MIC94090/1/2/3/4/5

High Side Load Switches for Consumer Applications

General Description

The MIC94090/1/2/3/4/5 is a family of high-side load switches designed for operation from 1.7V to 5.5V input voltage. The load switch pass element is an internal 130mΩ $R_{DS(ON)}$ P-channel MOSFET which enables the device to support up to 1.2A continuous current. Additionally, the load switch supports 1.5V logic level control and shutdown features.

The MIC94090 and MIC94091 feature rapid turn on. The MIC94092 and MIC94093 provide a slew rate controlled soft-start turn-on of 790µs, while the MIC94094 and MIC94095 provide a slew rate controlled soft-start turn-on of 120µs. The soft-start feature option prevents an in-rush current event from pulling down the input supply voltage.

The MIC94091, MIC94093, and MIC94095 include a 250Ω auto discharge load circuit that is switched on when the load switch is disabled.

An active pull-down on the enable input keeps the MIC94090/1/2/3/4/5 in a default OFF state until the enable pin is pulled above 1.25V. Internal level shift circuitry allows low voltage logic signals to switch higher supply voltages. The enable voltage can be as high as 5.5V and is not limited by the input voltage.

The MIC94090/1/2/3/4/5 operating voltage range makes them ideal for Lithium ion and NiMH/NiCad/Alkaline battery powered systems, as well as non-battery powered applications. The devices provide low quiescent current and low shutdown current to maximize battery life.

Datasheets and support documentation can be found on Micrel's web site at: www.micrel.com.

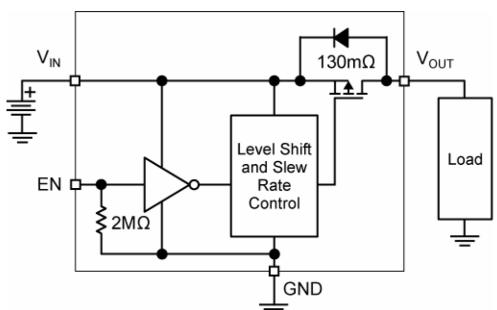
Features

- 1.7V to 5.5V input voltage range
- 1.2A continuous operating current
- 130mΩ $R_{DS(ON)}$
- Internal level shift for CMOS/TTL control logic
- Ultra low quiescent current
- Micro-power shutdown current
- Rapid turn-on: MIC94090/1
- Soft-Start: MIC94092/3 (790µs), MIC94094/5 (120µs)
- Load discharge circuit: MIC94091/3/5
- Space saving and thermally capable 1.2mm x 1.2mm Thin MLF® package
- Industry standard SC-70-6 package

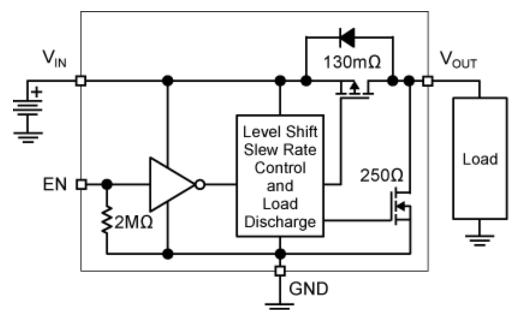
Applications

- Cellular phones
- Portable Navigation Devices (PND)
- GPS modules
- Personal Media Players (PMP)
- Ultra Mobile PCs
- Other Portable applications
- PDAs
- Portable instrumentation
- Industrial and DataComm equipment

Typical Application



MIC94090 (ultra fast turn on)
MIC94092 (790µs soft-start)
MIC94094 (120µs soft-start)



MIC94091 (ultra fast turn on with auto-discharge)
MIC94093 (790µs soft-start with auto-discharge)
MIC94095 (120µs soft-start with auto-discharge)

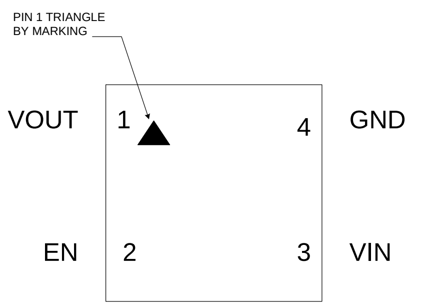
Ordering Information

Part Number Pb-Free	Part Marking Pb-Free[1]	Fast Turn On	Soft-Start	Load Discharge	Package[2] [3]
MIC94090YMT	D1	●			4-Pin 1.2mm x 1.2mm Thin MLF®
MIC94091YMT	D2	●		●	4-Pin 1.2mm x 1.2mm Thin MLF®
MIC94092YMT	D5		790µs		4-Pin 1.2mm x 1.2mm Thin MLF®
MIC94093YMT	D7		790µs	●	4-Pin 1.2mm x 1.2mm Thin MLF®
MIC94094YMT	0D		120µs		4-Pin 1.2mm x 1.2mm Thin MLF®
MIC94095YMT	1D		120µs	●	4-Pin 1.2mm x 1.2mm Thin MLF®
MIC94090YC6	D1D	●			SC-70-6
MIC94091YC6	D2D	●		●	SC-70-6
MIC94092YC6	D5D		790µs		SC-70-6
MIC94093YC6	D7D		790µs	●	SC-70-6
MIC94094YC6	0DD		120µs		SC-70-6
MIC94095YC6	1DD		120µs	●	SC-70-6

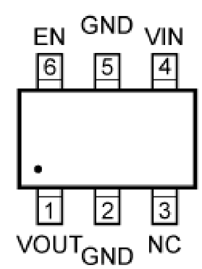
Notes:

1. Under bar symbol (_) may not be to scale.
2. Thin MLF® ▲ = Pin 1 identifier.
3. Thin MLF® is a GREEN RoHS-compliant package. Lead finish is NiPdAu. Mold compound is Halogen Free.

Pin Configuration



4-Pin (1.2mm x 1.2mm) Thin MLF® (MT)
Top View



6-Pin SC-70-6 (C6)
Top View

Pin Description

Pin Number		Pin Name	Pin Function
TMLF-4	SC-70-6		
1	1	V_{OUT}	Drain of P-Channel MOSFET.
4	2, 5	GND	Ground: Connect to electrical ground.
3	4	V_{IN}	Source of P-Channel MOSFET.
2	6	EN	Enable (Input): Active-high CMOS-compatible control input for switch. Internal 2MΩ pull down resistor to GND, output will be off if this pin is left floating.
--	3	NC	No Internal Connection. A signal or voltage applied to this pin will have no effect on device operation.

Absolute Maximum Ratings[1]

Input Voltage (V_{IN}) .... +6V
Enable Voltage (V_{EN}) .... +6V
Continuous Drain Current (I_D)[3]
T_A = 25°C (MLF®)... ±1.2A
T_A = 25°C (SC-70) .... ±1.2A
Pulsed Drain Current (I_{DP})[4] .... ±6.0A
Continuous Diode Current (I_S)[5] .... –50mA
Storage Temperature (T_s) .... –55°C to +150°C
ESD Rating – HBM[6] 3kV

Operating Ratings[2]

Input Voltage (V_{IN})....................................... +1.7 to +5.5V
Junction Temperature (T_J) ....–40°C to +125°C
Package Thermal Resistance
Thin MLF® (θ_{JC})[3] ....60°C/W
Thin MLF® (θ_{JA})[3] ....140°C/W
SC-70-6 (θ_{JC}) ....100°C/W
SC-70-6 (θ_{JA}) ....240°C/W

Electrical Characteristics

T_A = 25°C, bold values indicate –40°C≤ T_A ≤ +85°C, unless noted.

