Impala Linear Corporation

ILC6377

0.5A, 300kHz, SO-8 PWM/PFM Step-Down DC-DC Converter With Shutdown

General Description

The ILC6377 is a 95% efficient, 300kHz step-down DC-DC converter in an SO-8 package; capable of delivering 500mA output current. The device is also capable of driving an external FET for higher output current applications.

The ILC6377 uses a unique p-channel architecture with built-in charge pump to maintain low on-resistance even at low input voltages. At high or normal currents, the ILC6377 operates in PWM mode with 300kHz operating frequency. Once the load current drops to where the device hits approximately 25% duty cycle, the device automatically switches over to PFM or pulse skipping mode. PFM (pulse frequency modulation) mode of operation extends efficiency at light loads.

Start-up is controlled via an external soft-start capacitor. The device will automatically re-enter start-up mode when an output current overload condition is sensed and will generate an error flag by temporarily taking the shutdown/soft-start pin low. Undervoltage lockout prevents faulty operation below the minimum operating voltage level. In shutdown, the ILC6377 consumes only 1.5µA current.

The ILC6377SO-XX offers fixed 3.3V or 5V ouput while ILC6377SO-Adj allows adjustable output. Both versions of ILC6377 are available in an SO-8 surface mount package.

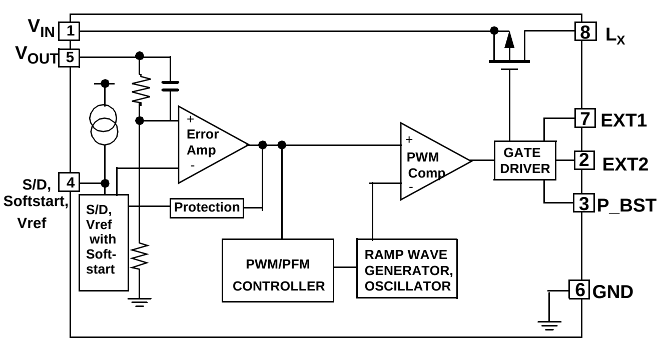
Features

- ±2.5% accurate output voltages
- Guaranteed 500mA output current
- 95% efficiency
- 20µA no load battery input current
- 1.5µA shutdown current
- Error flag for overcurrent condition
- Undervoltage lockout and softstart
- External transistor drive available for higher I_{out}
- 300kHz operation
- Automatic switchover to PFM mode at low currents for longest battery life
- Fixed 3.3V or 5V or adjustable output
- SO-8 package

Applications

- Cellular Phones
- Palmtops and PDAs
- Portable Instrumentation
- Buck Converter for Industrial / Networking Applications

Block Diagram

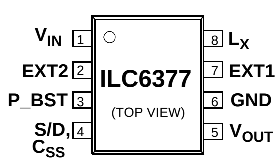


Ordering Information	
ILC6377SO-33	3.3V, 300kHz step-down PWM/PFM converter
ILC6377SO-50	5V, 300kHz step-down PWM/PFM converter
ILC6377SO-Adj	Adjustable, 300kHz step-down PWM/PFM converter

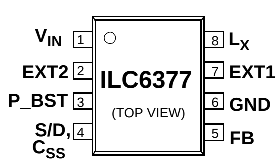
Pin Description

Pin	Symbol	Function
1	V_{IN}	Power supply input
2	EXT2	External gate drive pin (low when P-Ch FET is ON)
3	P-BST	P-Ch gate boost
4	S/D, Softstart, Vref	Shutdown, also soft-start capacitor pin and Vref output
5	V_{OUT} / FB	Output voltage sense pin for ILC6377SO-XX; 1V feedback pin for ILC6377SO-adj
6	GND	Ground connection
7	EXT1	External gate drive pin (low when P-Ch FET is ON)
8	L_X	Inductor switch pin

Pin-Package Configurations



ILC6377SO-XX
SO-8 Package



ILC6377SO-Adj
SO-8 Package

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Absolute Maximum Ratings (T_A=25°C)

