MIC2224

High Efficiency 2MHz PWM Converter with DAC Input and 40mΩ Bypass Switch

Preliminary

General Description

The MIC2224 is a high efficiency 2MHz PWM synchronous buck switching regulator optimized for powering 2.5G and 3G CDMA RF Power Amplifiers. The output voltage of MIC2224 can be dynamically adjusted with an external DAC to maximize PA efficiency versus required output power. When the PA requires the highest power, the DAC can be used to enable a low on-resistance, 40mΩ, bypass switch that powers the PA directly from the battery.

The 2MHz PWM operation of MIC2224 allows the smallest possible components. It also allows the device to easily meet stringent W-CDMA V_{OUT} response specifications.

The MIC2224 operates from a 2.7V to 5.5V input, making it ideal for single cell Li-Ion applications. The device features built-in power MOSFETs that can supply up to 600mA of output current in PWM mode, or over 1A in bypass mode. The MIC2224 can operate with a maximum duty cycle of 100% for use in low-dropout conditions.

The MIC2224 has a junction temperature range of −40°C to +125°C and is available in a 3mm x 3mm MLF^{TM}-10L package.

Features

- 2.7V to 5.5V input voltage range
- DAC-adjustable output voltage down to 0.3V
- 600mA output current in PWM mode
- Internally protected 40mΩ bypass switch
  - Allows direct connection of battery to load
- Over 95% efficient
- Fully integrated MOSFET switches
- Constant 2MHz PWM operation
- Internal soft-start
- 1% line and load regulation
- <1μA shutdown current
- Under-voltage lockout
- Thermal shutdown and current limit protection
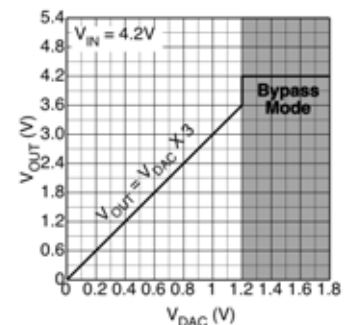- −40°C to +125°C junction temperature range

Applications:

- Cellular phones
- PDAs
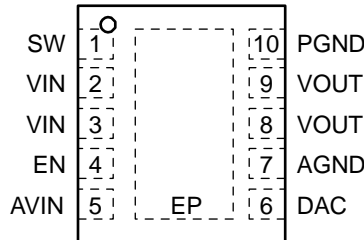
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Typical Application
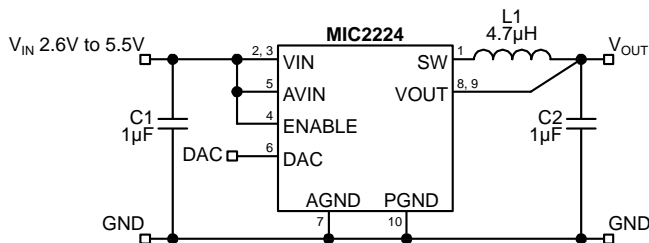
2MHz PWM Converter with DAC input and 40mΩ Bypass Switch

Ordering Information

Part Number	Output Voltage[1]	Junction Temp. Range	Package	Lead Finish
MIC2224YML	Adj.	−40° to +125°C	3x3 MLF-10L	Pb-free

Pin Configuration

```
SW   1          10  PGND
VIN  2           9  VOUT
VIN  3           8  VOUT
EN   4           7  AGND
AVIN 5   EP      6  DAC
```

3mm x 3mm MLF-10L (ML)

Pin Description

Pin	Pin Name	Pin Function
1	SW	Switch (Output): Internal power MOSFET output switches.
2, 3	VIN	Supply Voltage (Input): Requires bypass capacitor to GND.
4	EN	A low level EN will power down the device, reducing the quiescent current to under 5uA (typ 1uA)
5	AVIN	Supply Voltage (Input): Requires bypass capacitor to GND.
6	DAC	DAC Control Input. Provides control of output voltage. The output voltage is 3 X the DAC voltage. (Ex. $0.5V_{DAC}=1.5V_{out}$) Bypass mode is enabled when the DAC voltage exceeds 1.2V.
7	AGND	Signal Ground of chip
8, 9	VOUT	Source of Internal P-Channel MOSFET and Feedback of internal PWM regulator.
10	PGND	Power Ground of chip.
EP	Exposed Pad	Connect to ground.

