Low Voltage Step-Up DC/DC Converter

■ FEATURES

- A Guaranteed Start-Up from less than 0.9 V.
- High Efficiency.
- Low Quiescent Current.
- Fixed or adjustable Output Voltage.
- Logic Controlled Shutdown.

■ APPLICATIONS

- Pagers.
- Cameras.
- Wireless Microphones.
- Pocket Organizers.
- Battery Backup Suppliers.
- Portable Instruments.

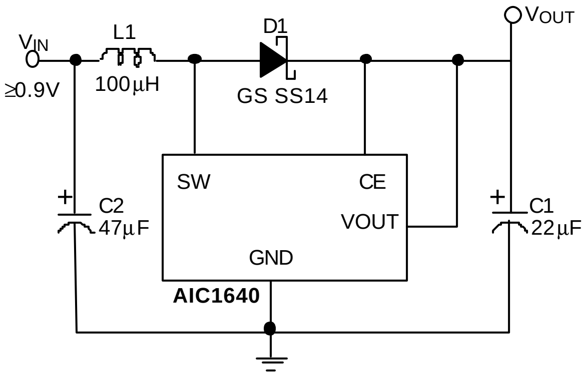
■ DESCRIPTION

The AIC1640 is a high efficiency step-up DC/DC converter for applications using 1 to 4 battery cells. Only three external components are required to deliver a fixed output voltage of 2.7V, 3V, 3.3V, or 5V.

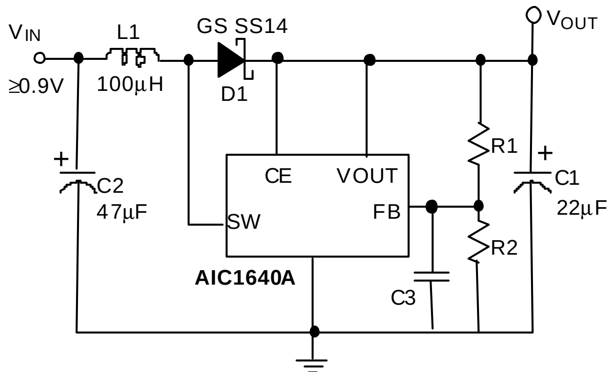
Pulse Frequency Modulation scheme brings optimized performance for applications with light output loading and low input voltage. The output ripple and noise are lower compared with the circuit operating in PSM mode. The AIC1640 starts up from less than 0.9V input to boost either 2.7V, 3V, 3.3V, or 5V output with 1mA load.

Some useful features include, shutdown mode for saving the life of battery, and adjustable output version. The PFM control circuit operates in 100KHz (max.) switching rate, resulting in smaller passive component size, which makes the AIC1640 an ideal choice of DC/DC converter for space conscious applications.

■ TYPICAL APPLICATION CIRCUIT



One Cell Step-Up DC/DC Converter with Fixed Output Voltage



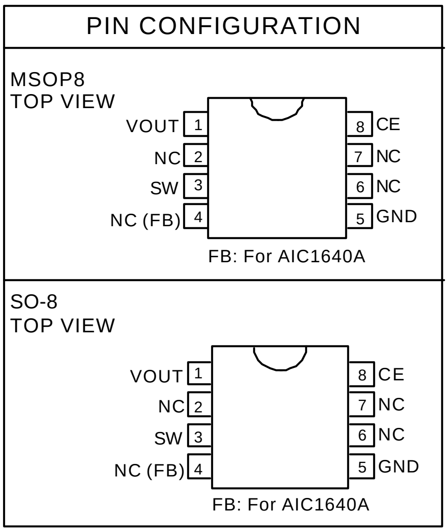
One Cell Step-Up DC/DC Converter with Adjustable Output Voltage

■ ORDERING INFORMATION

AIC1640-XXCXXX

- PACKING TYPE
  - TR: TAPE & REEL
  - TB: TUBE
- PACKAGE TYPE
  - O: MSOP8
  - S: SMALL OUTLINE
- OUTPUT VOLTAGE
  - 27: 2.7V
  - 30: 3.0V
  - 33: 3.3V
  - 50: 5.0V
  - A: Adjustable

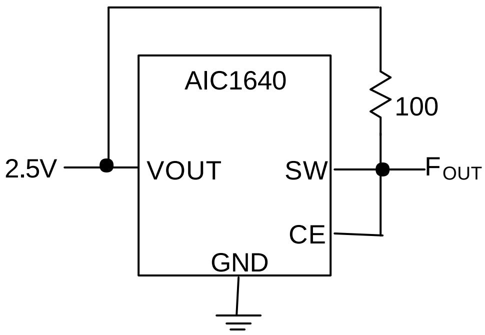
Example: AIC1640-27COTR
→ 2.7V Version, in MSOP8 Package & Tape & Reel Packing Type



