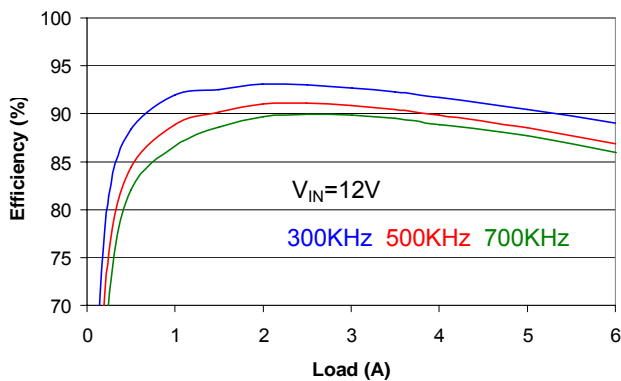


Figure 13. 1.8V_{OUT} Efficiency Over Frequency vs. Load (Circuit Value Changes)

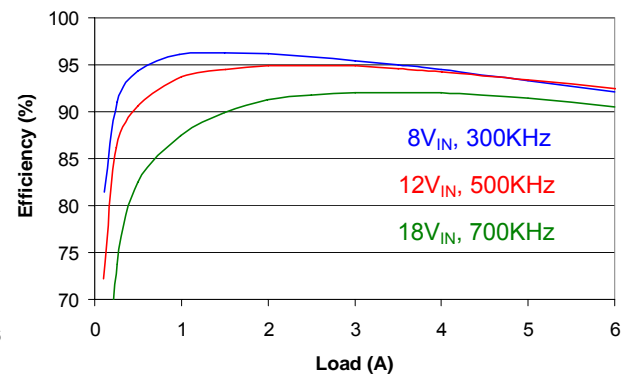


Figure 14. 3.3V_{OUT} Efficiency vs. Load (Circuit Value Changes)

Typical Performance Characteristics (Continued)

Typical operating characteristics using the circuit shown in Figure 10. $V_{IN}=16V$, $V_{CC}=5V$, unless otherwise specified.