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{EN_TH}	Enable Threshold Voltage	V_{IN} = 1.7V to 4.5V, I_D = –250µA	**0.4**		**1.25**	V
I_Q	Quiescent Current Measured on the V_{IN} Pin	V_{IN} = V_{EN} = 5.5V, I_D = OPEN Measured on V_{IN} MIC94090/1		0.1	1	µA
		V_{IN} = V_{EN} = 5.5V, I_D = OPEN Measured on V_{IN} MIC94092/3/4/5		8	15	µA
I_{EN}	Enable Input Current	V_{IN} = V_{EN} = 5.5V, I_D = OPEN		2.5	4	µA
I_{SD}	Shutdown Current	V_{IN} = +5.5V, V_{EN} = 0V, I_D = OPEN Measured on the V_{IN} pin[7]		0.01	1	µA
$I_{SHUT-SWITCH}$	OFF State Leakage Current	V_{IN} = +5.5V, V_{EN} = 0V, I_D = SHORT Measured on V_{OUT}[7]		0.01	1	µA
$R_{DS(ON)}$	P-Channel Drain to Source ON Resistance	V_{IN} = +5.0V, I_D = –100mA, V_{EN} = 1.5V		130	225	mΩ
		V_{IN} = +4.5V, I_D = –100mA, V_{EN} = 1.5V		135	235	mΩ
		V_{IN} = +3.6V, I_D = –100mA, V_{EN} = 1.5V		140	255	mΩ
		V_{IN} = +2.5V, I_D = –100mA, V_{EN} = 1.5V		170	315	mΩ
		V_{IN} = +1.8V, I_D = –100mA, V_{EN} = 1.5V		235	355	mΩ
		V_{IN} = +1.7V, I_D = –100mA, V_{EN} = 1.5V		260	375	mΩ
$R_{SHUTDOWN}$	Turn-Off Resistance	V_{IN} = +3.6V, I_{TEST} = 1mA, V_{EN} = 0V MIC94091/3/5		250	400	Ω

Electrical Characteristics (Dynamic)

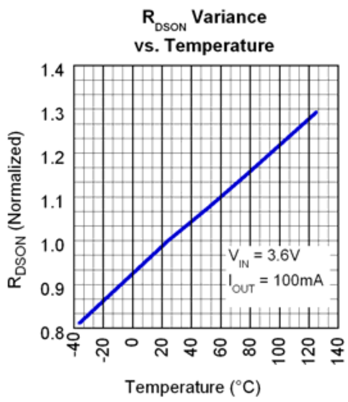
T_A = 25°C, bold values indicate –40°C≤ T_A ≤ +85°C, unless noted.

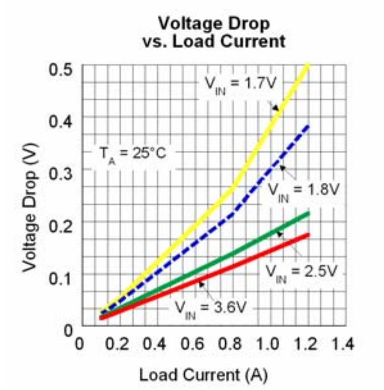
Symbol	Parameter	Condition	Min	Typ	Max	Units
t_{ON_DLY}	Turn-On Delay Time	V_{IN} = +3.6V, ID = –100mA, V_{EN} = 1.5V MIC94090/1		0.4	1.5	µs
		V_{IN} = +3.6V, ID = –100mA, V_{EN} = 1.5V MIC94092/3	200	740	1500	µs
		V_{IN} = +3.6V, ID = –100mA, V_{EN} = 1.5V MIC94094/5	65	110	165	µs
t_{ON_RISE}	Turn-On Rise Time	V_{IN} = +3.6V, ID = –100mA, V_{EN} = 1.5V MIC94090/1		0.4	1.5	µs
		V_{IN} = +3.6V, ID = –100mA, V_{EN} = 1.5V MIC94092/3	400	790	1500	µs
		V_{IN} = +3.6V, ID = –100mA, V_{EN} = 1.5V MIC94094/5	65	120	175	µs
t_{OFF_DLY}	Turn-Off Delay Time	V_{IN} = +3.6V, ID = –100mA, V_{EN} = 1.5V		60	200	ns
t_{OFF_FALL}	Turn-Off Fall Time	V_{IN} = +3.6V, ID = –100mA, V_{EN} = 1.5V		10	100	ns

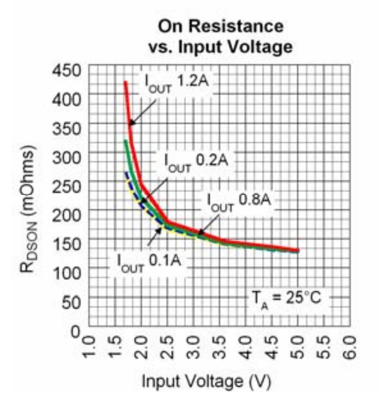
Notes:

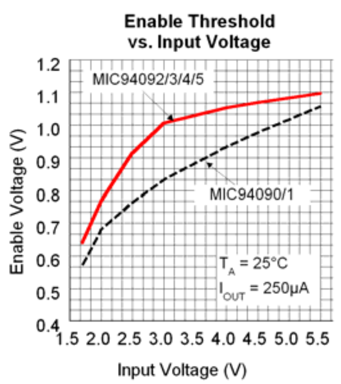
1. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. With backside thermal contact to PCB. See thermal considerations section.
4. Pulse width <300µs with < 2% duty cycle.
5. Continuous body diode current conduction (reverse conduction, i.e. V_{OUT} to V_{IN}) is not recommended.
6. Devices are ESD sensitive. Handling precautions recommended. HBM (Human body model), 1.5kΩ in series with 100pF.
7. Measured on the MIC94090YMT.