■ ABSOLUATE MAXIMUM RATINGS

Supply Voltage	12V
SW Pin Voltage	12V
FB Pin Voltage	12V
SW Pin Switch Current	0.6A
Operating Temperature Range	-40 °C to 85°C
Storage Temperature Range	-65°C to 150 °C
Lead Temperature (Soldering 10 Sec.)	260°C

■ TEST CIRCUIT



Oscillator Test Circuit

ELECTRICAL CHARACTERISTICS (T_A=25°C, I_O=10mA, Unless otherwise specified)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Output Voltage	AIC1640-27 V_{IN}=1.8V AIC1640-30 V_{IN}=1.8V AIC1640-33 V_{IN}=2.0V AIC1640-50 V_{IN}=3.0V	V_{OUT}	2.633 2.925 3.218 4.875	2.700 3.000 3.300 5.000	2.767 3.075 3.382 5.125	V
Input Voltage		V_{IN}			8	V
Start-Up Voltage	I_{OUT}=1mA, V_{IN}:0→2V	V_{START}		0.8	0.9	V
Hold-on Voltage	I_{OUT}=1mA, V_{IN}:2→0V	V_{HOLD}			0.7	V
No-Load Input Current	I_{OUT}=0mA	I_{IN}		15		µA
Supply Current	AIC1640-27 AIC1640-30 AIC1640-33 AIC1640-50 V_{IN}=V_{OUT} x 0.95 Measurement of the IC input current (VOUT pin)	I_{DD1}		42 50 60 90		µA
Supply Current	V_{IN}=V_{OUT} + 0.5V Measurement of the IC input current (VOUT pin)	I_{DD2}		7		µA
FB Reference Voltage		V_{REF}	1.21	1.24	1.27	V
SW Leakage Current	V_{SW}=10V, V_{IN}=V_{OUT} + 0.5V				0.5	µA
SW Switch-On Resistance	AIC1640-27 AIC1640-30 AIC1640-33 AIC1640-50 V_{IN}=V_{SW} x 0.95, V_{SW}=0.4V	R_{ON}		1.3 1.2 1.1 1		Ω
Oscillator Duty Cycle	V_{IN}=V_{OUT} x 0.95 Measurement of the SW Pin wave-form	DUTY	65	75	85	%

ELECTRICAL CHARACTERISTICS (Continued)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Max. Oscillator Freq.	$V_{IN}=V_{OUT}$ x 0.95 Measurement of the SW pin wave-form	F_{OSC}	80	105	130	KHz
CE "High" Voltage Level 1	$V_{OUT} \geq 1.5V$	V_{CEH1}	V_{OUT} - 0.4			V
CE "Low" Voltage Level 1	$V_{OUT} \geq 1.5V$	V_{CEL1}			0.4	V
CE "High" Voltage Level 2	$0.8V \leq V_{OUT} \leq 1.5V$	V_{CEH2}	V_{OUT} - 0.3			V
CE "Low" Voltage Level 2	$0.8V \leq V_{OUT} \leq 1.5V$	V_{CEL2}			0.15	V
CE "High" Input Current	Same as I_{DD1}, $V_{CE}=V_{OUT}$ x 0.95	I_{CEH}			0.5	µA
CE "Low" Input Current	Same as I_{DD1}, V_{CE}= 0V	I_{CEL}	-0.5			µA
Efficiency		η		85		%

TYPICAL PERFORMANCE CHARACTERISTICS

Capacitor (C1) : 47µF (Tantalum Type)
Diode (D1) : 1N5819 Schottky Type

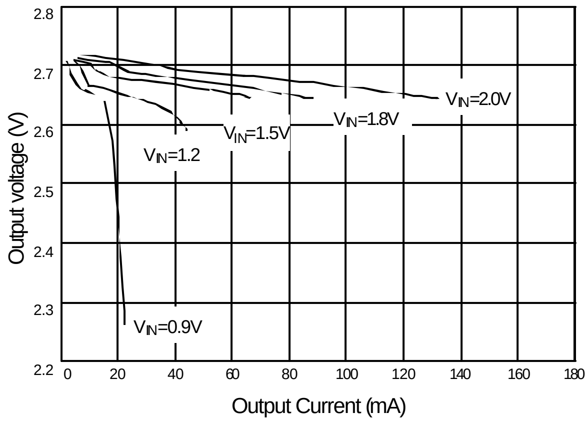


Fig. 1 AIC1640-27 Load Regulation (L=100µH CD54)