Parameter	Symbol	Ratings	Units
V_{IN} input voltage pin	V_{IN}	-0.3 to +12	V
Vout pin (ILC6370SO-XX) FB pin (ILC6377SO - Adj)	V_{OUT} V_{FB}	-0.3 to +12 -0.3 to V_{IN} + 0.3	V
Voltage on L_x pin	V_{Lx}	V_{IN}-V_{LX} = -0.3 to +12	V
Peak switch current on L_x pin	I_{Lx}	700	mA
Voltage on P_BST pin	V_{P_BST}	V_{IN}-V_{P_BST}=-0.3 to +12	V
Current on EXT1, EXT2 pins	I_{EXT1}, I_{EXT2}	±50	mA
Voltage on all other pins	~	-0.3 to V_{IN} + 0.3	V
Continuous Total Power Dissipation	P_d	500	mW
Operating Ambient Temperature	T_{opr}	-30~+80	°C
Storage Temperature	T_{stg}	-40~+125	°C

Electrical Characteristics ILC6377SO-33

Unless otherwise specified all limits are at V_{OUT}=3.3V, Vin=4V, F_{OSC}=300kHz, Iout=130mA, T_A=25°C. Circuit configuration of Figure 1.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Output Voltage	V_{OUT}		3.218	3.300	3.383	V
Input Voltage	V_{IN}				10	V
Output Current	I_{OUT}		500	600		mA
Input Supply Current	I_{IN}	V_{IN} = 3.5V, No load V_{IN} = 4.5V, No load		55 20	86	µA
Shutdown Current	$I_{S/D}$	$V_{S/D}$ = 0V		1.5	2.5	µA
L_X Switch On -Resistance	$R_{ds(on)}$	Open loop measurement, $V_{S/D}$=V_{IN}, V_{LX}=V_{IN}-0.4V, Vout = 3V		0.64	0.85	Ω
L_X Switch Leakage Current	I_{LXL}	Open loop measurement, Vout = V_{IN}, V_{LX}=0V			2.0	µA
Oscillator Frequency	F_{OSC}	Measure waveform at EXT pin, V_{IN}=3.6V, Iout = 20mA	255	300	345	kHz
Max Duty Cycle	MAXDTY			100		%
PFM Duty Cycle	PFMDTY	No load	15	25	35	%
Efficiency	EFFI			95		%
Undervoltage Lockout	V_{UVLO}	Minimum Vin when Vref does not start up	0.9		1.8	V
Soft-start Time	Tss	Vref rises to 0V from 0.9V	6.0	10.0	16.0	msec

Electrical Characteristics ILC6377SO-33(Continued)

Unless otherwise specified all limits are at V_{OUT}=3.3V, Vin=4V, F_{OSC}=300kHz, Iout=130mA, T_A=25°C. Circuit configuration of Figure 1.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Internal Protection Time	Tpro	Time from Vout=0V to $V_{S/D}$ going low	3.0	5.0	8.0	msec
Shutdown Input Voltage	$V_{S/D}$	High = Regulator "ON" Low = Regulator "OFF"	0.65		0.2	V
EXT1, EXT2 HI On-Resistance	$Rext_{HI}$	Open loop measurement		35	47	Ω
EXT1, EXT2 Low On-Resistance	$Rext_{LOW}$	Open loop measurement		29	37	Ω

Electrical Characteristics ILC6377SO-50

Unless otherwise specified all limits are at V_{OUT}=5.0V, Vin=6V, F_{OSC}=300kHz, Iout=200mA, T_A=25°C. Circuit configuration of Figure 1.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Output Voltage	V_{OUT}		4.875	5.000	5.125	V
Input Voltage	V_{IN}				10	V
Output Current	I_{OUT}		500	600		mA
Input Supply Current	I_{IN}	V_{IN} = 5.25V, No load V_{IN} = 6V, No load		71 10	110	µA
Shutdown Current	$I_{S/D}$	$V_{S/D}$ = 0V		1.5	2.5	µA
L_X Switch On -Resistance	$R_{ds(on)}$	Open loop measurement, $V_{S/D}$=V_{IN}, V_{LX}=V_{IN}-0.4V, Vout = 4.5V		0.44	0.58	Ω
L_X Switch Leakage Current	I_{LXL}	Open loop measurement, Vout = V_{IN}, V_{LX}=0V			2.0	µA
Oscillator Frequency	F_{OSC}	Measure waveform at EXT pin, V_{IN}=5.3V, Iout = 20mA	255	300	345	kHz
Max Duty Cycle	MAXDTY			100		%
PFM Duty Cycle	PFMDTY	No load	15	25	35	%
Efficiency	EFFI			95		%
Undervoltage Lockout	V_{UVLO}	Minimum Vin when Vref does not start up	0.9		1.8	V
Soft-start Time	Tss	Vref rises to 0V from 0.9V	6.0	10.0	16.0	msec
Internal Protection Time	Tpro	Time from Vout=0V to $V_{S/D}$ going low	3.0	5.0	8.0	msec
Shutdown Input Voltage	$V_{S/D}$	High = Regulator "ON" Low = Regulator "OFF"	0.65		0.2	V
EXT1, EXT2 HI On-Resistance	$Rext_{HI}$	Open loop measurement		24	32	Ω
EXT1, EXT2 Low On-Resistance	$Rext_{LOW}$	Open loop measurement		20	26	Ω