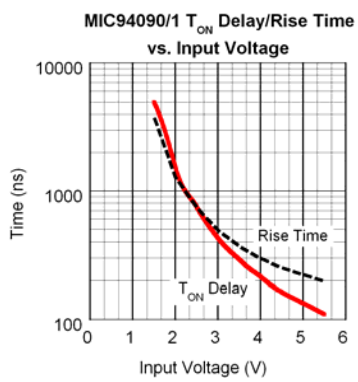
Typical Characteristics

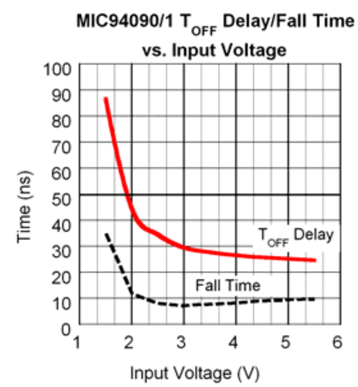


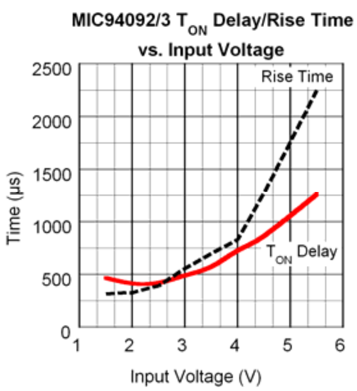


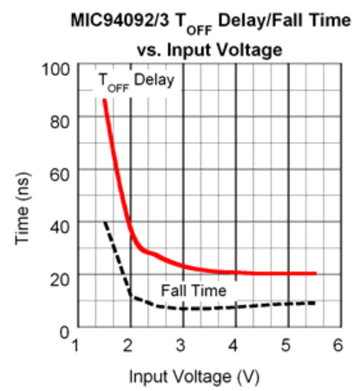


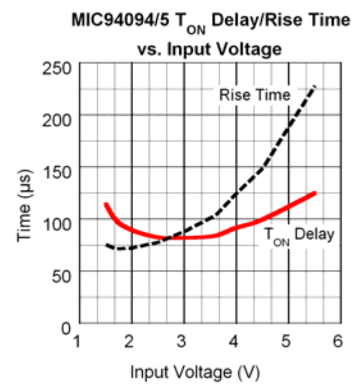


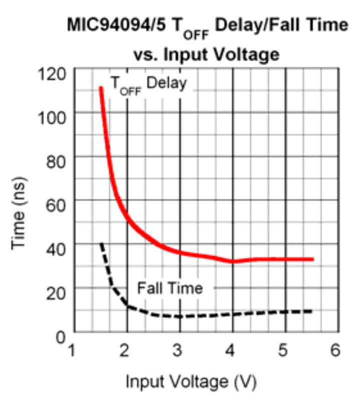


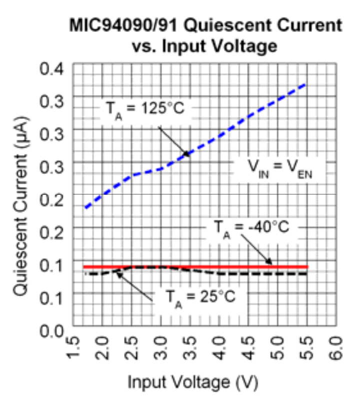


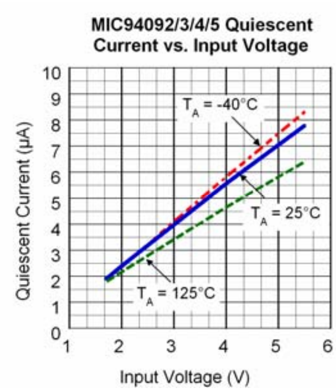




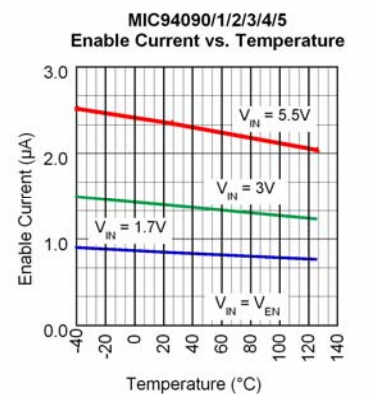






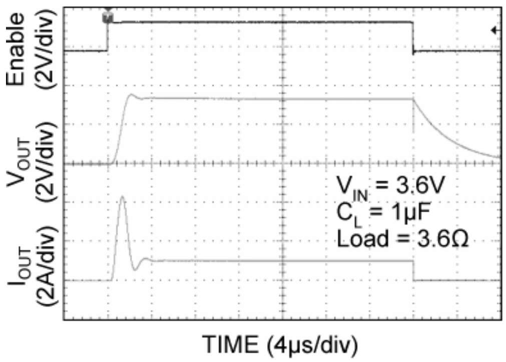


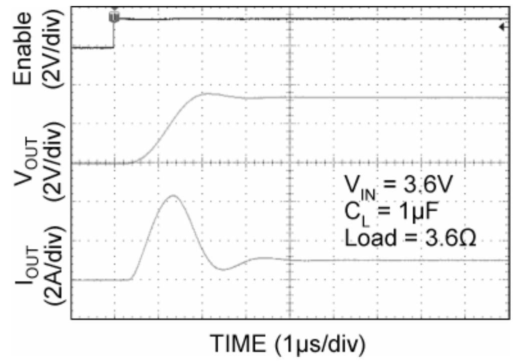
Typical Characteristics

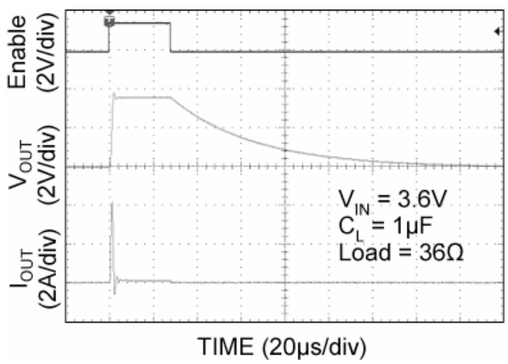


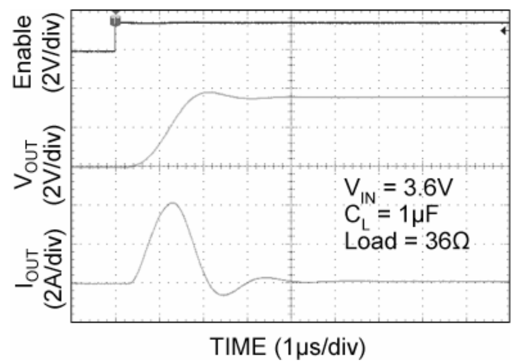
Functional Characteristics

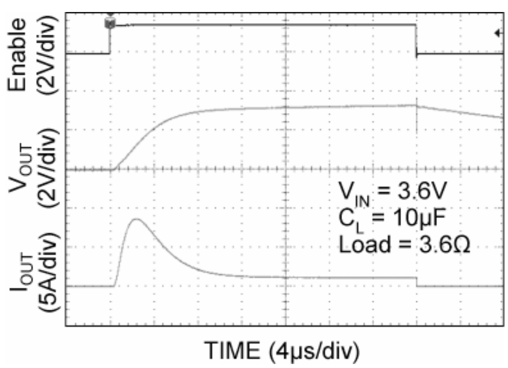
MIC94090

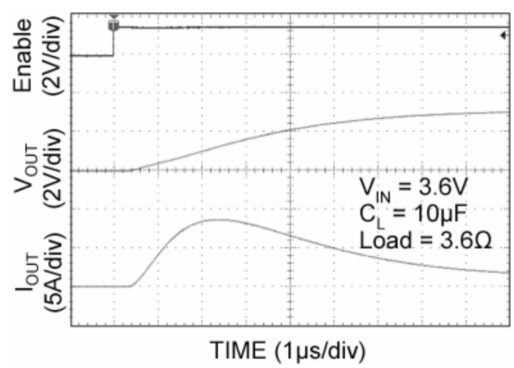


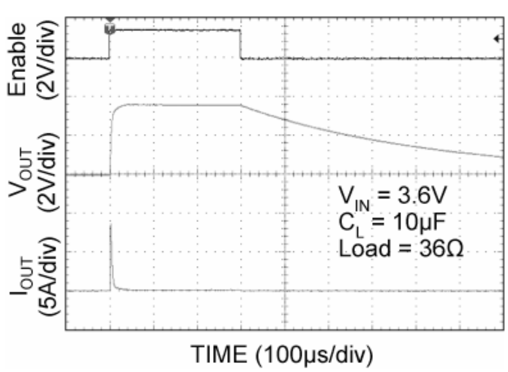


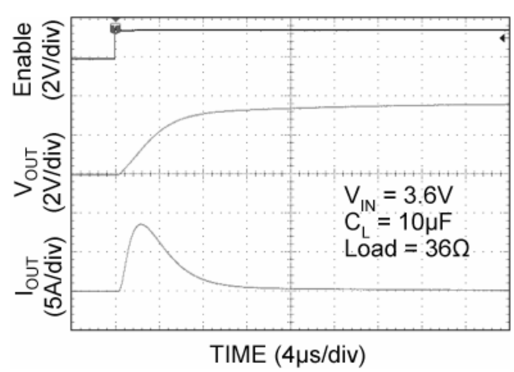