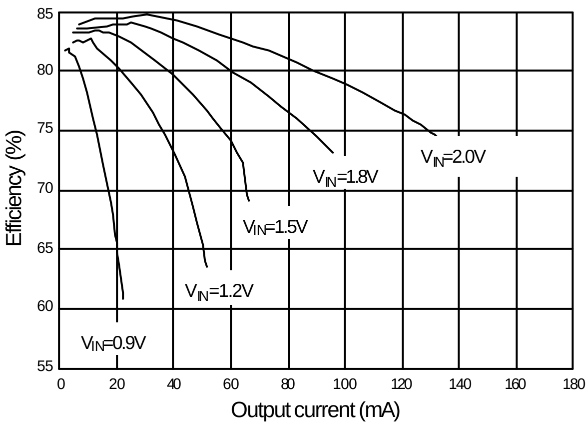


Fig. 2 AIC1640-27 Efficiency (L=100µH CD54)

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

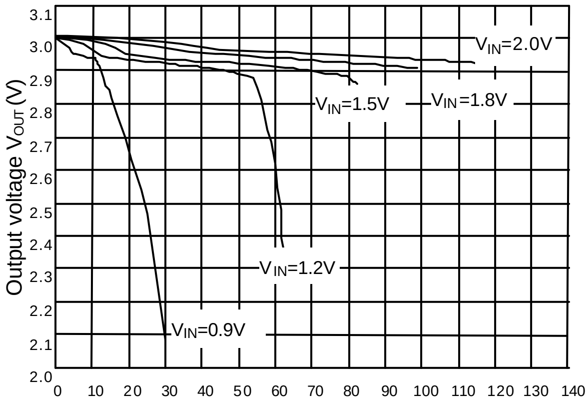


Fig. 3 AIC1640-30 Load Regulation (L=100μH CD54)

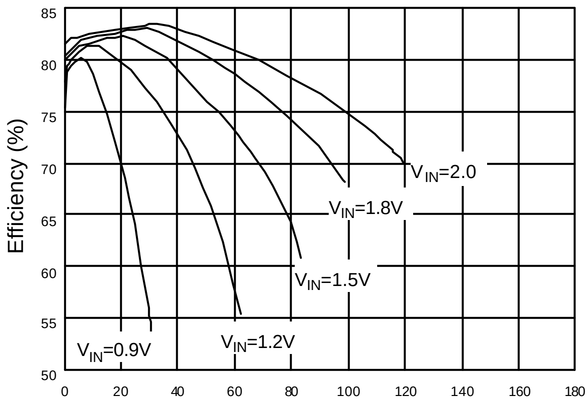


Fig. 4 AIC1640-30 Efficiency (L=100μH CD54)

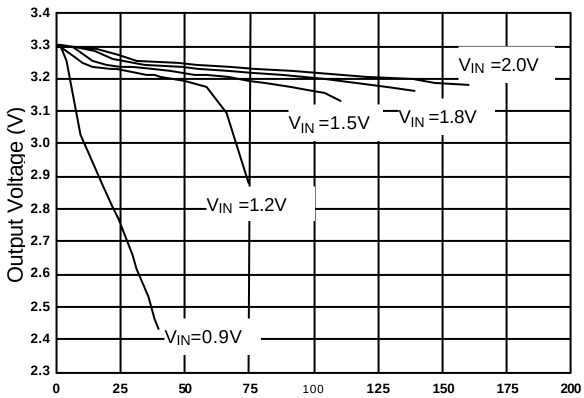


Fig. 5 AIC1640-33 Load Regulation (L=100μH CD54)

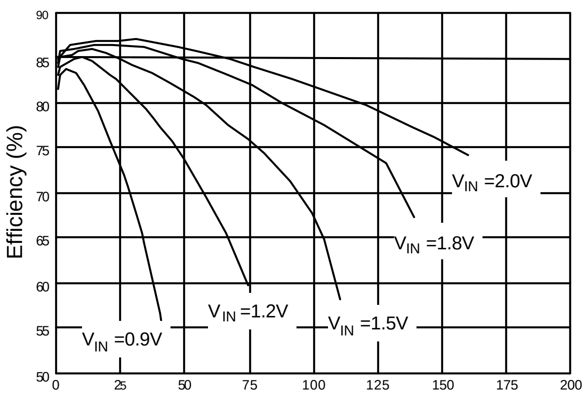


Fig. 6 AIC1640-33 Efficiency (L=100μH CD54)