Electrical Characteristics ILC6377SO-Adj

Unless otherwise specified all limits are at V_{OUT} programmed to 5V, Vin=6V, F_{OSC}=300kHz, Iout=200mA, T_A=25°C. Circuit configuration of Figure 4 (R_{FB1} = 400kΩ, R_{FB2} = 100kΩ, C_{FB} = 100pF).

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Feedback Voltage (pin 5)	V_{FB}		0.980	1.000	1.020	V
Output Voltage Range	$V_{out(min)}$ $V_{out(max)}$	$R_{FB1} + R_{FB2} \leq 2M\Omega$		1.5 8		V
Output Current	I_{OUT}		500	600		mA
Input Supply Current	I_{IN}	V_{IN} = 5.25V, No load V_{IN} = 6V, No load		71 10	110	µA
Shutdown Current	$I_{S/D}$	$V_{S/D}$ = 0V		1.5	2.5	µA
L_X Switch On -Resistance	$R_{ds(on)}$	Open loop measurement, $V_{S/D}=V_{IN}$, $V_{LX}=V_{IN}$-0.4V, Vout = 4.5V		0.44	0.58	Ω
L_X Switch Leakage Current	I_{LXL}	Open loop measurement, Vout = V_{IN}, V_{LX}=0V			2.0	µA
Oscillator Frequency	F_{OSC}	Measure waveform at EXT pin, V_{IN}=5.3V, Iout = 20mA	255	300	345	kHz
Max Duty Cycle	MAXDTY			100		%
PFM Duty Cycle	PFMDTY	No load	15	25	35	%
Efficiency	EFFI			95		%
Undervoltage Lockout	V_{UVLO}	Minimum Vin when Vref does not start up	0.9		1.8	V
Soft-start Time	Tss	Vref rises to 0V from 0.9V	6.0	10.0	16.0	msec
Internal Protection Time	Tpro	Time from Vout=0V to $V_{S/D}$ going low	3.0	5.0	8.0	msec
Shutdown Input Voltage	$V_{S/D}$	High = Regulator "ON" Low = Regulator "OFF"	0.65		 0.2	V
EXT1, EXT2 HI On-Resistance	$Rext_{HI}$	Open loop measurement		24	32	Ω
EXT1, EXT2 Low On-Resistance	$Rext_{LOW}$	Open loop measurement		20	26	Ω

Application Hints

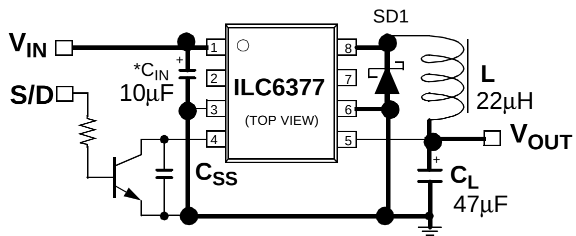


Fig 1. Typical step-down DC-DC converter application

L : 22µH (Sumida, CD54, 0.18Ω (max) DC resistance)
22µH (Coilcraft, DO3308P-223,0.19Ω (max) DCR)
SD1 : MA735 Schottky Diode (MATSUSHITA)
C_L : 10V/47µF Tantalum Capacitor (NICHICON, F93)
C_{SS} : 4700pF Ceramic Capacitor
C_{IN} : 16V / 10µF Tantalum Capacitor (NICHICON, F93)

Fig.1 shows a typical fixed output voltage step-down DC-DC converter application circuit for ILC6377SO-XX.