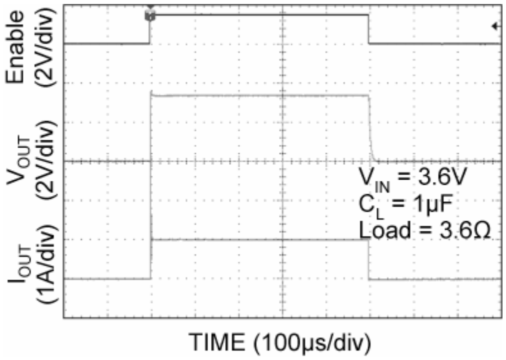


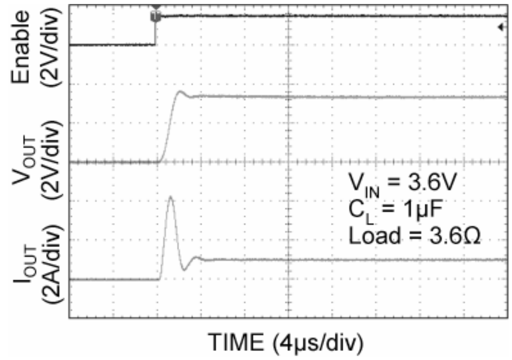






MIC94091


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (1A/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 3.6Ω
TIME (100µs/div)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I_{OUT} (2A/div)
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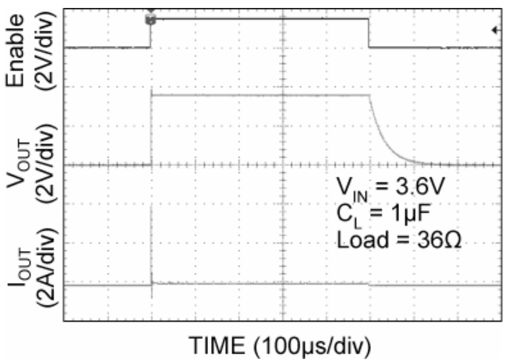
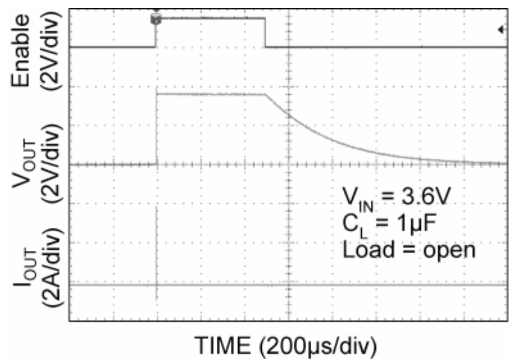
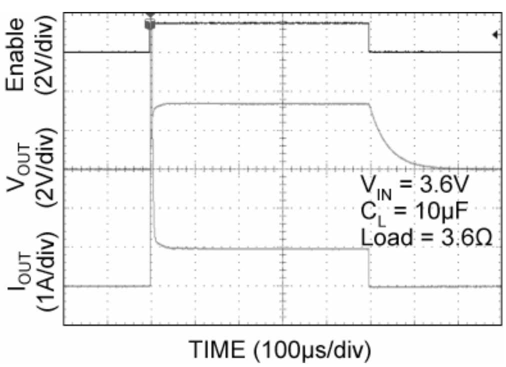
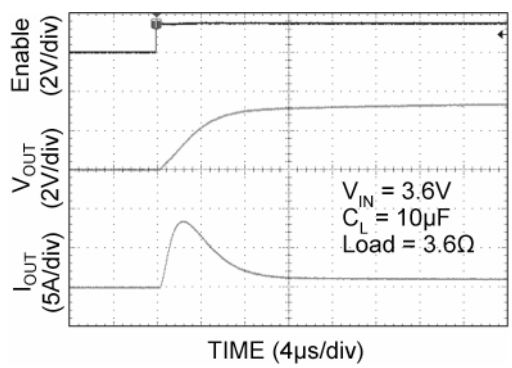
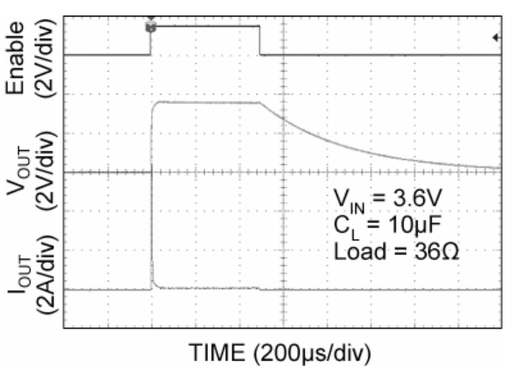
C_L = 1µF
Load = 3.6Ω
TIME (4µs/div)

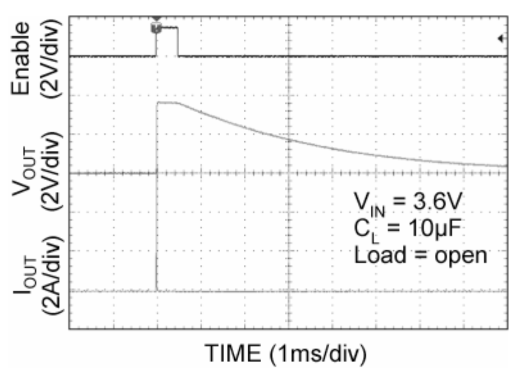

Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (2A/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 36Ω
TIME (100µs/div)