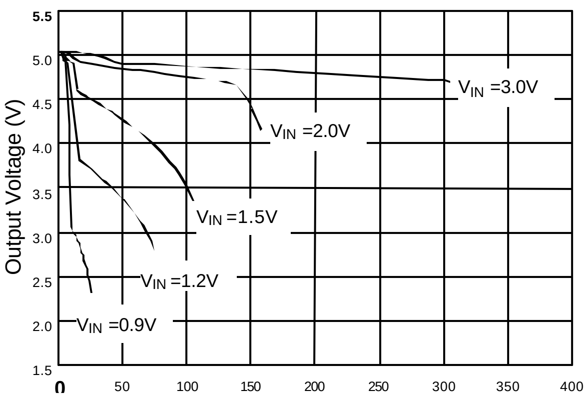


Fig. 7 AIC1640-50 Load Regulation (L=100μH CD54)

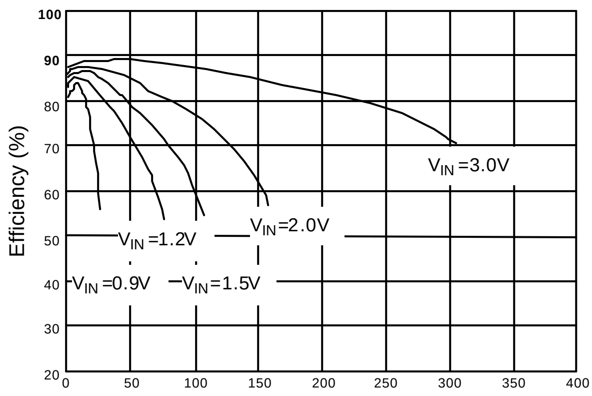


Fig. 8 AIC1640-50 Efficiency (L=100μH CD54)

■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

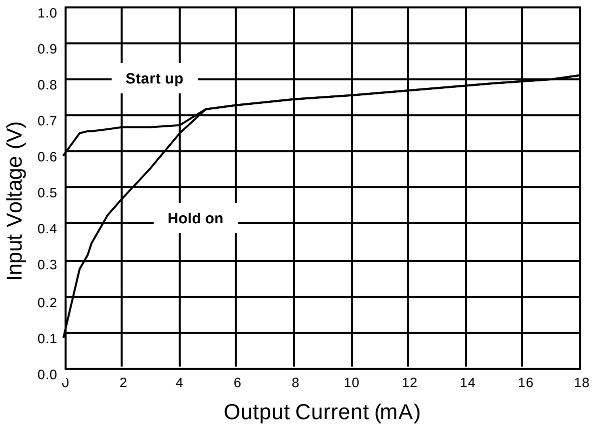


Fig. 9 AIC1640-27 Start-up & Hold-on Voltage

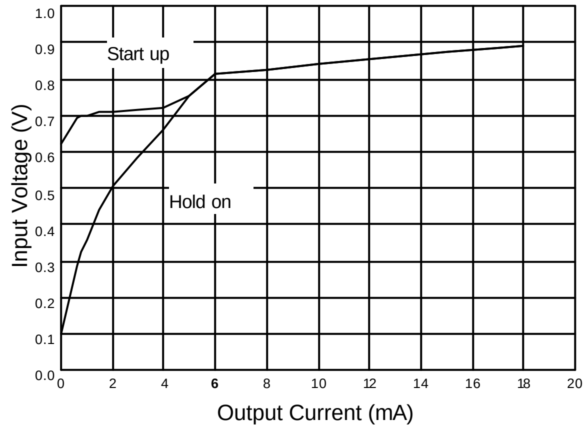


Fig. 10 AIC1640-30 Start-up & Hold-on Voltage

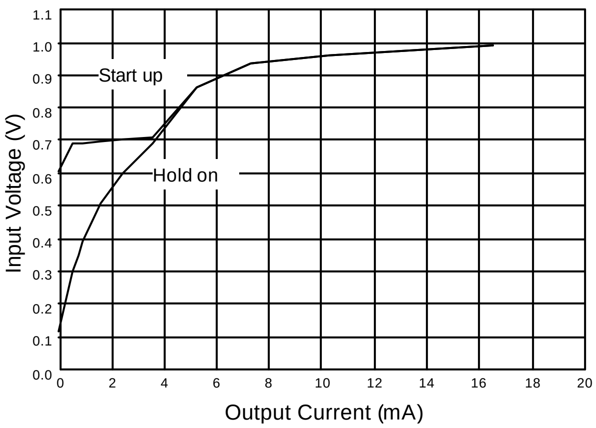


Fig. 11 AIC1640-33 Start-up & Hold-on Voltage (L=100μH)