External component selection

Proper selection of external components is important for achieving high performance. The output inductor selected should have low DC resistance on the order of 0.2Ω or less and saturation current rating of 1A or higher. Recommended inductors are Sumida CD54 (22µH, 0.18Ω max DC resistance) or Coilcraft DO3308P-223 (22µH, 0.19Ω max DC resistance) or equivalent.

The catch diode should be a schottky diode with low forward drop and rated at 1A or greater current, MA735 or it's equivalent is recommended.

Input and output capacitors should be tantalum capacitors with voltage rating higher than the actual application. Moreover, the output tantalum capacitor should have an equivalent series resistance (ESR) rating greater than 100mΩ; too small an ESR can lead to instability and therefore oscillation.

Soft-start

Pin 4 of ILC6377 functions as the softstart pin as well as the shutdown pin. A softstart capacitor (from pin 4 to ground) controls the rate at which the power supply starts up thus preventing large overshoots at the ouput as well as large in-rush current. The value for C_{SS} should be 100pF or greater.

Shutdown

The ILC6377 is placed in shutdown mode by taking pin 4 to ground. In shutdown, the quiescent current of the device is under 2µA. **When using the shutdown feature, pin 4 must be driven from an open collector or open drain output without employing an external pull-up resistor, as shown in Fig.1. Since pin 4 is also used to charge an external capacitor for softstart, this pin should not be driven from a push-pull CMOS type output.**

Over-current error flag

In the event of an over-current condition, the ILC6377 cycles the softstart pin in a hiccup mode. When the output voltage decreases due to overload, the ILC6377 will operate continuously at the maximum duty cycle. If the period of maximum duty cycle operation exceeds T_{PRO} (typically 5 msec), pin 4 will be pulled low thus discharging the external softstart capacitor C_{SS}. This action inhibits the regulator's PWM action. Next, the ILC6377's softstart circuitry starts recharging C_{SS} and initiates a controlled start-up. If the overload condition continues to exist then the above sequence of events will repeat thus continuing to cycle the softstart function. A low voltage at pin 4 may be used as a system error flag to not only notify an over-current condition but to also initiate a controlled shutdown by forcing pin 4 low. **Note that the ILC6377 is not protected from short circuit to ground. Exceeding the 700mA peak switch current on the L_x pin or exceeding the maximum package power dissipation limit may cause damage to the ILC6377.**

Keep in mind that the duration of maximum duty cycle condition is used to trigger the ILC6377's fault protection circuit. As such, a small input-output (V_{IN} - V_{OUT}) differential voltage may trigger the device's fault protection circuitry even at low output current.

Undervoltage Lockout

The undervoltage lockout feature prevents faulty operation by disabling the operation of the regulator when input voltage is below the minimum operating voltage, V_{UVLO}. When the input voltage is lower than V_{UVLO}, the device disables the internal P-channel MOSFET and provides "high" output at both EXT1 and EXT2 outputs.

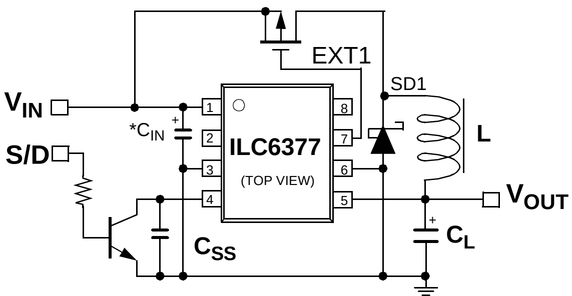


Fig.2 1Amp output current application using external MOSFET

EXT1 and EXT2 pins

The EXT1 and EXT2 pins are provided so as to drive external transistors thus allowing design flexibility. The EXT output drive signal has same timing as the gate drive to the internal P-channel MOSFET i.e EXT output is low as long as the internal P-Ch MOSFET is on. Although both EXT1 and EXT2 are in phase, there is approximately 100ns dead time built in. A high to low transition at EXT2 pin causes EXT1 pin to go low after approximately 100ns delay; furthermore, after the EXT1 pin goes from low to high, there is approximately 100ns delay before EXT2 pin goes from low to high. Both EXT1 and EXT2 pins are capable of driving 1000pF gate capacitance. For example, a high output current application circuit using an external P-channel MOSFET is shown in Fig.2