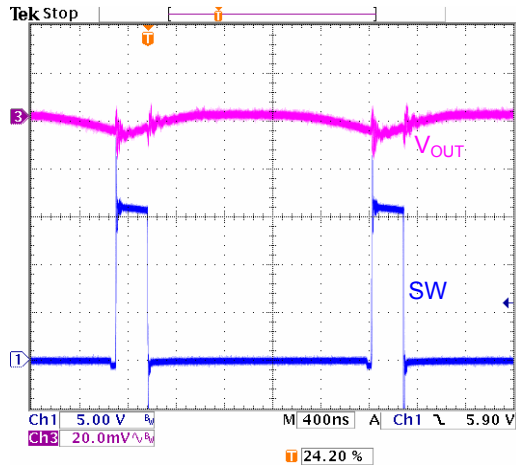


Figure 15. SW and V_{OUT} Ripple, 6A Load

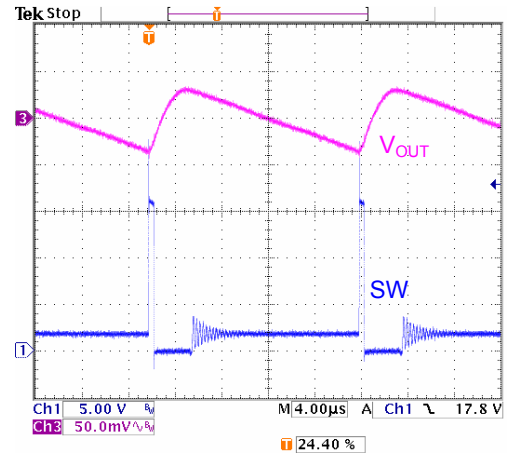


Figure 16. SW and V_{OUT} Ripple, 0.3A Load

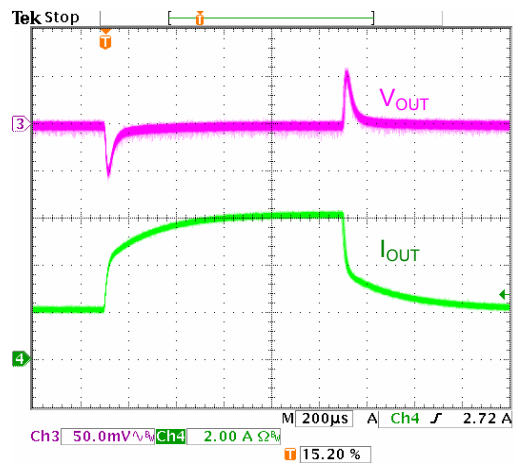


Figure 17. Transient Response, 2-6A Load

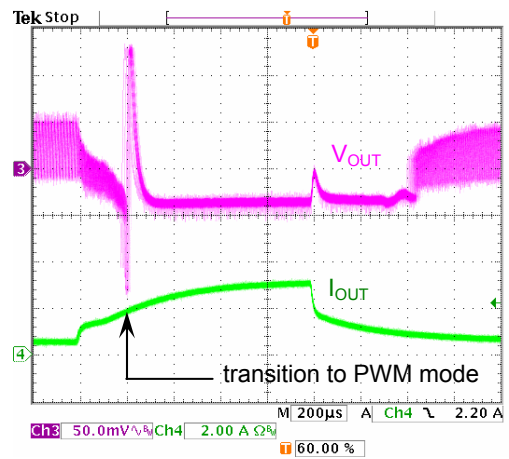


Figure 18. Transient Response, 0.3-3A Load

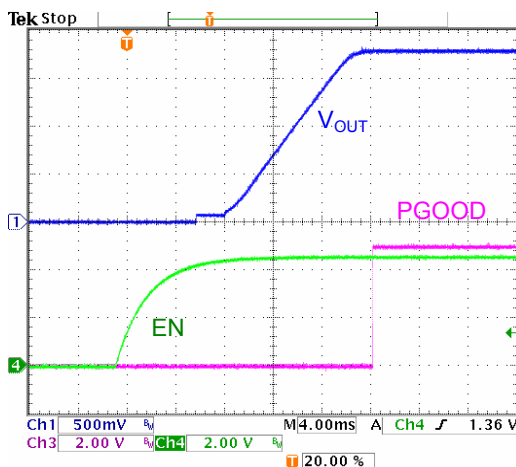


Figure 19. Start-Up, 3A Load

Circuit Description

Application Note AN-6033 — *FAN2106 Design Guide* includes a spreadsheet design aid to calculate external component values and verify loop stability given the following inputs:

- Output voltage
- Input voltage range
- Maximum output load current
- Maximum load transient current and maximum allowable output drop during load transient
- Maximum allowable output ripple
- Desired switching frequency

Initialization

Once V_{CC} exceeds the UVLO threshold and EN is HIGH, the IC checks for an open or shorted FB pin before releasing the internal soft-start ramp (SS).

If R1 is open, the error amplifier output (COMP) is forced LOW and no pulses are generated. After the SS ramp times out (T1.0), an under-voltage latched fault occurs.

If the parallel combination of R1 and R_{BIAS} is $\leq 1K\Omega$, the internal SS ramp is not released and the regulator does not start.

Soft-Start

Once SS has charged to 0.8V (T0.8), the output voltage is in regulation. Until SS reaches 1.0V (T1.0), the “Fault Latch” and power-saving mode operations are inhibited.

To avoid skipping the soft-start cycle, it is necessary to apply PVIN before V_{CC} reaches its UVLO threshold.

Soft-start time is a function of oscillator frequency.

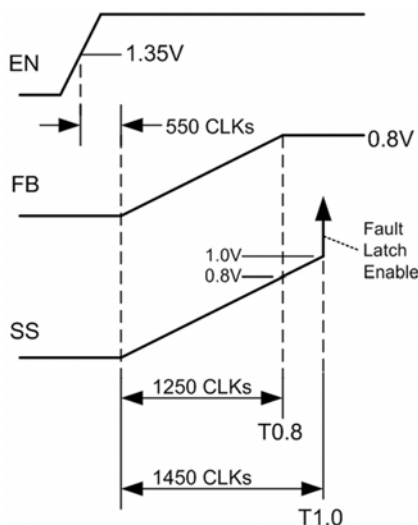


Figure 20. Soft-Start Timing Diagram

The regulator does not allow the low-side MOSFET to operate in full synchronous rectification mode until SS reaches 95% of V_{REF} (~0.76V). This prevents the regulator from discharging the output and ensures that inductor current does not “ratchet” up during the soft-start cycle.