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (2A/div)
V_{IN} = 3.6V
C_L = 1µF
Load = open
TIME (200µs/div)


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (1A/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 3.6Ω
TIME (100µs/div)


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (5A/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 3.6Ω
TIME (4µs/div)


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (2A/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 36Ω
TIME (200µs/div)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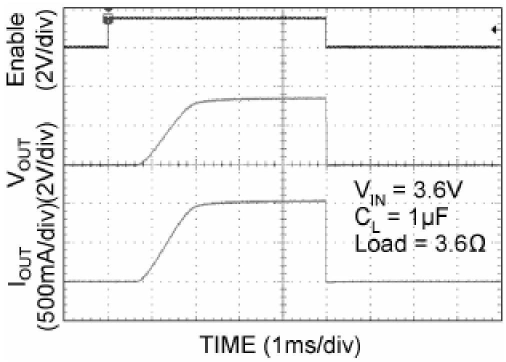
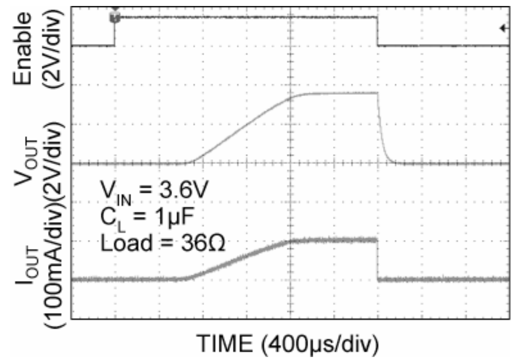
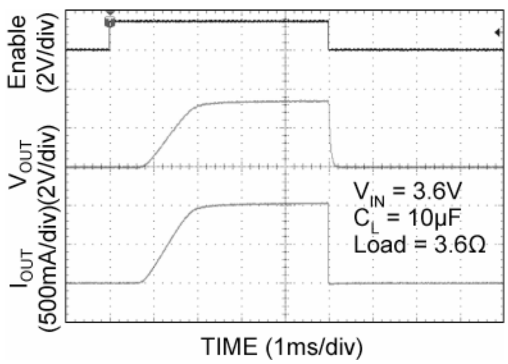
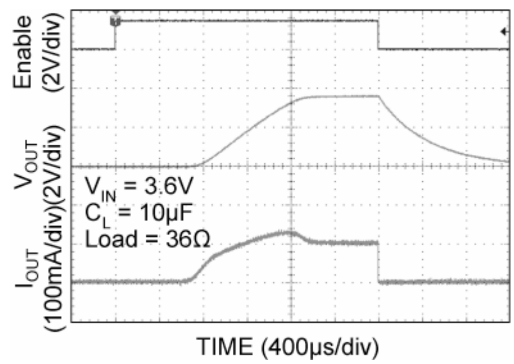
V_{OUT} (2V/div)
I_{OUT} (2A/div)
V_{IN} = 3.6V
C_L = 10µF
Load = open
TIME (1ms/div)

MIC94092

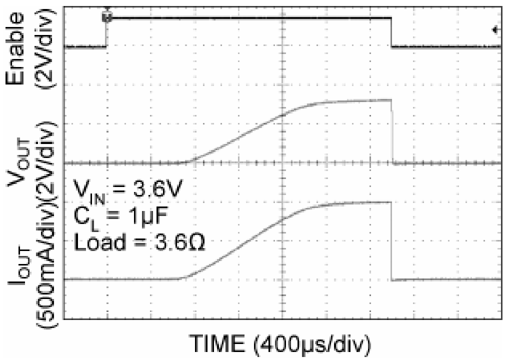

Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (500mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 3.6Ω
TIME (1ms/div)


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (100mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 36Ω
TIME (400µs/div)

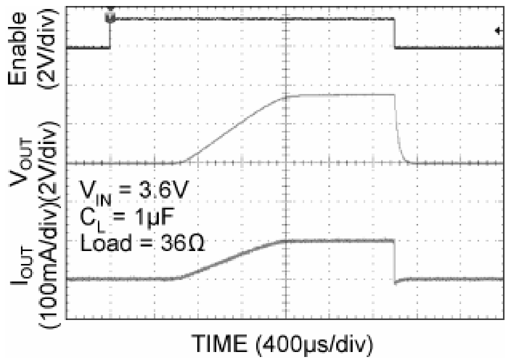

Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (500mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 3.6Ω
TIME (1ms/div)


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (100mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 36Ω
TIME (400µs/div)

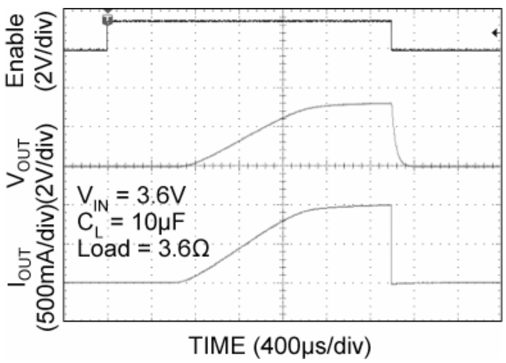
MIC94093



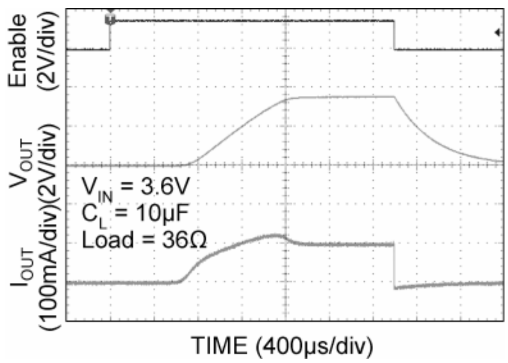
Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (500mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 3.6Ω
TIME (400µs/div)



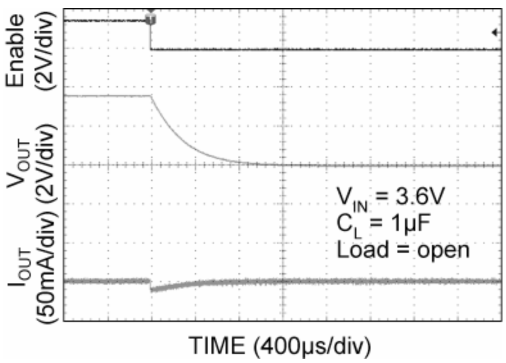
Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (100mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 36Ω
TIME (400µs/div)



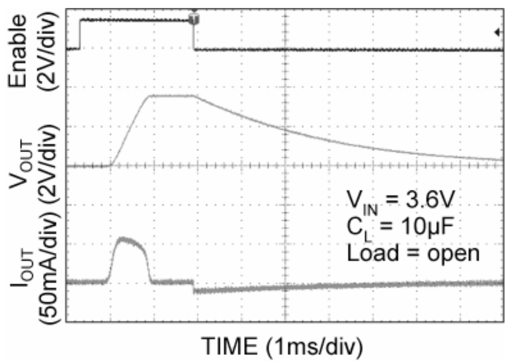
Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (500mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 3.6Ω
TIME (400µs/div)



Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (100mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 36Ω
TIME (400µs/div)

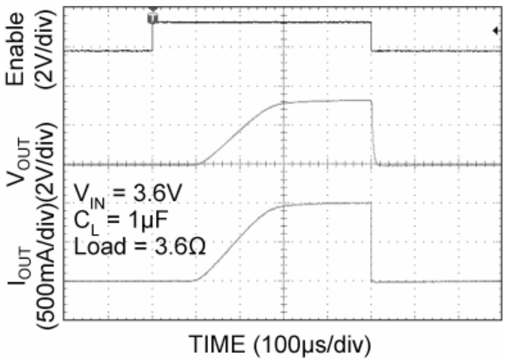


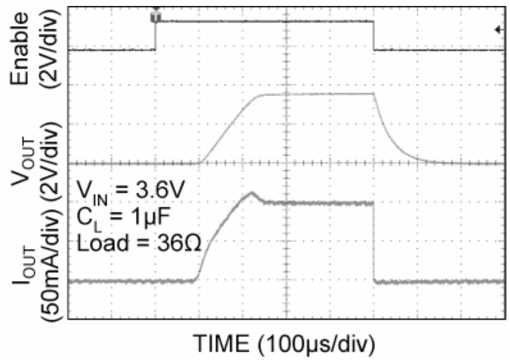
Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (50mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = open
TIME (400µs/div)

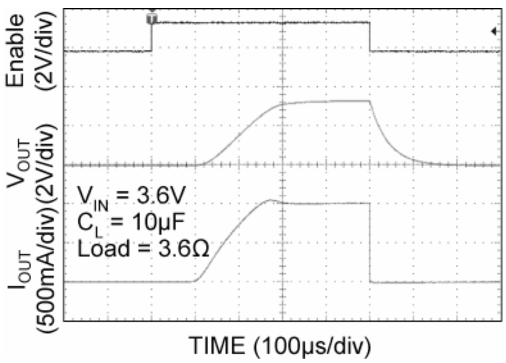


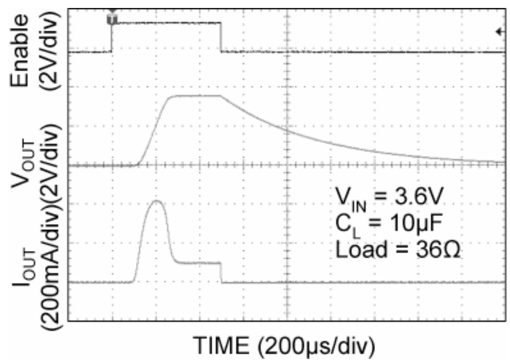
Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (50mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = open
TIME (1ms/div)

MIC94094

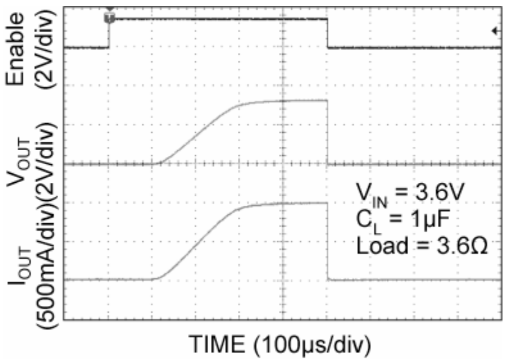

Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (500mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 3.6Ω
TIME (100µs/div)


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (50mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 36Ω
TIME (100µs/div)

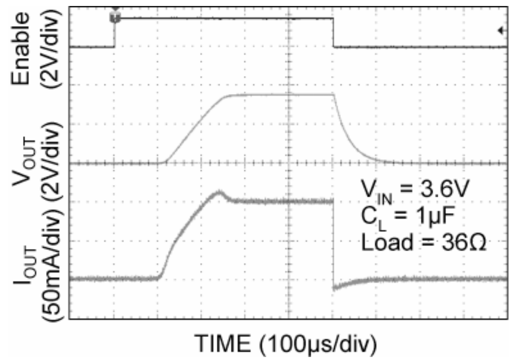

Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (500mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 3.6Ω
TIME (100µs/div)


Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (200mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 36Ω
TIME (200µs/div)

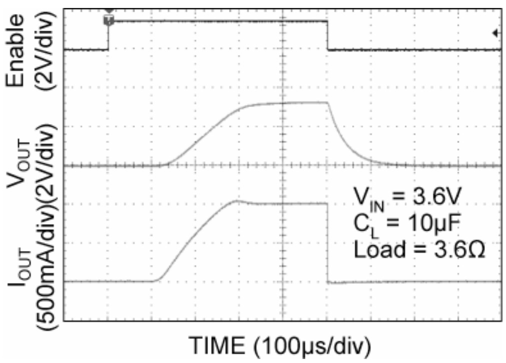
MIC94095



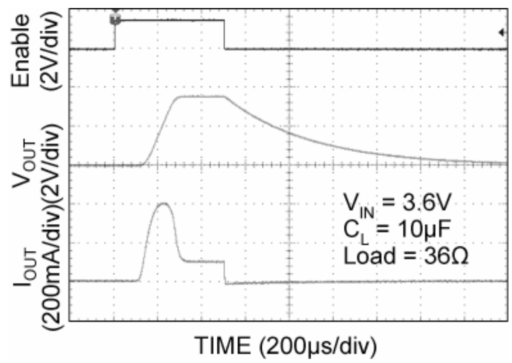
Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (500mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 3.6Ω
TIME (100µs/div)



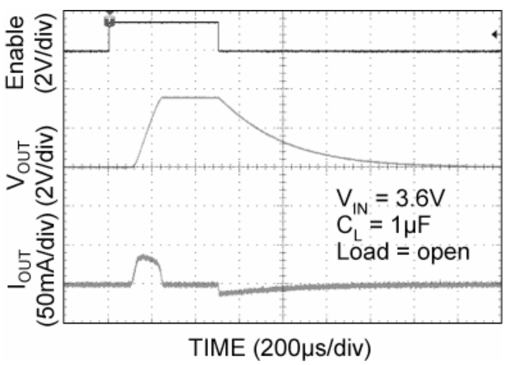
Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (50mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = 36Ω
TIME (100µs/div)



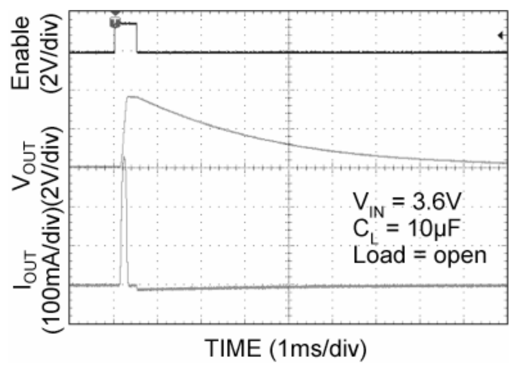
Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (500mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 3.6Ω
TIME (100µs/div)



Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (200mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = 36Ω
TIME (200µs/div)



Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (50mA/div)
V_{IN} = 3.6V
C_L = 1µF
Load = open
TIME (200µs/div)



Enable (2V/div)
V_{OUT} (2V/div)
I_{OUT} (100mA/div)
V_{IN} = 3.6V
C_L = 10µF
Load = open
TIME (1ms/div)

Application Information

Power Dissipation Considerations

As with all power switches, the ultimate current rating of the switch is limited by the thermal properties of the package and the PCB it is mounted on. There is a simple, ohms law type relationship between thermal resistance, power dissipation and temperature which are analogous to an electrical circuit:

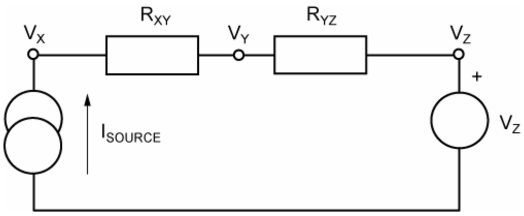


Figure 1. Electrical Circuit

From this simple circuit we can calculate Vx if we know Isource, Vz and the resistor values, Rxy and Ryz using the equation:

$$Vx = Isource \cdot (Rxy + Ryz) + Vz$$

Thermal circuits can be considered using these same rules and can be drawn similarly replacing current sources with Power dissipation (in Watts), Resistance with Thermal Resistance (in $^oC/W$) and Voltage sources with temperature (in ^oC).

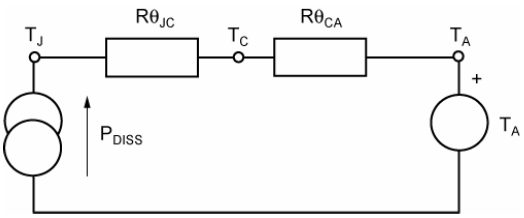


Figure 2. Thermal Equivalent Circuit

Now replacing the variables in the equation for Vx, we can find the junction temperature (Tj) from power dissipation, ambient temperature and the known thermal resistance of the PCB ($R\theta_{CA}$) and the package ($R\theta_{JA}$).

$$T_J = P_{DISS} \cdot (R\theta_{JC} + R\theta_{CA}) + T_{AMB} \quad (1)$$

It is this equation that is used to determine the graphs on page 7. P_{DISS} is calculated as (I_{SWITCH}^2 x R_{SWmax}). $R\theta_{JC}$ is found in the operating ratings section of the datasheet and $R\theta_{CA}$ (the PCB thermal resistance) values for various PCB copper areas can be taken from 'Designing with Low Dropout Voltage Regulators'[1] available from the Micrel website (LDO Application Hints).

Example:

A switch is intended to drive a 500mA load and is placed on a printed circuit board which has a ground plane area of at least 25mm square. The Voltage source is a Li-ion battery with a lower operating threshold of 3V and the ambient temperature of the assembly can be up to 50^oC.

Summary of variables:

$I_{SW} = 0.5A$

VIN = 3V to 4.2V

Tamb = 50^oC

$R\theta_{JC} = 60^oC/W$ from Datasheet (P. 3)

$R\theta_{CA} = 53^oC/W$ Read from Graph in Fig. 3

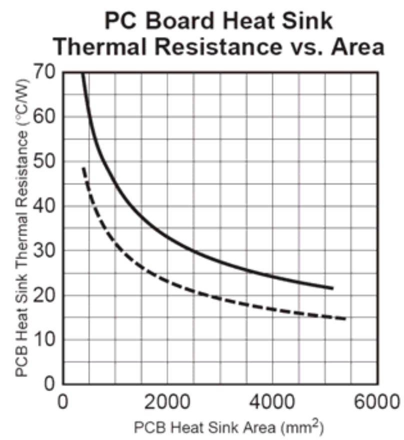


Figure 3. Excerpt from the LDO Book [1]

$P_{DISS} = I_{SW}^2 \times R_{SWmax}$

The worst case switch resistance (R_{SWmax}) at the lowest VIN of 3V is not available in the datasheet, so the next lower value of VIN is used.

R_{SWmax} @ 2.5v = 315mΩ

If this were a figure for worst case R_{SWmax} for 25^oC, an additional consideration is to allow for the maximum junction temperature of 125^oC, the actual worst case resistance in this case will be 30% higher (See $R_{DS(on)}$ variance vs. temperature graph).

R_{SWmax} @ 2.5v (@ 125'C) = 315 x 1.3 = 410mΩ

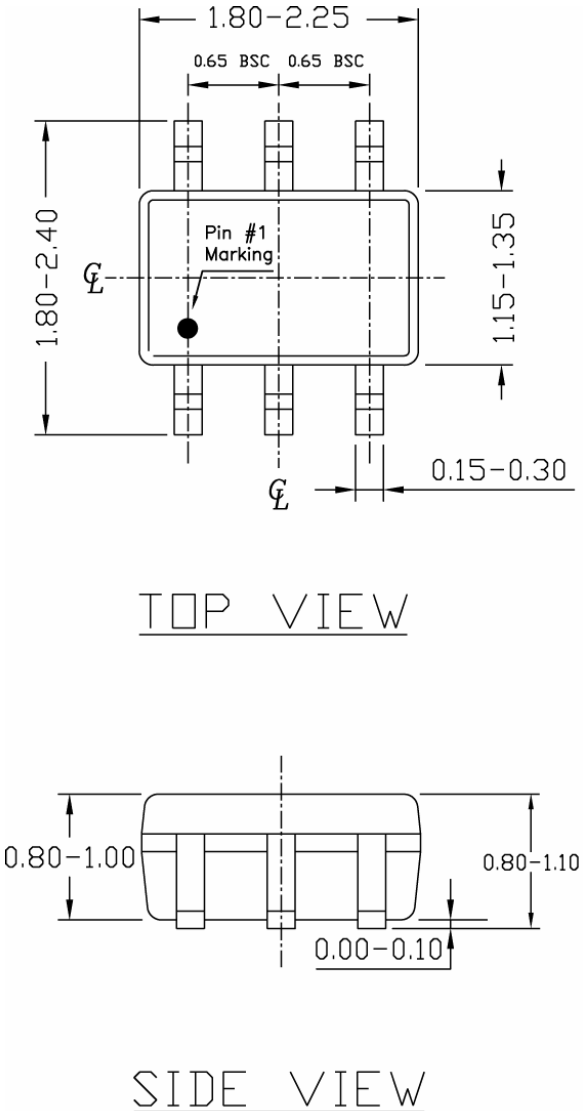
Therefore junction temperature (T_J):

$T_J = 0.5^2 \times 0.41 \times (60+53) + 50$ from (Eqn. 1)