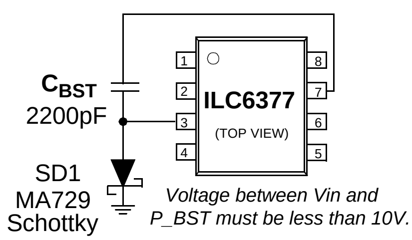


Figure 3. P-Channel Negative Boost Circuit

P-Channel Boost Circuit

The ILC6377 includes a unique P-Channel MOSFET architecture with built-in charge pump to maintain low on resistance even at low input voltages. As shown in Fig.3, a 2200pF ceramic capacitor and a schottky diode (MA729 or equivalent) allows the gate voltage of the internal P-Channel MOSFET to be driven negative thus reducing the switch on-resistance. This technique can be employed to increase efficiency at low input voltages and high output currents.

Note that the voltage between V_{IN} and P_BST should not exceed 10V, otherwise damage to the device may occur. Use of P-Channel boost circuit should be limited to input voltage of 6V or less. The voltage at pin 3 (P_BST) is approximately -1/2V_{IN}.

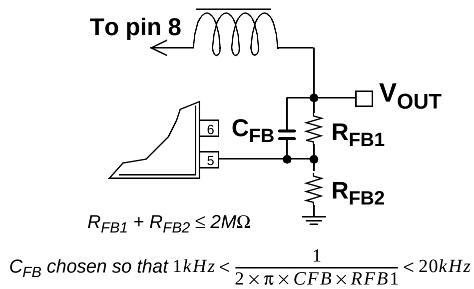


Fig.4 Adjustable output using ILC6377SO-Adj

(Note : rest of circuit is same as Fig.1)

Adjustable Output (ILC6377SO-Adj)

For adjustable output voltage, ILC6377SO-Adj should be used. All connections to the ILC6377SO-Adj are the same as ILC6377SO-XX, except for the feedback voltage divider network shown in Fig.4. The output voltage, Vout, can be calculated from the following equation :

$V_{out} = V_{FB} (1 + R_{FB1}/R_{FB2})$,

where V_{FB} is approximately 1V and

$R_{FB1} + R_{FB2} \le 2M\Omega$

The feedback compensation capacitor should be chosen such that the pole frequency, f, is between 1kHz and 20kHz :

$$1kHz < \frac{1}{2 \times \pi \times CFB \times RFB1} < 20kHz$$

The pole frequency should generally be set at 5kHz. The value of C_{FB} calculated from above equation may require some adjustment depending on the output inductor (L) and output capacitor (CL) values chosen.

As an example, for 3V output :

