

# MIC38@/H@42/3/4/5, MIC18@/H@42/3/4/5

## **BiCMOS Current-Mode PWM Controller**

## **Preliminary Information**

## **General Description**

The MIC38C4x and MIC38HC4x are fixed frequency, high performance, current-mode PWM controllers. Micrel's BiCMOS devices are pin compatible with 384x bipolar devices but feature several improvements. 'HC' versions support even faster rise and fall times than 'C' versions.

Undervoltage lockout circuitry allows the '42 and '44 versions to start up at 14.5V and operate down to 9V, and the '43 and '45 versions start at 8.4V with operation down to 7.6V. All versions operate up to 20V.

When compared to bipolar 384x devices operating from a 15V supply, start-up current has been reduced to  $50\mu$ A typical and operating current has been reduced to 4.0 mA typical. Decreased output rise and fall times drive larger MOSFETs, and rail-to-rail output capability increases efficiency, especially at lower supply voltages. The MIC38C4x and MIC38HC4x also feature a trimmed oscillator discharge current and bandgap reference.

MIC38xC4x denotes 8-pin plastic DIP and SOIC packages. MIC38HC4x-1 denotes 14-pin plastic DIP and SOIC packages. Devices identified as MIC18xC4x and MIC18xC4x-1 are military temperature range 8- and 14-pin ceramic DIPs, respectively. 8-pin devices feature small size, while 14-pin devices separate the analog and power connections for improved performance and power dissipation.

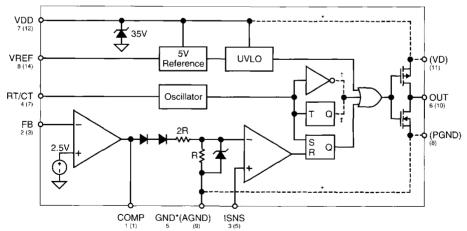
### **Features**

- Fast output rise/fall times: 40ns rise/30ns fall for the MIC38C42 20ns rise/15ns fall for the MIC38HC42
- -40°C to +85°C temperature range meets UC284x specifications
- · High-performance, low-power BiCMOS Process
- Ultra-low start-up current (50μA typical)
- · Low operating current (4mA typical)
- · High output drive (1A peak current, HC version)
- · CMOS outputs with rail-to-rail swing
- · Current-mode operation ≥500kHz
- Trimmed 5V bandgap reference
- Pin-for-pin compatible with UC3842/3843/3844/3845(A)
- · Trimmed oscillator discharge current
- · UVLO with hysteresis
- · Low cross-conduction currents

## **Applications**

- Current-mode, off-line, switched-mode power supplies
- · Current-mode, dc-to-dc converters.
- · Step-down "buck" regulators
- · Step-up "boost" regulators
- · Flyback, isolated regulators
- · Forward converters
- · Synchronous FET converters

## **Functional Diagram**



- () pins are on MICx8C/HC4x-1 (14-lead) versions only
- \* MICx8C/HC4x (8-lead) versions only
- † MICx8C/HC42, MICx8C/HC43 (96% max. duty cycle) versions only
- ‡ MICx8C/HC44, MICx8C/HC45 (50% max. duty cycle) versions only

# **Ordering Information**

Part Number	Temperature Range	Package
MIC18C42AJ	-55°C to +125°C	8-pin CerDIP
MIC18C43AJ	-55°C to +125°C	8-pin CerDIP
MIC18C44AJ	-55°C to +125°C	8-pin CerDIP
MIC18C45AJ	-55°C to +125°C	8-pin CerDIP
MIC18C42-1AJ	-55°C to +125°C	14-pin CerDIP
MIC18C43-1AJ	-55°C to +125°C	14-pin CerDIP
MIC18C44-1AJ	-55°C to +125°C	14-pin CerDIP
MIC18C45-1AJ	-55°C to +125°C	14-pin CerDIP
MIC38C42BN	-40°C to +85°C	8-pin Plastic DIP
MIC38C43BN	-40°C to +85°C	8-pin Plastic DIP
MIC38C44BN	-40°C to +85°C	8-pin Plastic DIP
MIC38C45BN	-40°C to +85°C	8-pin Plastic DIP
MIC38C42-1BN	-40°C to +85°C	14-pin Plastic DIP
MIC38C43-1BN	-40°C to +85°C	14-pin Plastic DIP
MIC38C44-1BN	-40°C to +85°C	14-pin Plastic DIP
MIC38C45-1BN	–40°C to +85°C	14-pin Plastic DIP
MIC38C42BM	-40°C to +85°C	8-pin SOIC
MIC38C43BM	-40°C to +85°C	8-pin SOIC
MIC38C44BM	-40°C to +85°C	8-pin SOIC
MIC38C45BM	-40°C to +85°C	8-pin SOIC
MIC38C42-1BM	-40°C to +85°C	14-pin SOIC
MIC38C43-1BM	-40°C to +85°C	14-pin SOIC
MIC38C44-1BM	-40°C to +85°C	14-pin SOIC
MIC38C45-1BM	-40°C to +85°C	14-pin SOIC