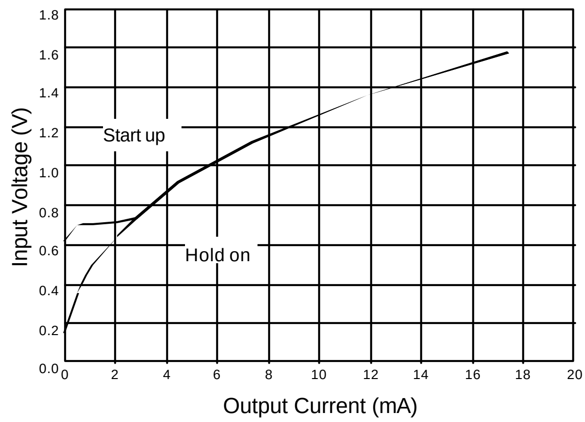


Fig. 12 AIC1640-50 Start-up & Hold-on Voltage (L=100μH)

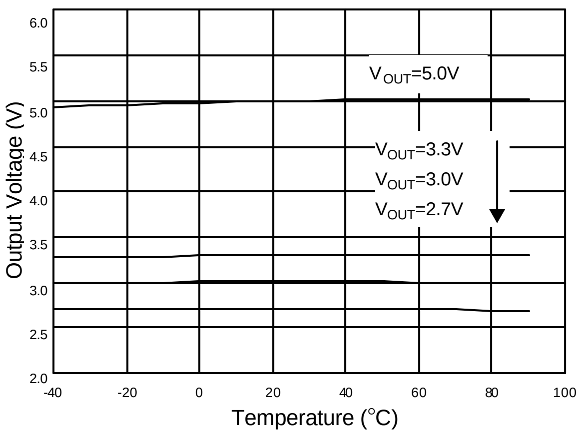


Fig. 13 AIC1640 Output Voltage vs. Temperature

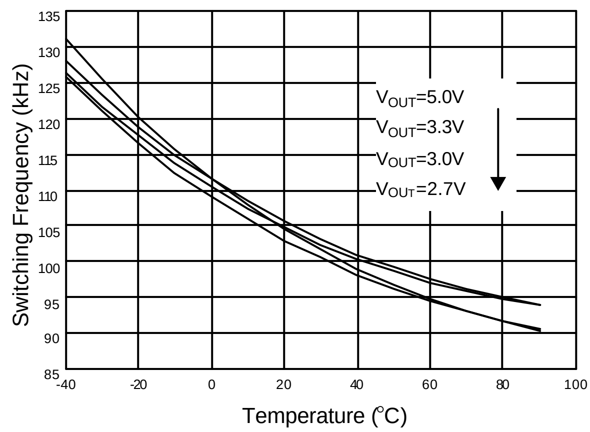


Fig. 14 AIC1640 Switching Frequency vs. Temperature

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

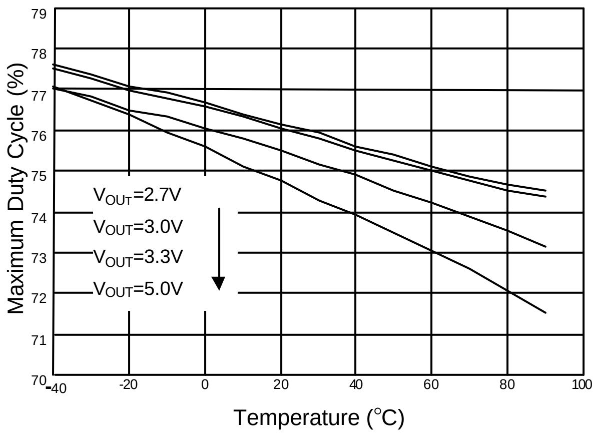


Fig. 15 AIC1640 Maximum Duty Cycle vs. Temperature

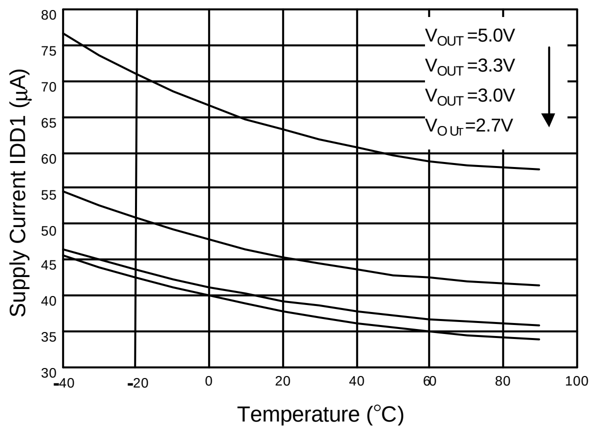


Fig. 16 AIC1640 Supply Current vs. Temperature

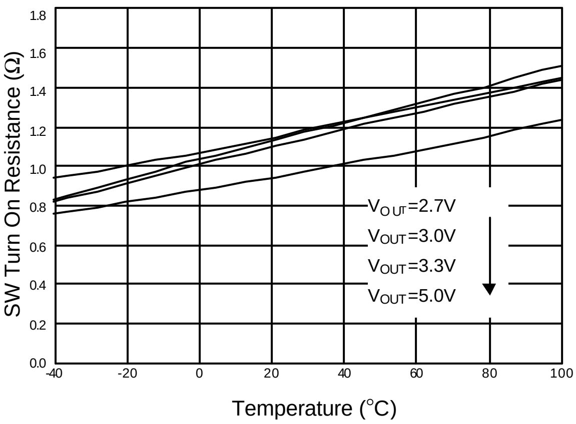
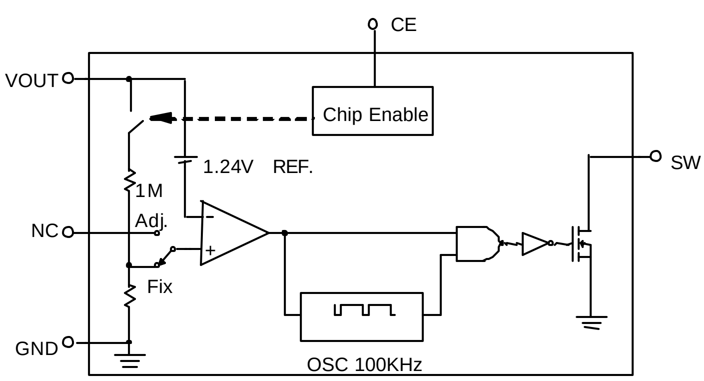
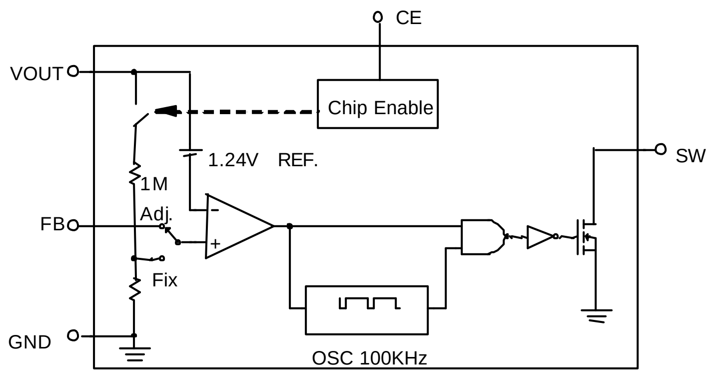


Fig. 17 AIC1640 SW ON Resistance vs. Temperature

BLOCK DIAGRAM



Fixed Version



Adjustable Version

PIN DESCRIPTIONS

NC - Not connected.

VOUT - IC supply pin. Connect VOUT to the controller output.

CE - Chip enable pin (Active High).