R_{FB1} = 400kΩ,

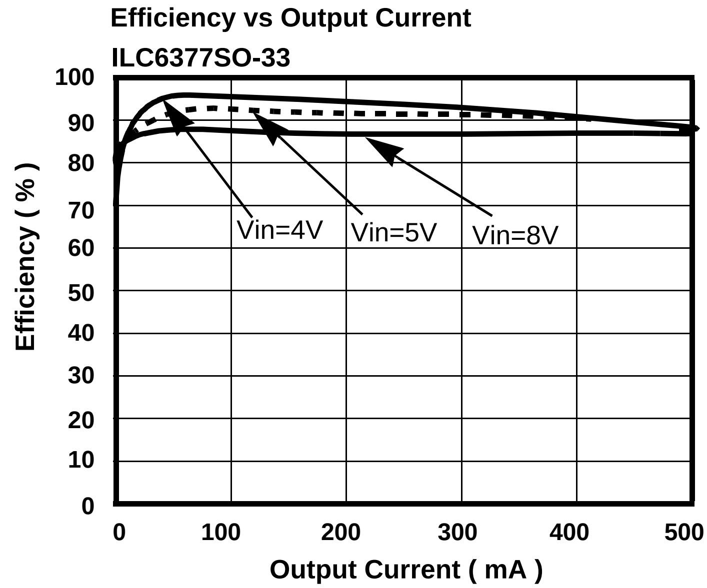
R_{FB2} = 200kΩ

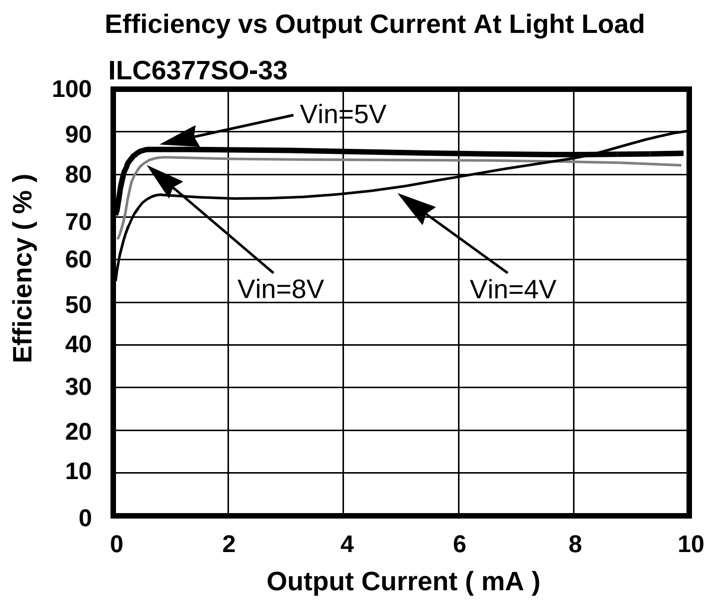
C_{FB} = 100pF

PC Board Layout

As with all switching DC-DC converter designs, good PC board layout is critical for optimum performance. **The heavy lines indicated in Fig.1 schematic should be wide printed circuit board traces and should be kept as short as is practical.** A large ground plane with as much copper area as is allowable should be used. All external components should be mounted as close to the IC as possible. For ILC6377SO-Adj, the feedback resistors and their associated wiring should be kept away from the inductor location and the vicinity of inductive flux.

Typical Performance Characteristics General conditions for all curves : Circuit of Fig.1; L = 22µH(Sumida, CD54), C_{IN} = 47µF (tantalum) with 0.1µF (ceramic), C_L = 47µH (tantalum), MA735(Matsushita) schottky diode, C_{SS} = 4700pF (ceramic), T_A = 25°C unless otherwise noted.





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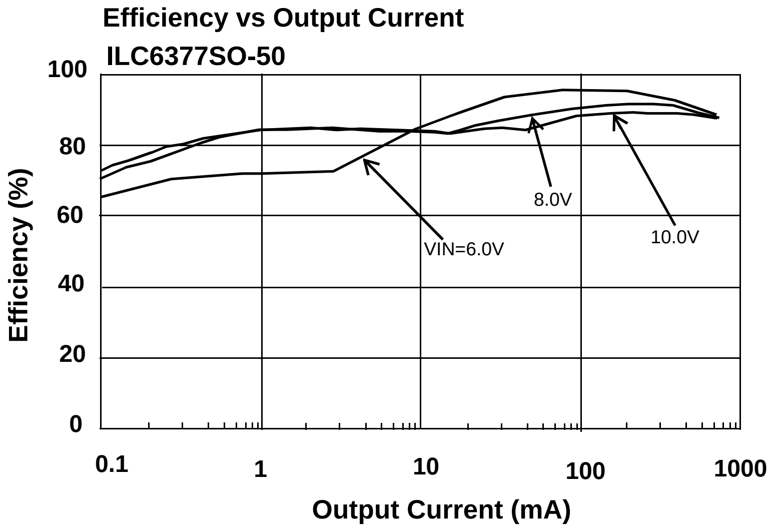