Part Number	Temperature Range	Package
MIC18HC42AJ	-55°C to +125°C	8-pin CerDIP
MIC18HC43AJ	-55°C to +125°C	8-pin CerDIP
MIC18HC44AJ	-55°C to +125°C	8-pin CerDIP
MIC18HC45AJ	-55°C to +125°C	8-pin CerDIP
MIC18HC42-1AJ	-55°C to +125°C	14-pin CerD1P
MIC18HC43-1AJ	-55°C to +125°C	14-pin CerDIP
MIC18HC44-1AJ	-55°C to +125°C	14-pin CerDIP
MIC18HC45-1AJ	-55°C to +125°C	14-pin CerDIP
MIC38HC42BN	-40°C to +85°C	8-pin Plastic DIP
MIC38HC43BN	-40°C to +85°C	8-pin Plastic DIP
MIC38HC44BN	-40°C to +85°C	8-pin Plastic DIP
MIC38HC45BN	-40°C to +85°C	8-pin Plastic DIP
MIC38HC42-1BN	-40°C to +85°C	14-pin Plastic DIP
MIC38HC43-1BN	-40°C to +85°C	14-pin Plastic DIP
MIC38HC44-1BN	-40°C to +85°C	14-pin Plastic DIP
MIC38HC45-1BN	–40°C to +85°C	14-pin Plastic DIP
MIC38HC42BM	-40°C to +85°C	8-pin SOIC
MIC38HC43BM	-40°C to +85°C	8-pin SOIC
MIC38HC44BM	–40°C to +85°C	8-pin SOIC
MIC38HC45BM	-40°C to +85°C	8-pin SOIC
MIC38HC42-1BM	-40°C to +85°C	14-pin SOIC
MIC38HC43-1BM	-40°C to +85°C	14-pin SOIC
MIC38HC44-1BM	-40°C to +85°C	14-pin SOIC
MIC38HC45-1BM	-40°C to +85°C	14-pin SOIC

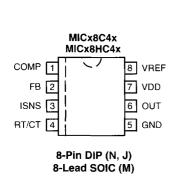
Refer to the Part Number Cross Reference for a listings of Micrel devices equivalent to UC284x and UC384x devices.

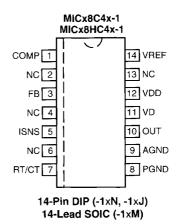
## **Selection Guide**

	UVLO Thresholds				
Duty Cycle	Startup 8.4V Minimum Operating 7.6V	Startup 14.5V Minimum Operating 9V			
0% to 96%	MIC18C43/HC43 MIC38C43/HC43	MIC18C42/HC42 MIC38C42/HC42			
0% to 50%	MIC18C45/HC45 MIC38C45/HC45	MIC18C44/HC44 MIC38C44/HC44			