Absolute Maximum Rating (Note 1)
Supply Voltage (V_{IN}) .... 0V to 6V
Output Switch Voltage (V_{SW}) 6V
DAC Input Voltage (V_{DAC}) .... 0V to V_{in}+0.3V
Output Switch Current (I_{SW}) 2.5A
Logic Input Voltage (V_{EN}) .... 0V to V_{IN}+0.3V
Storage Temperature (T_S) .... -65°C to +150°C

Operating Ratings
Supply Voltage (V_{IN}) .... 2.7V to 5.5V
Output Voltage (V_{OUT}) .... 0V to 5.5V
DAC Input Voltage (V_{DAC}) .... 0.1V to V_{in}
Junction Temperature Range (T_J) .. -40°C to +125°C
Thermal Resistance
   θ_{JA} MLF .... 60°C/W

Electrical Characteristics [4]

$V_{IN} = V_{EN} = 3.6V$; V_{DAC}=0.6V; L = 4.7μH; C_{OUT} = 1μF; T_A = 25°C, unless noted. **Bold** values indicate –40°C$\leq T_J \leq$ +125°C

Parameter	Condition	Min	Typ	Max	Units
Supply Voltage Range		**2.7**		**5.5**	V
Total Quiescent Current	V_{DAC} = 0.6V V_{OUT} = 2.4V (regulator on, not switching)		360	**450**	μA
Shutdown Current	V_{EN} = 0V (regulator off)		1	**5**	μA
Maximum Duty Cycle		**100**			%
Regulation					
Output Voltage	V_{DAC} = 0.6V, I_{LOAD} =0mA	**1.746**	1.8	**1.854**	V
Output Voltage Line Regulation	$3.0V \leq V_{IN} \leq 4.5$, I_{LOAD}= 10mA		0.05	0.5	%/V
Output Voltage Load Regulation	0mA < I_{OUT} < 500mA		0.2		%
Output					
Switch On-Resistance	I_{SW} = -100mA, High-Side Switch		0.55	0.75	Ω
	I_{SW} = 100mA , Low-Side Switch		0.6	0.85	
Current limit (Peak SW Current)		**0.65**	0.85	**1.6**	A
Oscillator					
Frequency		**1.8**	2	**2.2**	MHz
Enable / UVLO					
Enable Pin Threshold		**0.5**	0.9	**1.3**	V
Enable Pin Hysteresis			30		mV
Enable Pin Input Current			0.01	**1**	μA
EN high to 90% V_{OUT}			25	**50**	μs
Under-Voltage Lockout Threshold	(turn-on)		2.6	**2.7**	V
UVLO Hysteresis			85		mV
DAC Input					
DAC Input Current			0.15	**2**	μA
Output Voltage/DAC Voltage	(internally set)		3		V/V

Parameter	Condition	Min	Typ	Max	Units
Bypass Switch					
Bypass Switch Threshold	DAC Voltage required to enable bypass mode	**1.176**	1.2	**1.224**	V
Bypass Switch Hysteresis			35		mV
Bypass Transition Time	Delay from V_{DAC} = 1.2V to V_{OUT} = 0.90V_{IN}		10		μs
Bypass Switch On-Resistance	V_{IN} = 3.0V, I_{BYPASS} = 100mA		40		mΩ
Bypass Switch Leakage	V_{DAC} < 1.2V			**5**	μA
Bypass Over-Current Limit		**1**	1.4	**2.5**	A
Current Limit Retry Time			32		μs
Current Limit Retry Duty Cycle			12.5		%
Over Temperature Shutdown					
Shutdown Temperature			160		°C
Over Temperature Shutdown Hysteresis			20		°C