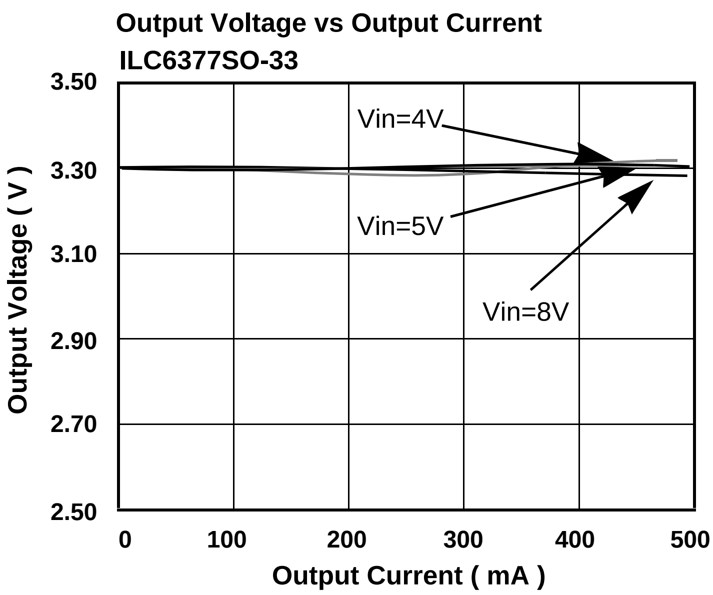

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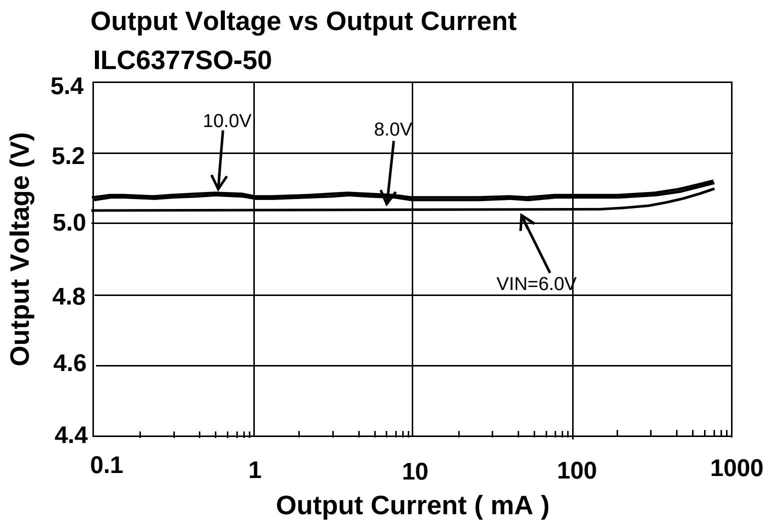