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## **Pin Configuration**





## **Pin Description**

Pin Number N, J, M	Pin Number -1xN, -1xJ, -1xM	Pin Name	Pin Function		
1	1	СОМР	Compensation: Connect external compensation network to modify the error amplifier output.		
	2	NC	Not internally connected.		
2	3	FB	Feedback (Input): Error amplifier input. Feedback is 2.5V at desired output voltage.		
	4	NC	Not internally connected.		
3	5	ISNS	Current Sense (Input): Current sense comparator input. Connect to current sensing resistor or current transformer.		
	6	NC	Not internally connected.		
4	7	RT/CT	Timing Resistor/Timing Capacitor: Connect external RC network to select switching frequency.		
5		GND	Ground: Combined analog and power ground.		
	8	PGND	Power Ground: N-channel driver transistor ground.		
	9	AGND	Analog Ground: Controller circuitry ground.		
6	10	OUT	Power Output: Totem-pole output.		
	11	VD	Power Supply (Input): P-channel driver transistor supply input. Return to power ground (PGND).		
7	12	VDD	Analog Supply (Input): Controller circuitry supply input. Return to analog ground (AGND).		
	13	NC	Not internally connected.		
8	14	VREF	5V Reference (Output): Connect external RC network.		

# **Absolute Maximum Ratings**

Zener Current	30MA
Operation at ≥18V may re	
special precautions (see Application	ons Information).
VDD	20V
VD (x8C4x-1, x8HC4x-1)	20V
ISNS	0.3V to 5.5V
FB	0.3V to 5.5V
Output Current (x8C42/43/44/45)	0.5A

Output Current (x8HC42/43/44/45)	1A
Operating Junction Temperature	150°C
Package Thermal Resistance	
θ <sub>JA</sub> 8-Pin Plastic DIP	100°C/W
θ <sub>JA</sub> 8-Pin Ceramic DIP	125°C/W
θ <sub>JA</sub> 8-Pin SOIC	170°C/W
θ <sub>JA</sub> 14-Pin Plastic DIP	90°C/W
θ <sub>JA</sub> 14-Pin Ceramic DIP	110°C/W
θ <sub>JA</sub> 14-Pin SOIC	145°C/W
Storage Temperature6	

# **Electrical Characteristics** $V_{DD}$ = 15V (Note 4), $R_{T}$ = 10k $\Omega$ , $C_{T}$ = 3.3nF

 $-55 \le T_{A} \le 125 ^{\circ}\text{C for MIC18C42/43/44/45}, \ 18 \text{HC42/43/44/45}; \ -40 \le T_{A} \le 85 ^{\circ}\text{C for MIC38C42/43/44/45}, \ 38 \text{HC42/43/44/45}; \ -40 \le T_{A} \le 85 ^{\circ}\text{C for MIC38C42/43/44/45}, \ 38 \text{HC42/43/44/45}; \ -40 \le T_{A} \le 85 ^{\circ}\text{C for MIC38C42/43/44/45}, \ 38 \text{HC42/43/44/45}; \ -40 \le T_{A} \le 85 ^{\circ}\text{C for MIC38C42/43/44/45}, \ 38 \text{HC42/43/44/45}; \ -40 \le T_{A} \le 85 ^{\circ}\text{C for MIC38C42/43/$ 