SW - Internal drain of N-MOSFET switch.

GND - Ground Terminal. Must be low impedance; solder directly to ground plane.

FB - Output Voltage Adjustable Pin. VOUT voltage is given by the following equation:

$$\frac{R2}{R1} = \frac{V_{OUT}}{1.24} - 1$$

APPLICATION INFORMATION

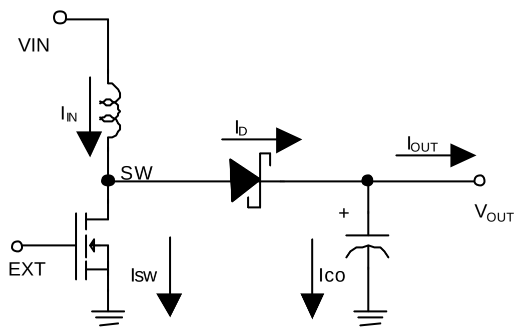
GENERAL DESCRIPTION

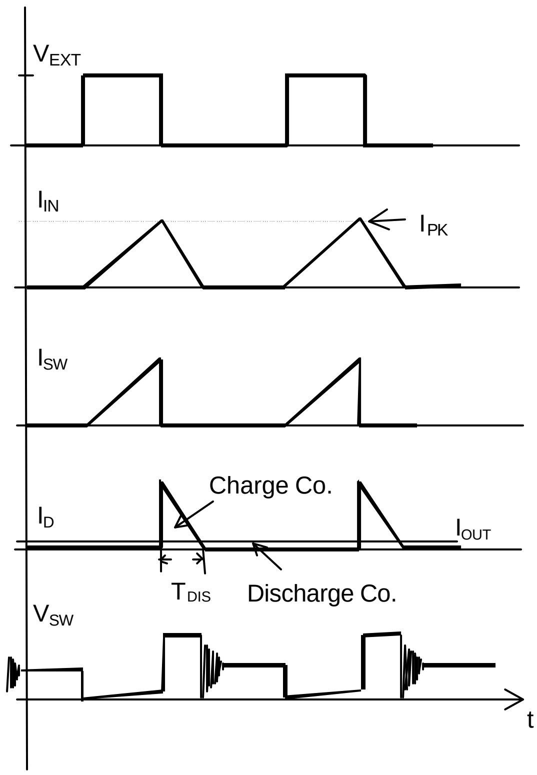
AIC1640 PFM (pulse frequency modulation) converter ICs combine a switch mode controller, N-channel power MOSFET, precision voltage reference, and voltage detector in a single monolithic device. They offer both extreme low quiescent current, high efficiency, and very low gate threshold voltage to ensure start-up with low battery voltage (0.8V typ.). Designed to maximize battery life in portable products, and minimize switching losses by only switching as needed service the load.