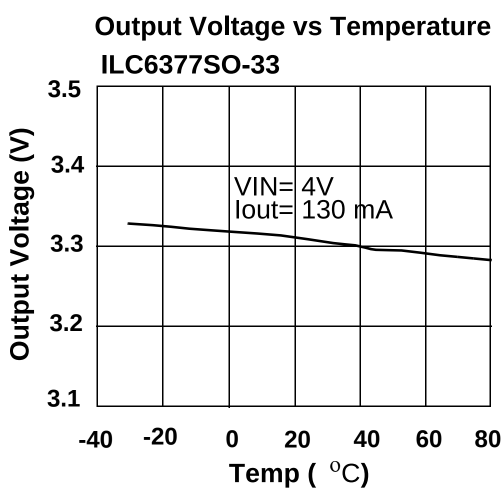

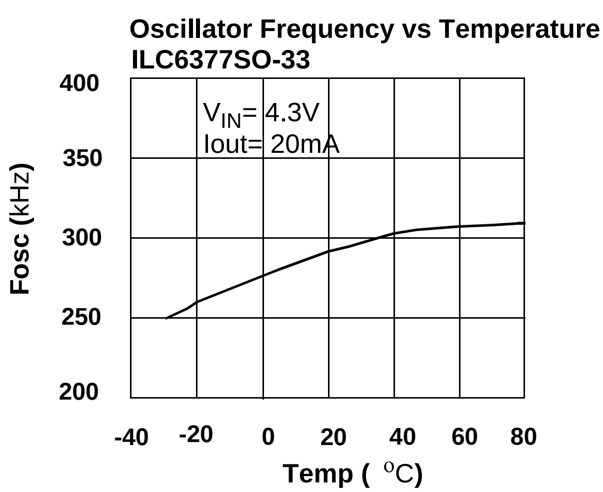

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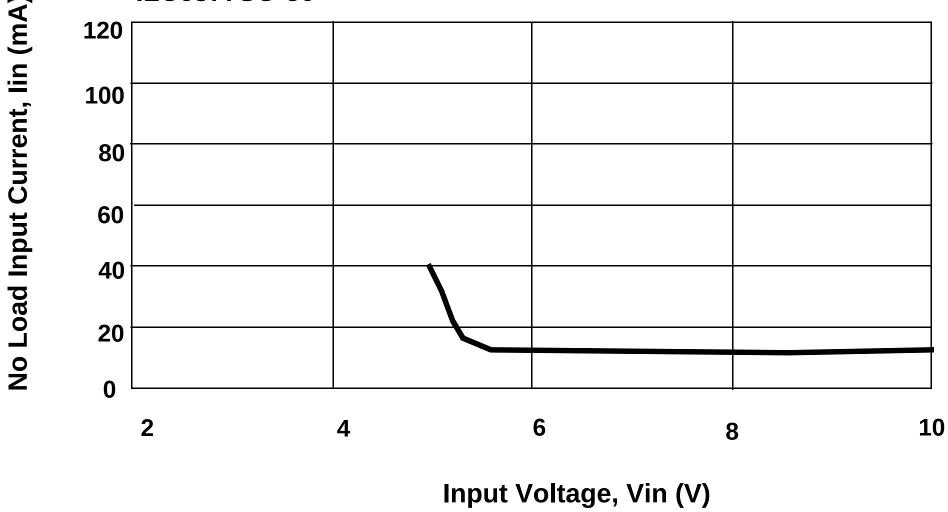
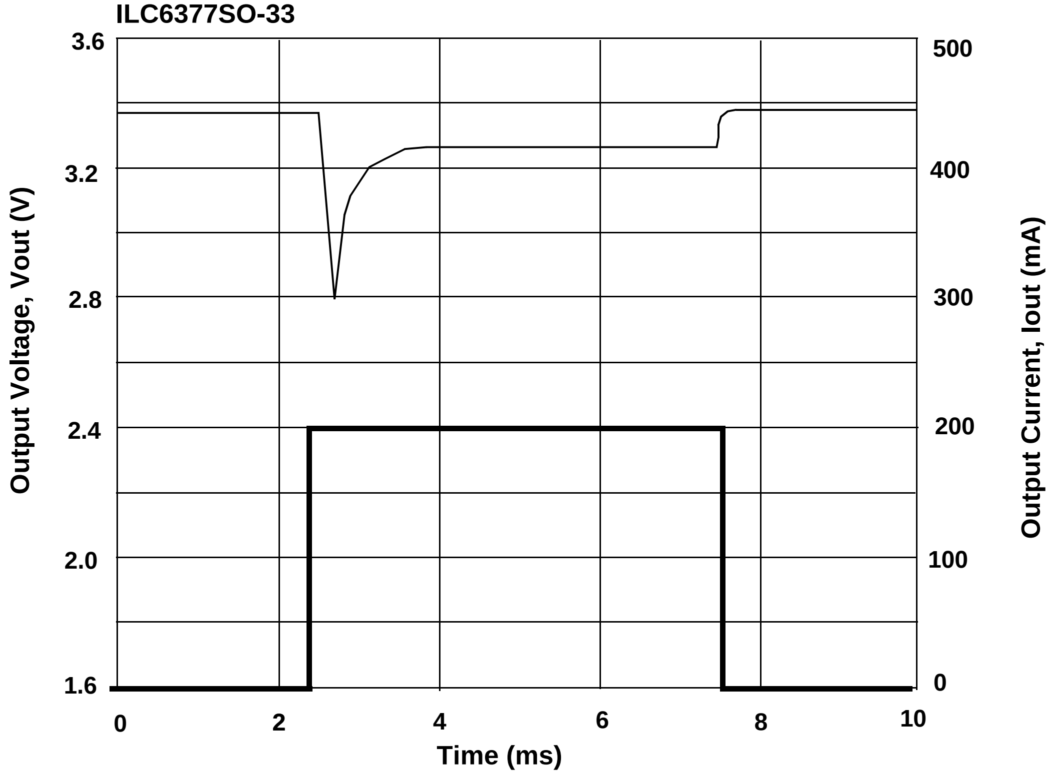
No Load Input Current vs Input Voltage

ILC6377SO-50



Dynamic Load Response (V_{IN}=5V)

ILC6377SO-33



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