Notes:

1. Exceeding the absolute maximum rating may damage the device.

2. The device is not guaranteed to function outside its operating rating.

3. Devices are ESD sensitive. Handling precautions recommended. Human body model: 1.5kΩ in series with 100pF.

4. Specification for packaged product only.

Typical Characteristics

Efficiency 2.7V$_{OUT}$

Efficiency 1.8V$_{OUT}$

Efficiency 1.5V$_{OUT}$

Efficiency 1.2V$_{OUT}$

Efficiency 0.9V$_{OUT}$

Efficiency 0.6V$_{OUT}$

Load Regulation

Output Voltage vs. Temperature

V$_{OUT}$/DAC vs. Temperature

Output Voltage vs. DAC Voltage

Frequency vs. Temperature

Quiescent Current vs. Temperature

Typical Characteristics (cont.)

Quiescent Current vs. Supply Voltage

Enable Threshold vs. Supply Voltage
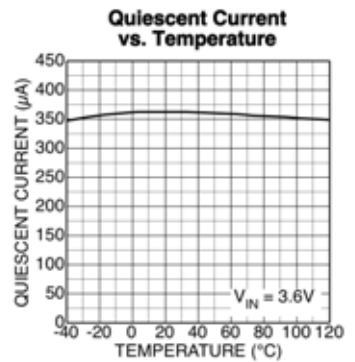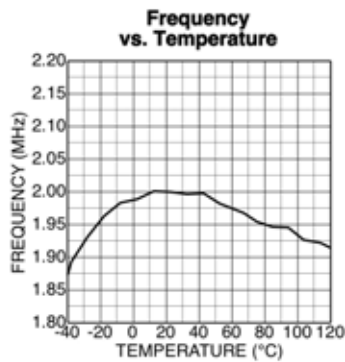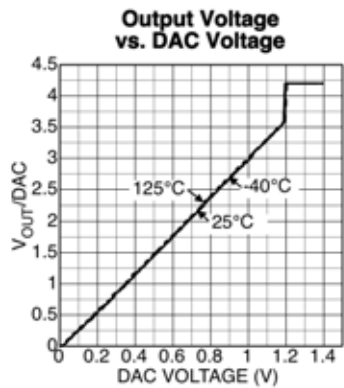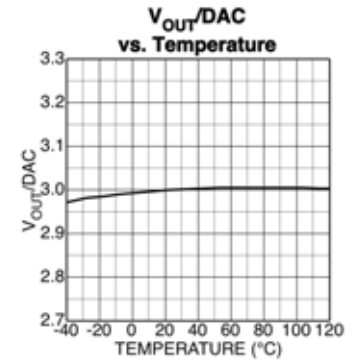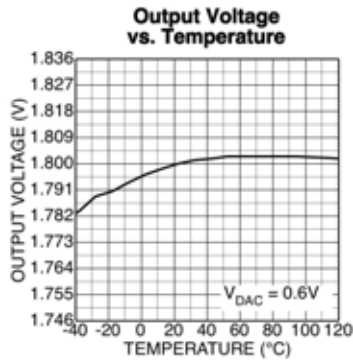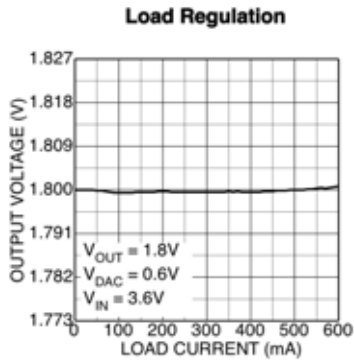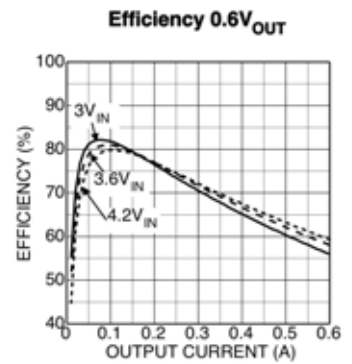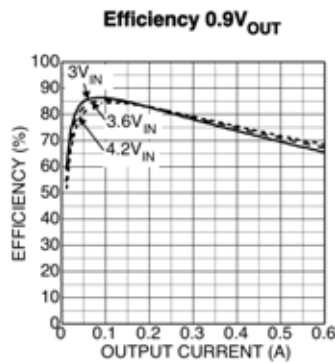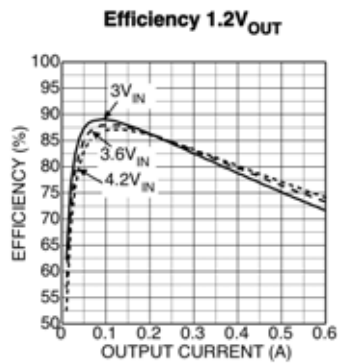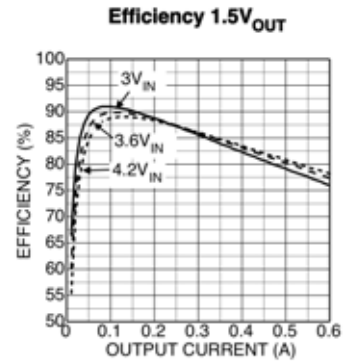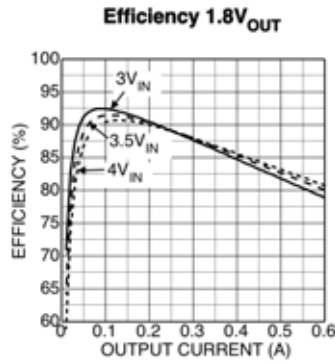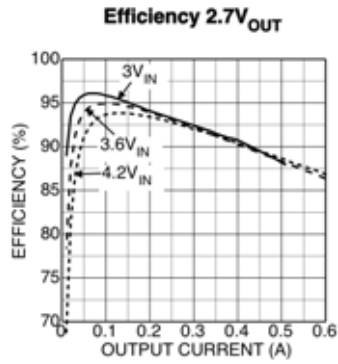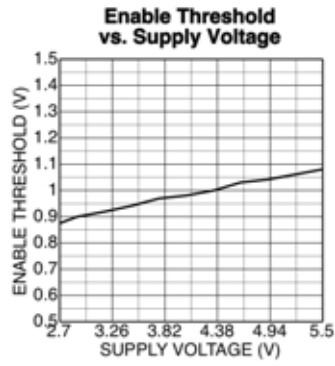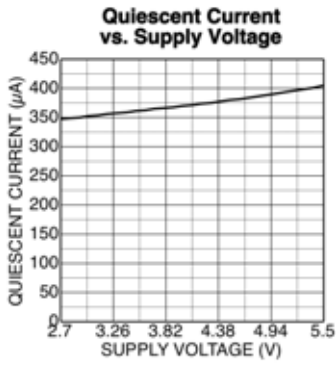
Function Characteristics

Bypass Mode Transient

$V_{IN} = 4.2V$
$L = 4.7\mu H$
$C_{OUT} = 1\mu F$

Output Voltage (2V/div)

0V

DAC Voltage (500mV/div)

0V

Time 10_s

Bypass Mode Transient

$V_{IN} = 4.2V$
$L = 4.7\mu H$
$C_{OUT} = 1\mu F$

Output Voltage (2V/div)

0V

DAC Voltage (500mV/div)