MIC18C42/ MIC18HC42				MIC38C42/43/44/45 MIC38HC42/43/44/45			_	
Parameter	Test Conditions	Min	Тур	Max	Min	Тур	Max	Units
Reference Section		•						
Output Voltage	$T_A = 25^{\circ}C$ , $I_O = 1mA$	4.95	5.00	5.05	4.90	5.00	5.10	٧
Line Regulation	12V ≤ V <sub>DD</sub> ≤ 18V, I <sub>O</sub> = 5 μA (Note 6)		2	20		2	20	mV
Load Regulation	1 ≤ I <sub>O</sub> ≤ 20 mA		1	25		1	25	mV
Temp. Stability	(Note 1)		0.2			0.2		mV/°C
Total Output Variation	Line, Load, Temp. (Note 1)	4.9		5.1	4.82		5.18	٧
Output Noise Voltage	10Hz ≤ f ≤ 10kHz, T <sub>A</sub> = 25°C (Note 1)		50			50		μV
Long Term Stability	T <sub>A</sub> = 125 °C, 1000 Hrs. (Note 1)		5	25		5	25	mV
Output Short Circuit		-30	-80	-180	-30	-80	-180	mA
Oscillator Section								
Initial Accuracy	T <sub>A</sub> = 25°C (Note 5)	49	52	55	49	52	55	kHz
Voltage Stability	12 ≤ V <sub>DD</sub> ≤ 18V (Note 6)		0.2	1.0		0.2	1.0	%
Temp. Stability	$T_{MIN} \le T_A \le T_{MAX}$ (Note 1)		0.04			0.04		%/°C
Clock Ramp	T <sub>A</sub> = 25°C, V <sub>RT/CT</sub> = 2V	7.7	8.4	9.0	7.7	8.4	9.0	mA
Reset Current	$T_A = T_{MIN}$ to $T_{MAX}$	7.2	8.4	9.5	7.2	8.4	9.5	mA
Amplitude	V <sub>RT/CT</sub> peak to peak		1.9			1.9		Vp-p
Error Amp Section								
Input Voltage	V <sub>COMP</sub> = 2.5V	2.45	2.50	2.55	2.42	2.50	2.58	٧
Input Bias Current	V <sub>FEEDBACK</sub> = 5.0V		-0.1	-1		-0.1	-2	μΑ
A <sub>VOL</sub>	2 ≤ V <sub>O</sub> ≤ 4V	65	90		65	90		dB
Unity Gain Bandwidth	(Note 1)	0.7	1.0		0.7	1.0		MHz
PSRR	12 ≤ V <sub>DD</sub> ≤ 18V	60			60			dB
Output Sink Current	V <sub>FEEDBACK</sub> = 2.7V, V <sub>COMP</sub> = 1.1V	2	14		2	14		mA
Output Source Current	V <sub>FEEDBACK</sub> = 2.3V, V <sub>COMP</sub> = 5V	-0.5	-1		-0.5	-1		mA
V <sub>OUT</sub> High	V <sub>FEEDBACK</sub> = 2.3V, R <sub>L</sub> = 15k to ground	5	6.8		5	6.8		٧
V <sub>OUT</sub> Low	V <sub>FEEDBACK</sub> = 2.7V, R <sub>L</sub> = 15k to V <sub>REF</sub>		0.1	1.1		0.1	1.1	٧

		MIC18C42/43/44/45 MIC18HC42/43/44/45			MIC38C42/43/44/45 MIC38HC42/43/44/45			
Parameter	Test Conditions	Min	Тур	Max	Min	Тур	Max	Units
Current Sense				l		<b>.</b>		
Gain	(Notes 2 & 3)	2.85	3.0	3.15	2.85	3.0	3.15	V/V
MaximumThreshold	V <sub>COMP</sub> = 5V (Note 2)	0.9	1	1.1	0.9	1	1.1	٧
PSRR	12 ≤ V <sub>DD</sub> ≤ 18V (Note 2)		70			70		đВ
Input Bias Current			-0.1	-1		-0.1	-2	μΑ
Delay to Output			120	250	_	120	250	ns
Output		•	•					
R <sub>DS(ON)</sub> 'C' High R <sub>DS(ON)</sub> 'C' Low	I <sub>SOURCE</sub> = 200 mA I <sub>SINK</sub> = 200 mA		20 11			20 11		Ω Ω
R <sub>DS(ON)</sub> 'HC' High R <sub>DS(ON)</sub> 'HC' Low			10 5.5			10 5.5		Ω Ω
Rise Time: 'C' version	T <sub>A</sub> = 25°C, C <sub>L</sub> = 1 nF		40	80		40	80	ns
Fall Time: 'C' version	T <sub>A</sub> = 25°C, C <sub>L</sub> = 1 nF		30	60		30	60	ns
Rise Time: 'HC' version	T <sub>A</sub> = 25°C, C <sub>L</sub> = 1 nF		20	50		20	50	ns
Fall Time: 'HC' version	T <sub>A</sub> = 25°C, C <sub>L</sub> = 1 nF		15	40		15	40	ns
Undervoltage Lockout								
Start Threshold	38C42/4, 18C42/4, 38HC42/4, 18HC42/4	13.5	14.5	15.5	13.5	14.5	15.5	V
	38C43/5, 18C43/5, 38HC43/5, 18HC43/5	7.8	8.4	9.0	7.8	8.4	9.0	٧
Min. Operating Voltage	38C42/4, 18C42/4, 38C42/4, 18HC42/4	8	9	10	8	9	10	٧
	38C43/5, 38C43/5, 38HC43/5, 38HC43/5	7.0	7.6	8.2	7.0	7.6	8.2	٧
Pulse Width Modulator								
Maximum Duty Cycle	38C42/3, 18C42/3, 38HC42/3, 18HC42/3	94	96		94	96		%
	38C44/5, 18C44/5, 38HC44/5, 18HC44/5	46	50		46	50		%
Minimum Duty Cycle				0			0	%
Total Standby Current	-	•					•	
Start-Up Current	V <sub>DD</sub> = 13V for x8C42/44, x8HC42/44 V <sub>DD</sub> = 7.5V for x8C43/45, x8HC43/45		50	150		50	200	μА
Operating Supply Current	V <sub>FEEDBACK</sub> = V <sub>I SENSE</sub> = 0V		4.0	6.0		4.0	6.0	mA
Zener Voltage (V <sub>DD</sub> )	I <sub>DD</sub> = 25mA (Note 6)	30	37		30	37		V