V_{CC} UVLO or toggling the EN pin discharges the SS and resets the IC.

Bias Supply

The FAN2106 requires a 5V supply rail to bias the IC and provide gate-drive energy. Connect a $\geq 1.0\mu f$ X5R or X7R decoupling capacitor between VCC and PGND.

Since V_{CC} is used to drive the internal MOSFET gates, supply current is frequency and voltage dependent. Approximate V_{CC} current (I_{CC}) can be calculated using:

$$I_{CC(\text{mA})} = 4.58 + \left[\left(\frac{V_{CC} - 5}{227} + 0.013 \right) \cdot (F - 128) \right] \quad \text{EQ. 1}$$

where frequency (F) is expressed in KHz.

Setting the Output Voltage

The output voltage of the regulator can be set from 0.8V to 90% of V_{IN} by an external resistor divider (R1 and R_{BIAS} in Figure 1).

The internal reference is 0.8V with 650nA, sourced from the FB pin to ensure that, if the pin is open, the regulator does not start.

The external resistor divider is calculated using:

$$\frac{0.8V}{R_{BIAS}} = \frac{V_{OUT} - 0.8V}{R1} - 650\text{nA} \quad \text{EQ. 2}$$

Connect R_{BIAS} between FB and AGND.

To minimize noise pickup on the FB node, the values of R1 and R_{BIAS} should be selected to provide a minimum parallel impedance of $1K\Omega$.

Setting the Frequency

Oscillator frequency is determined by an external resistor, R_T , connected between the R(T) pin and AGND:

$$F_{(\text{KHz})} = \frac{10^6}{(65 \cdot R_T) + 135} \quad \text{EQ. 3}$$

where R_T is expressed in $K\Omega$.

$$R_{T(K\Omega)} = \frac{(10^6 / F) - 135}{65} \quad \text{EQ. 4}$$

where frequency (F) is expressed in KHz.

The regulator can not start if R_T is left open.

Calculating the Inductor Value

Typically the inductor is set for a ripple current (ΔI_L) of 10% to 35% of the maximum DC load. Regulators requiring fast transient response use a value on the high side of this range, while regulators that require very low output ripple and/or use high-ESR capacitors restrict allowable ripple current:

$$\Delta I_L = \frac{V_{OUT} \cdot (1-D)}{L \cdot F} \quad \text{EQ. 5}$$

where F is the oscillator frequency, and

$$L = \frac{V_{OUT} \cdot (1-D)}{\Delta I_L \cdot F} \quad \text{EQ. 6}$$

Setting the Ramp Resistor Value

The internal ramp voltage excursion (ΔV_{RAMP}) during t_{ON} should be set to 0.6V. R_{RAMP} is approximately:

$$R_{RAMP(K\Omega)} = \frac{(V_{IN} - 1.8) \cdot V_{OUT}}{18 \times 10^{-6} \cdot V_{IN} \cdot F} - 2 \quad \text{EQ. 7}$$

where frequency (F) is expressed in KHz.

Setting the Current Limit

The FAN2106 uses its internal low-side MOSFET as the current-sensing element. The current-limit threshold voltage (V_{ILIM}) is compared to the voltage drop across the low-side MOSFET, sampled at the end of each PWM off-time/cycle.

The default threshold (I_{LIM} open) is temperature compensated.