0V
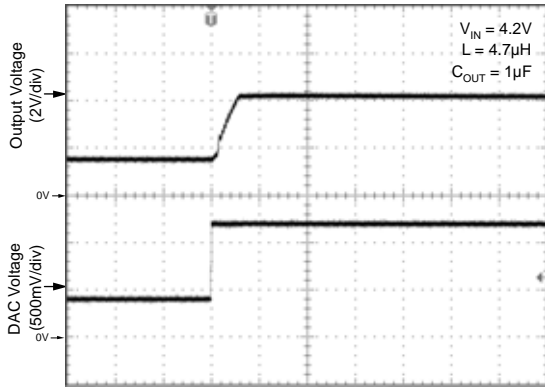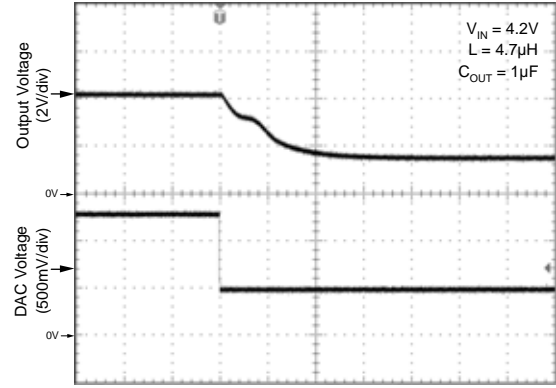
Time 10_s

Current Limit Transient (Bypass Mode)

$V_{IN} = 3.6V$
$VDAC = 1.3V$
$L = 4.7\mu H$
$C_{OUT} = 1\mu F$

Output Voltage (2V/div)

0V

Output Current (500mA/div)

0mA

Time 2ms
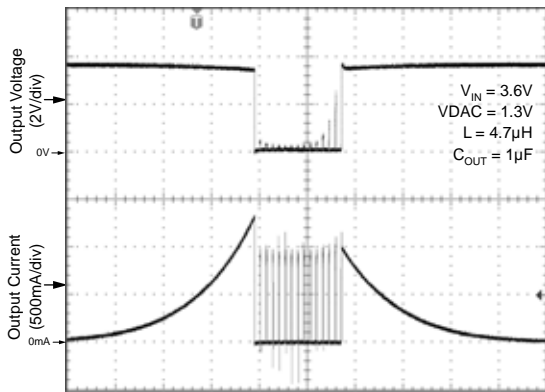
Current Limit Transient (PWM Mode)

$V_{IN} = 3.6V$
$VDAC = 1.3V$
$L = 4.7\mu H$
$C_{OUT} = 1\mu F$

Output Voltage (2V/div)

0V

Output Current (500mA/div)

0mA

Time 100µs

Enable Transient

$V_{IN} = 3.6V$
$VDAC = 0.6V$
$L = 4.7\mu H$
$C_{OUT} = 1\mu F$

Output Voltage (1V/div)

0V

Enable Voltage (1V/div)

0V

Time 10µs

Load Transient

$V_{IN} = 3.6V$
$VDAC = 0.6V$
$L = 4.7\mu H$
$C_{OUT} = 1\mu F$

Output Voltage (100mV/div)

Output Current (100mA/div)