PFM conveters transfer a discrete amount of energy per cycle and regulate the output voltage by modulating switching frequency with the constant turn-on time. Switching frequency depends on load, input voltage, and inductor value, and it can range up to 100KHz. The SW on-resistance is typically 1 to 1.5Ω to minimize switch losses.

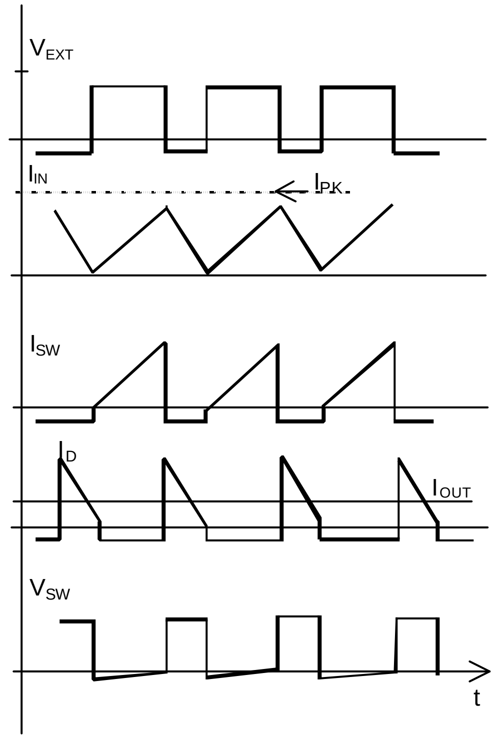
When the output voltage drops, the error comparator enable 100kHz oscillator that turns on the MOSFET around 7.5µs and 2.5µs off time. Turning on the MOSFET allows inductor current to ramp up, storing energy in a magnetic field. When MOSFET turns off that forces inductor current through diode to the output capacitor and load. As the stored energy is depleted, the current ramp down until the diode turns off. At this point, inductor may ring due to residual energy and stray capacitance. The output capacitor stores charge when current flowing through the diode is high, and release it when current is low, thereby maintaining a steady voltage across the load.

As the load increases, the output capacitor discharges faster and the error comparator initiates cycles sooner, increasing the switching frequency. The maximum duty cycle ensure adequate time for energy transfer to output during the second half each cycle. Depending on circuit, PFM converter can operate in either discontinuous mode or continuous conduction mode. Continuous conduction mode means that the inductor current does not ramp to zero during each cycle.





Discontinuous Conduction Mode



Continuous Conduction Mode

At the boundary between continuous and discontinuous mode, output current (IOB) is determined by

$$I_{OB} = \left(\frac{V_{IN}}{V_{OUT} + V_D}\right) * \frac{1}{2} * \frac{V_{IN}}{L} * T_{ON} * (1 - x)$$

where V_D is the diode drop,

$$X = (R_{ON} + R_S) * \frac{T_{ON}}{L}$$

R_{ON}= Switch turn on resistance, Rs= Inductor DC resistance

T_{ON} = Switch ON time

In the discontinuous mode, the switching frequency (Fsw) is

$$F_{SW} = \frac{2(L) * (V_{OUT} + V_D - V_{IN}) * (I_{OUT})}{V_{IN}^2 * T_{ON}^2} * (1 + x)$$

In the continuous mode, the switching frequency is

$$f_{SW} = \frac{1}{T_{ON}} \frac{(V_{OUT} + V_D - V_{IN})}{(V_{OUT} + V_D - V_{SW})} * [1 + \frac{x}{2} * (\frac{V_{IN} - V_{SW}}{V_{OUT} + V_D - V_{SW}})] \cong \frac{1}{T_{ON}} \left(\frac{V_{OUT} + V_D - V_{IN}}{V_{OUT} + V_D - V_{SW}} \right)$$

where Vsw = switch drop and proportion to output current.