The 10 μ A current sourced from the ILIM pin can be used to establish a lower, temperature-dependent, current-limit threshold by connecting an external resistor (R_{ILIM}) to AGND:

$$R_{ILIM(K\Omega)} = 0.45 \cdot R_{DS} \cdot K_T \cdot (I_{OUT} - \frac{\Delta I_L}{2}) + 142.5 \quad \text{EQ. 8}$$

where:

- I = desired current limit set point in Amps,
- R_{DS} is expressed in m Ω ,
- K_T = the normalized temperature coefficient of the low-side MOSFET (Q2) from Figure 8.

After 16 consecutive, pulse-by-pulse, current-limit cycles, the fault latch is set and the regulator shuts down. Cycling V_{CC} or EN restores operation after a normal soft-start cycle (refer to Auto-Restart section).

The over-current protection fault latch is active during the soft-start cycle.

Loop Compensation

The loop is compensated using a feedback network around the error amplifier. Figure 21 shows a complete Type-3 compensation network. Type-2 compensation eliminates R3 and C3.

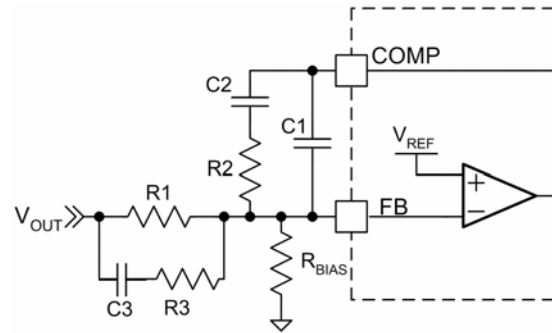


Figure 21. Compensation Network

Since the FAN2106 employs summing current-mode architecture, Type-2 compensation can be used for many applications. For applications that require wide loop bandwidth and/or use very low-ESR output capacitors, Type-3 compensation may be required. The AN-6033 spreadsheet calculator can be used to calculate these component values.

Protection

The converter output is monitored and protected against extreme overload, short-circuit, over-voltage, and under-voltage conditions.

An internal "Fault Latch" is set for any fault intended to shut down the IC. When the fault latch is set, the IC discharges V_{OUT} by enhancing the low-side MOSFET until $FB < 0.25V$. The MOSFET is not turned on again unless $FB > 0.5V$. This behavior discharges the output without causing undershoot (negative output voltage).

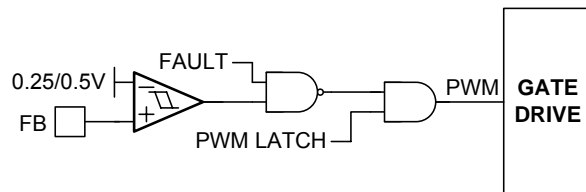


Figure 22. Latched Fault Response

Under-Voltage Shutdown

If FB remains below the under-voltage threshold for 16 consecutive clock cycles, the fault latch is set and the converter shuts down. This fault is prevented from setting the fault latch during soft-start.

Over-Voltage Protection / Shutdown

If FB exceeds 115% $\cdot V_{REF}$ for two consecutive clock cycles, the fault latch is set and shutdown occurs.

A shorted high-side MOSFET condition is detected when SW voltage exceeds $\sim 0.7V$ while the low-side

MOSFET is fully enhanced. The fault latch is set immediately upon detection.

These two fault conditions are allowed to set the fault latch at any time, including during soft-start.

Auto-Restart

After a fault, EN is discharged with 1μA to a 1.1V threshold before the 800KΩ pull-up is restored. A new soft-start cycle begins when EN charges above 1.35V.

Depending on the external circuit, the FAN2106 can be provisioned to remain latched-off or automatically restart after a fault.

Table 1. Fault / Restart Provisioning

EN pin	Controller / Restart State
Pull to GND	OFF (disabled)
V _{CC}	No restart – latched OFF
Open	Immediate restart after fault
Cap to GND	New soft-start cycle after: $t_{DELAY} (msec) = 3.9 \cdot C(nf)$

With EN left open, restart is immediate.

If auto-restart is not desired, tie the EN pin to the V_{CC} pin or drive it with a logic gate to keep the 1μA current sink from discharging EN to 1.1V.