0mA
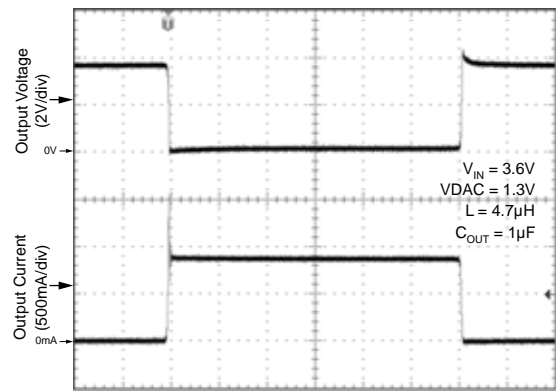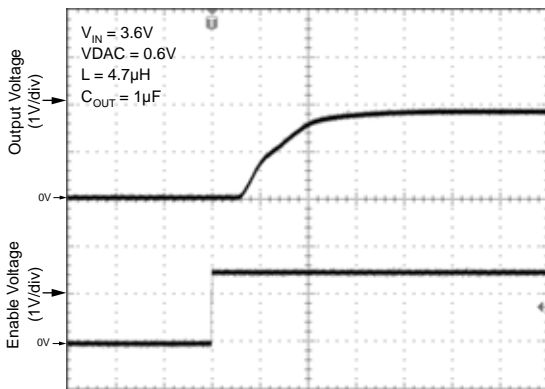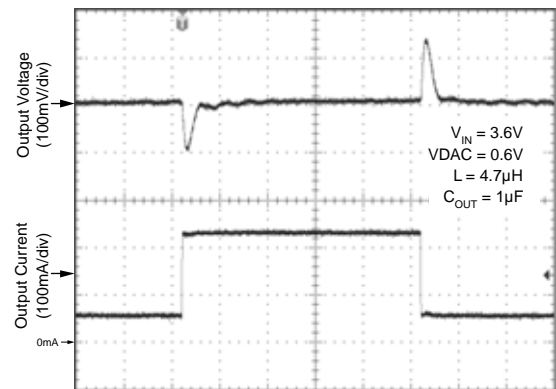
Time 10µs

Functional Characteristics (cont.)

Output Voltage Transient

Output Voltage
(1V/div)

0V

DAC Voltage
(500mV/div)

0V

V_{IN} = 3.6V
L = 4.7µH
C_{OUT} = 1µF

Time 10µs

Output Voltage Transient

Output Voltage
(1V/div)

0V

DAC Voltage
(500mV/div)

0V

V_{IN} = 3.6V
L = 4.7µH
C_{OUT} = 1µF
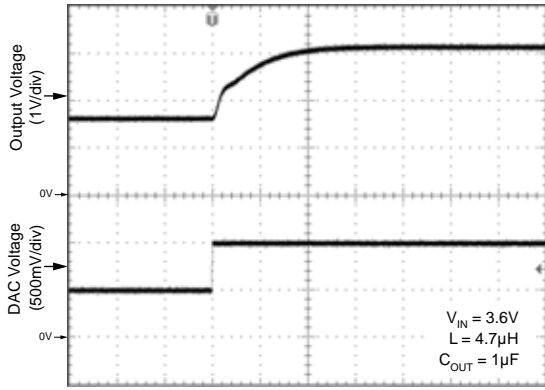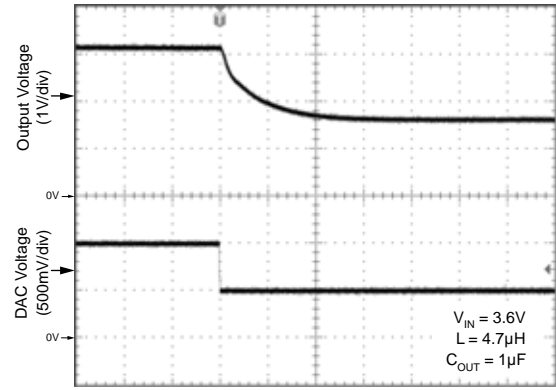
Time 10µs

Switch Voltage - Output Ripple

Output Voltage Ripple
AC Coupled
(10mV/div)

Switch Voltage
(2V/div)

V_{IN} = 3.6V   L = 4.7µH
VDAC = 0.6V C_{OUT} = 1µF
I_{OUT} = 600mA
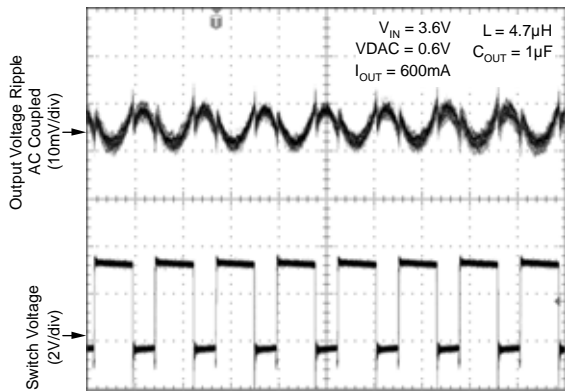
Time 400nµs