Note 1: These parameters, although guaranteed, are not 100% tested in production.

**Note 2:** Parameter measured at trip point of latch with  $V_{EA} = 0$ .

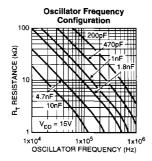
Note 3: Gain defined as:

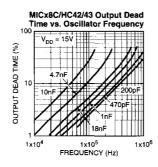
$$A = \frac{\Delta |V_{\text{PIN1}}|}{|V_{\text{TH}}(I_{\text{SENSE}})|} \; ; \; 0 \leq V_{\text{TH}}(I_{\text{SENSE}}) \leq 0.8V$$

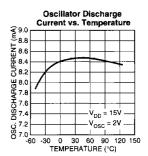
Note 4: Adjust  $V_{DD}$  above the start threshold before setting at 15V. Note 5: Output frequency equals oscillator frequency for the '8C42 and '8C43. Output frequency for the '8C44, and '8C45 equals one half the oscillator frequency.

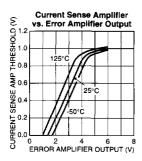
Note 6: On 8-pin version, 20V is maximum input on pin 7, as this is also the supply pin for the output stage. On 14-pin version, 40V is maximum for pin 12 and 20V maximum for pin 11.

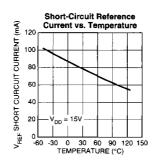
## **Typical Characteristics**

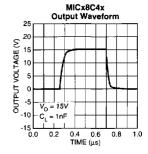












## **Application Information**

Familiarity with 384x converter designs is assumed.

The MICx8C4x and MICx8HC4x have been designed to be compatible with 384xA series controllers. Micrel's 'C' and 'HC' controllers are intended for existing and new designs.

### MIC38C4x and MIC38HC4x Advantages

#### Start-up Current

Start-up current has been reduced to an ultra-low  $50\mu A$  (typical) permitting higher-valued, lower-wattage, start-up resistors (powers controller during power supply start-up). The reduced resistor wattage reduces cost and printed circuit space.

### Operating Current

Operating current has been reduced to 4mA compared to 11mA for a typical bipolar controller. The controller runs cooler and the  $V_{DD}$  hold-up capacitance required during start-up may be reduced.

#### Output Driver

Complementary internal P- and N-channel MOSFETs produce rail-to-rail output voltages for better performance driving external power MOSFETs. The driver transistor's low onresistance and high peak current capability can drive gate capacitances of greater than 1000pF. The value of output capacitance which can be driven is determined only by the rise/fall time requirements. Within the restrictions of output capacity and controller power dissipation, switching frequencies can approach 1MHz.

#### **Design Precautions**

When operating near 20V, circuit transients can easily exceed the 20V absolute maximum rating, permanently damag-

ing the controller's CMOS construction. To reduce transients, use a  $0.1\mu F$  low-ESR capacitor to next to the controller's supply  $V_{DD}$  (or  $V_D$  for '-1' versions) and ground connections. Film type capacitors, such as Wima MKS2, are recommended.