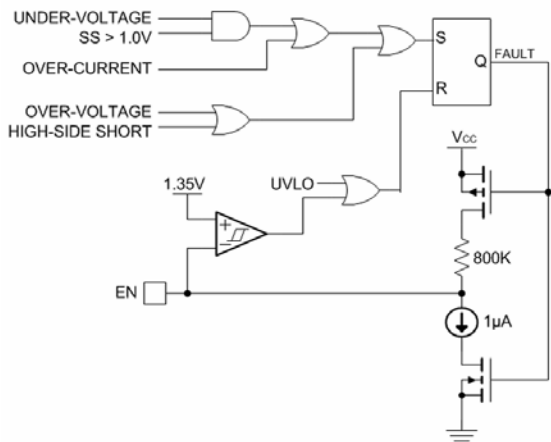


Figure 23. Fault Latch with Delayed Auto-Restart

Over-Temperature Protection

The chip incorporates an over-temperature protection circuit that sets the fault latch when a die temperature of about 150°C is reached. The IC is allowed to restart when the die temperature falls below 125°C.

Power Good (PGOOD) Signal

PGOOD is an open-drain output that asserts LOW when V_{OUT} is out of regulation, as measured at the FB pin. Thresholds are specified in the Electrical Specifications section. PGOOD does not assert HIGH until the fault latch is enabled (T1.0).

Power-Saving Mode

The FAN2106 maintains high efficiency at light load by changing to a discontinuous constant peak current, power-saving mode (PSM).

The transition to power-saving mode occurs when the load is $\leq \Delta I_L/2$ for eight consecutive clock cycles.

In power-saving mode, a constant peak inductor current (ΔI_{LPSM}) is generated each on-cycle. ΔI_{LPSM} is nominally 35% larger than PWM mode inductor ripple (ΔI_L).

During power-saving mode, the output is regulated to a slightly higher value than its set point, since the current pulse is triggered when FB crosses V_{REF}.

The IC is prevented from switching in the audible band. If the FB pin has not dropped to V_{REF} within 40μsec of the last pulse, the IC sinks current through the inductor to initiate a new cycle.

Transition back to PWM mode is achieved when a load transient causes the output voltage to drop 1.5% below its regulation point.

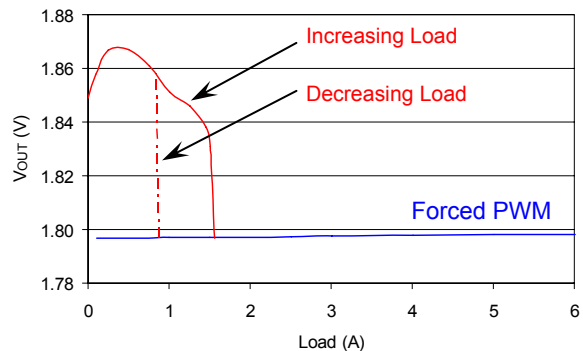


Figure 24. Power-Saving Mode Regulation (Using Figure 10 Circuit)

Power-saving mode operation is defeated by connecting the PWM# pin to AGND, allowing only PWM operation. The PWM# pin has a 1μA pull-down. If <0.6V is detected, power-saving mode operation is disabled.