Functional Block Diagram
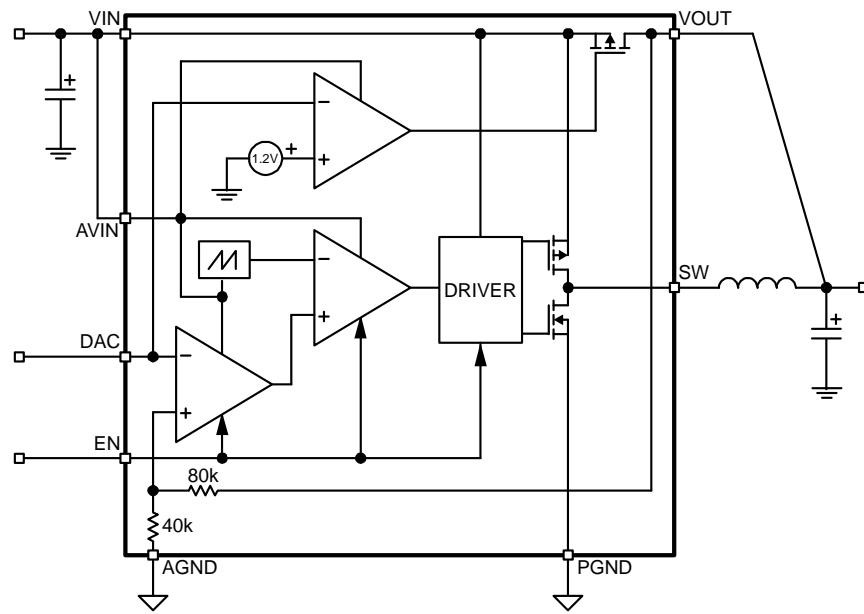
MIC2224 Block Diagram

Functional Description

VIN

VIN provides power to the MOSFETs for the switch mode regulator section, along with the current limiting sensing. Due to the high switching speeds, a 1μF capacitor is recommended close to VIN and the power ground (PGND) pin for bypassing.

AVIN

Analog V_{IN} (AVIN) provides power to the internal reference and control section. AVIN and VIN must be tied together. Careful layout should be considered to ensure high frequency switching noise caused by VIN is reduced before reaching AVIN.

DAC

The DAC pin is the control pin that sets the output voltage. The Output voltage is 3X the voltage set on the DAC pin. When 1.2V or greater is applied to the DAC pin, the MIC2224 enters bypass mode. In bypass mode, the input supply is connected to the output through a 40mOhm P-Channel MOSFET.

EN

The enable pin provides a logic level control of the output. In the off state, supply current of the device is greatly reduced (typically <1μA). Also, in the off state, the output drive and bypass switch are placed in a "tri-stated" condition, where both the high side P-channel Mosfet and the low-side N-channel are in an off or non-conducting state. Do not drive the enable pin above the supply voltage.

VOUT

The VOUT pin connects the internal bypass drain and the feedback signal to the output. The bypass applies the input voltage through a low resistance (40mOhm typical) P-Channel MOSFET switch.

The feedback signal provides the control path to set the output at 3X the DAC voltage.

SW

The switch (SW) pin connects directly to the inductor and provides the switching current necessary to operate in PWM mode. Due to the high speed switching on this pin, the switch node should be routed away from sensitive nodes.

PGND

Power ground (PGND) is the ground path for the high current PWM mode. The current loop for the power ground should be as small as possible and separate from the Analog ground (AGND) loop.