$T_J = 62^oC$

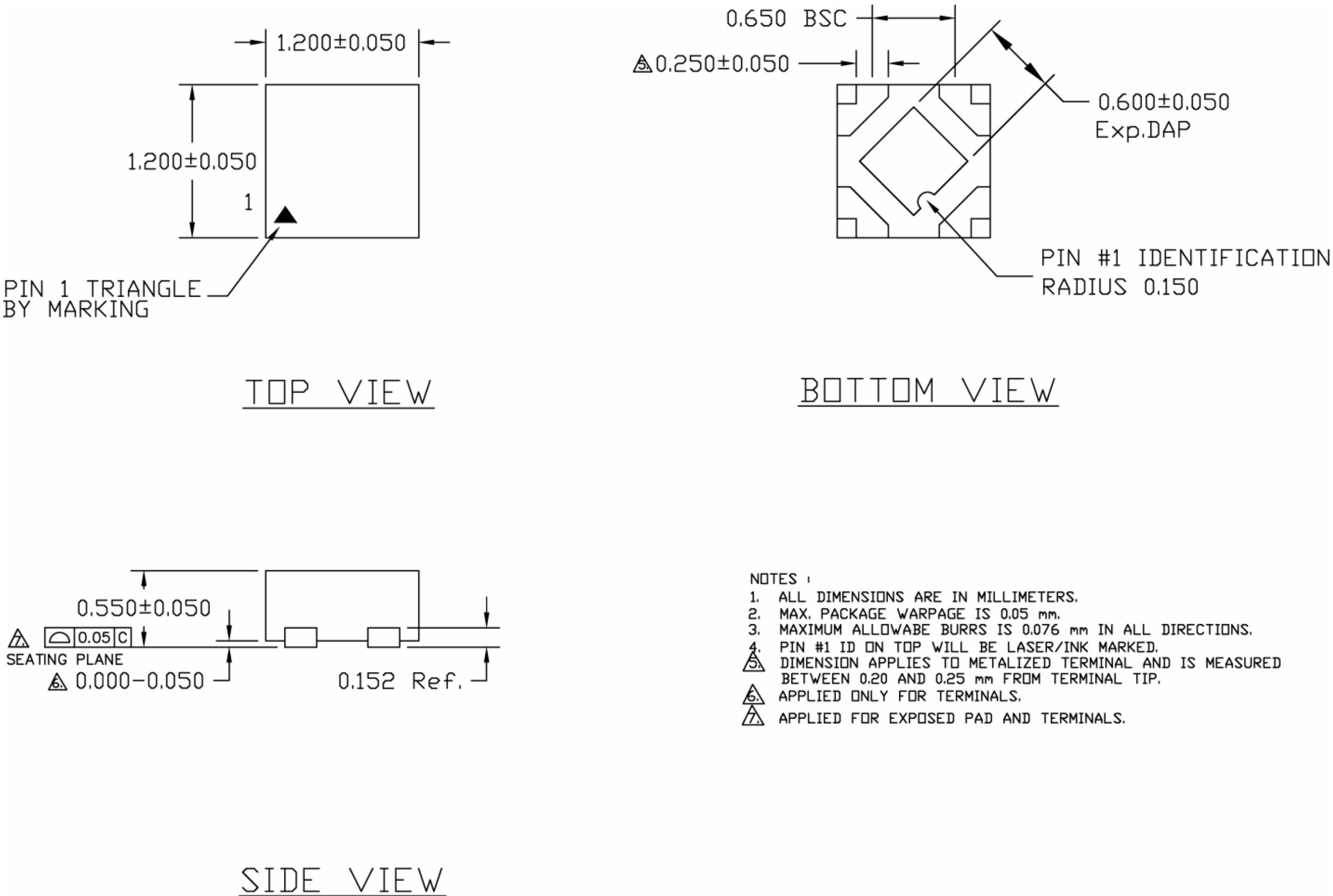
This is well below the maximum 125^oC.

Package Information



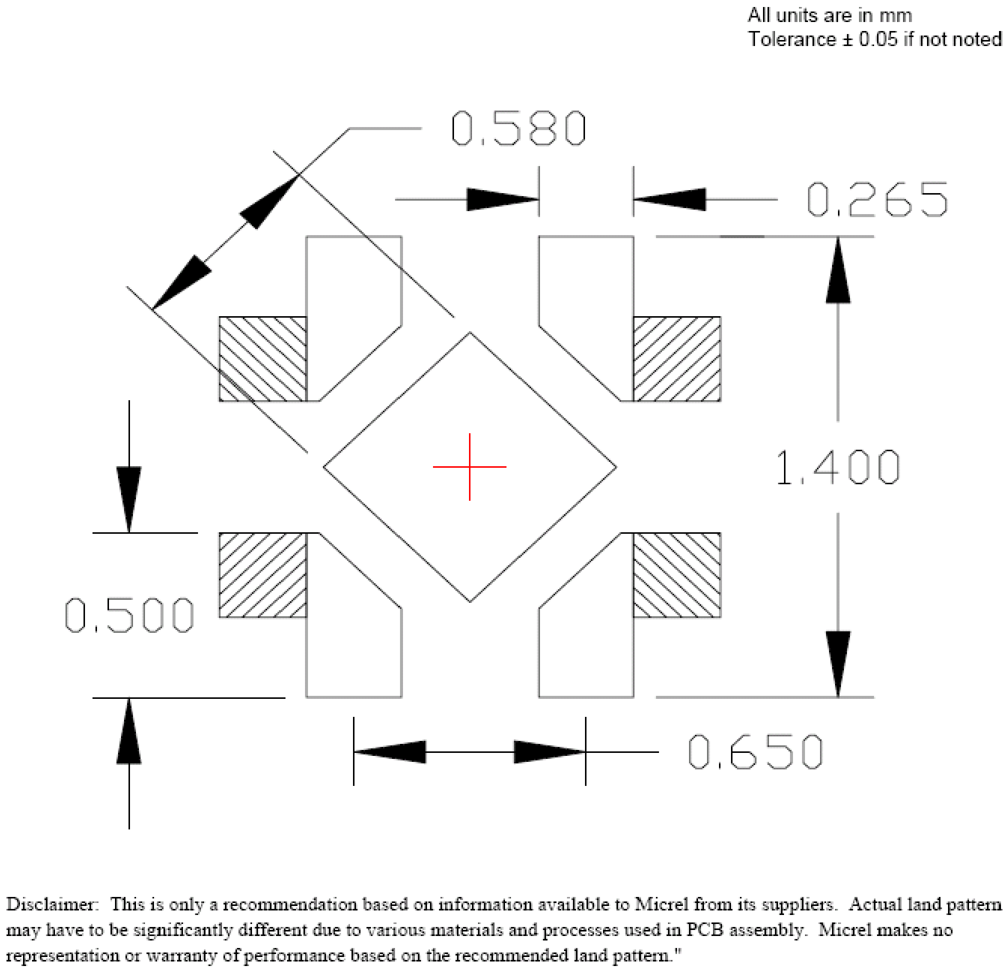
NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS ARE INCLUSIVE OF PLATING.
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.

6-Pin SC-70 (C6)



4-Pin Thin MLF® (MT)

Landing Pattern



Optional for maximum thermal performance. Heatsink should be connected to GND plane of PCB for maximum thermal performance.

Suggested Land Pattern 4-Pin Thin MLF® (MT)

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