PCB Layout

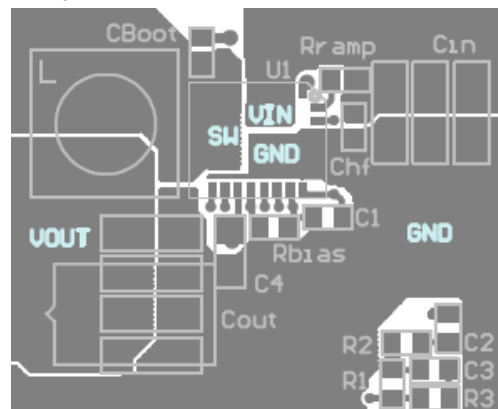
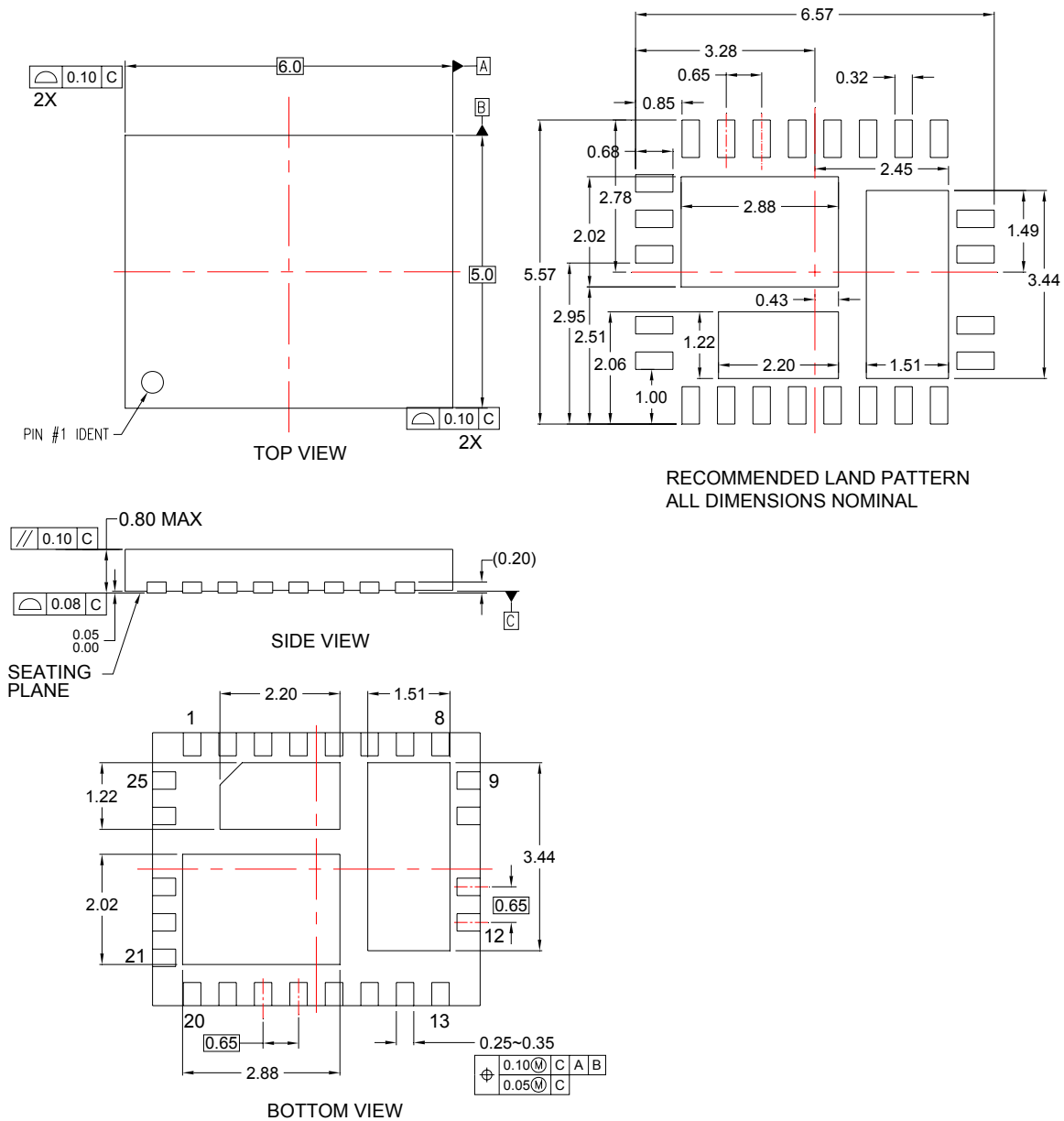


Figure 25. Recommended PCB Layout

Physical Dimensions

Dimensions are in millimeters (inches) unless otherwise noted.



NOTES:

- A. DIMENSIONS ARE IN MILLIMETERS.
- B. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994
- C. ENGINEERING DRAWING ONLY, CHANGES MAY OCCUR

MLP25ArevA

Figure 26. 5x6mm Molded Leadless Package (MLP)



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