INDUCTOR SELECTION

To operate as an efficient energy transfer element, the inductor must fulfill three requirement. First, the inductance must be low enough for the inductor to store adequate energy under the worst case condition of minimum input voltage and switch ON time. Second, the inductance must also be high enough so maximum current rating of AIC1640 and inductor are not exceed at the other worst case condition of maximum input voltage and ON time. Lastly, the inductor must have sufficiently low DC resistance so excessive power is not lost as heat in the windings. But unfortunately this is inversely related to physical size.

Minimum and Maximum input voltage, output voltage and output current must be established before and inductor can be selected.

In discontinuous mode operation, at the end of the switch ON time, peak current and energy in the inductor build according to

$$I_{PK} = \left(\frac{V_{IN}}{R_{ON} + R_S} \right) * \left(1 - \exp(-\frac{R_{ON} + R_S}{L} * T_{ON}) \right) \cong \left(\frac{V_{IN}}{L} \right) * (T_{ON}) * \left(1 - \frac{x}{2} \right) \cong \frac{V_{IN}}{L} * T_{ON}$$

(simple lossless equation), where

$$X = (R_{ON} + R_S) * \frac{T_{ON}}{L}$$

$$E_L = \frac{1}{2} L * I_{PK}^2$$

Power required from the inductor per cycle must be equal or greater than

$$\frac{P_L}{f_{SW}} = (V_{OUT} + V_D - V_{IN}) * (I_{OUT}) * (\frac{1}{f_{SW}})$$

in order for the converter to regulate the output.

When loading is over IOB, PFM controller operates in continuous mode. Inductor peak current can be derived from

$$I_{PK} = \left(\frac{V_{OUT} + V_D - V_{SW}}{V_{IN} - V_{SW}} - \frac{x}{2} \right) * I_{OUT} + \left(\frac{V_{IN} - V_{SW}}{2L} \right) * T_{ON} * \left(1 - \frac{x}{2} \right)$$

Valley current (Iv) is

$$I_V = \left(\frac{V_{OUT} + V_D - V_{SW}}{V_{IN} - V_{SW}} - \frac{x}{2} \right) * I_{OUT} - \left(\frac{V_{IN} - V_{SW}}{2L} \right) * T_{ON} * \left(1 - \frac{x}{2} \right)$$

Table 1 Indicates resistance and height for each coil.

Power Inductor Type		Inductance (mH)	Resistance (W)	Rated Current (A)	Height (mm)
Coilcraft SMT Type (www.coilcraft.com)	DS1608	22	0.10	0.7	2.9
		47	0.18	0.5	
		100	0.38	0.3	
	DO3316	22	0.08	2.7	5.2
		47	0.14	1.8	
Sumida SMT Type CD54		47	0.25	0.7	4.5
		100	0.50	0.5	
Hold SMT Type PM54		47	0.25	0.7	4.5
		100	0.50	0.5	
Hold SMT Type PM75		33	0.11	1.2	5.0

CAPACITOR SELECTION

A poor choice for a output capacitor can result in poor efficiency and height output ripple. Ordinary aluminum electrolytic, while inexpensive may have unacceptably poor ESR and ESL. There are low ESR aluminum capacitors for switch mode DC-DC converters which work much better than general-purpose unit. Tantalum capacitors provide still better performance at more expensive. OS-CON capacitors have extremely low ESR in a small size. If capacitance is reduced, output ripple will increase.

Most of the input supply is supplied by the input bypasss capacitor, the capacitor voltage rating should be at least 1.25 times greater than a maximum input voltage.

DIODE SELECTION

Speed, forward drop, and leakage current are the three main consideration in selecting a rectifier diode. Best performance is obtained with Schottky rectifier diode such 1N5819. Motorola makes MBR0530 in surface mount. For lower output power a 1N4148 can be used although efficiency and start-up voltage will suffer substantially.

COMPONENT POWER DISSIPATION

Operating in discontinuous mode, power loss in the winding resistance of inductor can be approximate equal to

$$PD_L = \frac{2}{3} * \left(\frac{T_{ON}}{L}\right) * (R_S) * \left(\frac{V_{OUT} + V_D}{V_{OUT}}\right) * (P_{OUT})$$

where $P_{OUT} = V_{OUT} * I_{OUT}$; Rs=Inductor DC R;

V_D = Diode drop.

The power dissipated in a switch loss is

$$PD_{SW} = \frac{2}{3} * \left(\frac{T_{ON}}{L}\right) * (R_{ON}) * \left(\frac{V_{OUT} + V_D - V_{IN}}{V_{OUT}}\right) * (P_{OUT})$$

The power dissipated in rectifier diode is

$$PD_D = \left(\frac{V_D}{V_{OUT}}\right) * (P_{OUT})$$

where $P_{OUT} = V_{OUT} * I_{OUT}$; R_S=Inductor DC R;