When designing high-frequency converters, avoid capacitive and inductive coupling of the switching waveform into high-impedance circuitry such as the error amplifier, oscillator, and current sense amplifier. Avoid long printed-circuit traces and component leads. Locate oscillator and compensation circuitry near the IC. Use high frequency decoupling capacitors on  $V_{\rm REF}$ , and if necessary, on  $V_{\rm DD}$ . Return high di/dt currents directly to their source and use large area ground planes.

#### **Buck Converter**

Refer to figure 1. When at least 26V is applied to the input, C5 is charged through R2 until the voltage  $V_{\rm DD}$  is greater than 14.5V (the undervoltage lockout value of the MlC38C42). Output switching begins when Q1 is turned on by the gate drive transformer T1, charging the output filter capacitor C3 through L1. D5 supplies a regulated +12V to  $V_{\rm DD}$  once the circuit is running.

Current sense transformer CT1 provides current feedback to ISNS for current-mode operation and cycle-by-cycle current limiting. This is more efficient than a high-power sense resistor and provides the required ground-referenced level shift

When Q1 turns off, current flow continues from ground through D1 and L1 until Q1 is turned on again.

The 100V Schottky diode D1 reduces the forward voltage drop in the main current path, resulting in higher efficiency than could be accomplished using an ultra-fast-recovery diode. R1 and C2 suppress parasitic oscillations from D1.

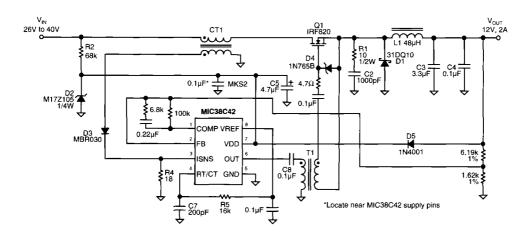


Figure 1. 500kHz, 25W, Buck Converter

Using a high-value inductance for L1 and a low-ESR capacitor for C3 permits small capacitance with minimum output ripple. This inductance value also improves circuit efficiency by reducing the flux swing in L1.

Test	Conditions	Results
Line Regulation	V <sub>IN</sub> = 26V to 80V, I <sub>O</sub> = 2A	0.5%
Load Regulation	V <sub>IN</sub> = 48V, I <sub>O</sub> = 0.2A to 2A	0.6%
Efficiency	V <sub>IN</sub> = 48V, I <sub>O</sub> = 2A	90%
Output Ripple	V <sub>IN</sub> = 48V, I <sub>O</sub> = 2A (20MHz BW)	100mV

Magnetic components are carefully chosen for minimal loss at 500kHz. CT1 and T1 are wound on Magnetics, Inc. P-type material toroids. L1 is wound on a Siemens N49 EFD core.

Symbol	Custom Coil <sup>1</sup>	ETS <sup>2</sup>
CT1	4923	ETS 92420
T1	4924	ETS 92419
L1	4925	ETS 92421

- 1. Custom Coils, Alcester, SD tel: (605) 934-2460
- 2. Energy Transformation Systems, Inc. tel: (415) 324-4949.

### Synchronous Buck Converter

Refer to figure 2. This MIC38C43 synchronous buck converter uses an MIC5022 half-bridge driver to alternately drive the PWM switch MOSFET (driven by GATEH, or high-side output) and a MOSFET which functions as a synchronous rectifier (driven by the GATEL, or low-side output).

The low-side MOSFET turns on when the high-side MOSFET is off, allowing current to return from ground. Current flows through the low-side MOSFET in the source to drain direction.

The on-state voltage drop of the low-side MOSFET is lower than the forward voltage drop of an equivalent Schottky rectifier. This lower voltage drop results in higher efficiency. A sense resistor  $(5m\Omega)$  is connected to the driver's high-side current sense inputs to provide overcurrent protection. Refer to the MIC5020, MIC5021, and MIC5022 data sheets for more information.

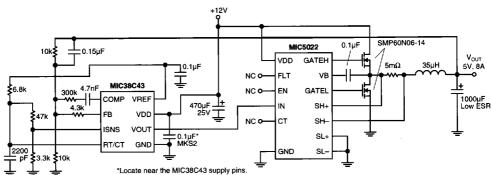


Figure 2. 100kHz, Synchronous Buck Converter