AGND

Signal ground (AGND) is the ground path for the biasing and control circuitry. The current loop for the signal ground should be separate from the Power ground (PGND) loop.

Applications Information

The MIC2224 is a 600mA PWM power supply that utilizes a dynamically adjustable output voltage for powering RF power amplifiers. By dynamically adjusting the output power as necessary, battery life can be dramatically improved in battery powered RF applications. For instances where high power is required, the MIC2224 also has a bypass mode. Bypass mode is enabled by driving the DAC pin above 1.2V. This bypasses the input supply directly to the output through a highly efficient, short circuit protected, 40mOhm P channel MOSFET.

Input Capacitor

A minimum 1μF ceramic is recommended on the VIN pin for bypassing. X5R or X7R dielectrics are recommended for the input capacitor. Y5V dielectrics lose most of their capacitance over temperature and are therefore not recommended.

A minimum 1μF is recommended close to the VIN and PGND pins for high frequency filtering. Smaller case size capacitors are recommended due to their lower ESR and ESL.

Output Capacitor

The MIC2224 is optimized for a 1μF ceramic output capacitor. The MIC2224 utilizes type III internal compensation and utilizes internal high frequency zeros to compensate for the double pole roll off of the LC filter. For this reason, larger output capacitors can create instabilities. X5R or X7R dielectrics are recommended for the output capacitor. Y5V dielectrics lose most of their capacitance over temperature and are therefore not recommended.

In addition to a 1μF, a small 10nF is recommended close to the load for high frequency filtering. Smaller case size capacitors are recommended due to there lower ESR and ESL.

Inductor Selection

The MIC2224 is designed for use with a 4.7μH inductor. Proper selection should ensure the inductor can handle the maximum average and peak currents required by the load. Maximum current ratings of the inductor are generally given in two methods; permissible DC current and saturation current. Permissible DC current can be rated either for a 40°C temperature rise or a 10% to 20% loss in

inductance. Ensure the inductor selected can handle the maximum operating current. When saturation current is specified, make sure that there is enough margin that the peak current will not saturate the inductor. Peak inductor current can be calculated as follows:

$$I_{PK} = I_{OUT} + \frac{V_{OUT}\left(1 - \dfrac{V_{OUT}}{V_{IN}}\right)}{2 \times f \times L}$$

Bill of Materials
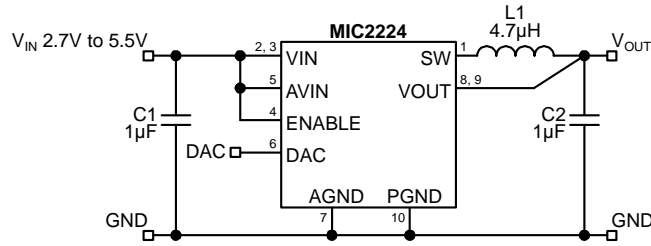
Ref	Part Number	Description	Manufacturer	Qty
C1,C2	06036D105MAT2	1uF Ceramic Capacitor X5R, 6.3V 0603	AVX	
	C1608X5R0J105K	1uF Ceramic Capacitor X5R, 6.3V 0603	TDK	
	GRM185R60J105KE21D	1uF Ceramic Capacitor X5R, 6.3V 0603	Murata	2
L1	LQH32CN4R7M53K	4.7uH 3.2mmx2.5mmx1.55mm	Murata	
	CDRH2D14-4R7	4.7uH Inductor 94mOhm 3.2mmx3.2mmx1.55mm	Sumida	1
	GLF201208T4R7M[1]	4.7uH Inductor 660mOhm[1]	TDK[1]	1[1]
U1	**MIC2224YML**	**2MHz Dynamically Controlled PWM Regulator**	**Micrel Semiconductor**	**1**

Notes:

1. For maximum load currents less than 200mA

Package Information

10-Lead MLF™ (ML)

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