ICL7663
CMOS Programmable Micropower Voltage Regulators

INTERSIL

GENERAL DESCRIPTION

The ICL7663 positive voltage regulator is a low-power, high-efficiency device which accepts inputs from 1.6V to 16V and provides adjustable outputs over the same range at currents up to 40mA. Operating current is typically less than 4μA, regardless of load.

Output current sensing and remote shutdown are available, providing protection for the regulator and the circuits it powers. A unique feature is a negative temperature coefficient output. This can be used, for example, to efficiently tailor the voltage applied to a multiplexed LCD through the driver e.g., ICM7231/2/3 so as to extend the display operating temperature range many times.

An enhanced direct replacement for this part called ICL7663S is now available and is more appropriate for new designs.

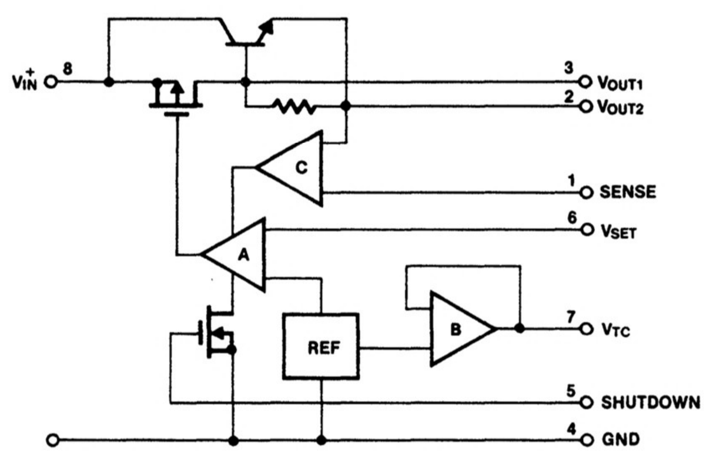
The ICL7663 is available in 8-pin plastic, TO-99 can, CERDIP, and SOIC packages.

FEATURES

- **Ideal for Battery-Operated Systems: Less Than 4μA Typical Current Drain**
- **Will Handle Input Voltages From 1.6V to 16V**
- **Very Low Input-Output Differential Voltage**
- **1.3V Bandgap Voltage Reference**
- **Up to 40mA Output Current**
- **Output Shutdown Via Current-Limit Sensing or External Logic Signal**
- **Output Voltages Programmable From 1.3V to 16V**
- **Output Voltages With Programmable Negative Temperature Coefficients**

ORDERING INFORMATION

Positive Regulator		
Part Number	**Temperature Range**	**Package**
ICL7663CBA	0°C to +70°C	8-Lead SOIC
ICL7663CPA	0°C to +70°C	8-Lead MiniDIP
ICL7663CJA	0°C to +70°C	8-Lead CERDIP
ICL7663CTV	0°C to +70°C	8-Lead TO-99



ICL7663
Figure 1: Functional Diagram

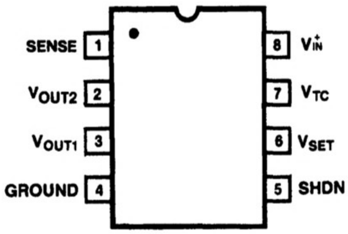
NOTE: All typical values have been characterized but are not tested.

ABSOLUTE MAXIMUM RATINGS, ICL7663 POSITIVE REGULATOR

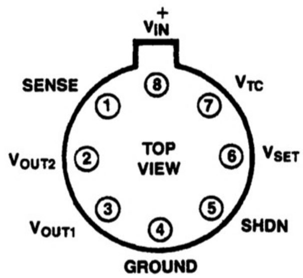
Input Supply Voltage .... +18V
Any Input or Output Voltage (Note 1) (Terminals 1, 2, 3, 5, 6, 7) .... (GND −0.3V) to (V^+_{IN} +0.3V)
Output Source Current
(Terminal 2) 50mA
(Terminal 3) 25mA
Output Sinking Current (Terminal 7) .... −10mA
Power Dissipation (Note 2)
MiniDIP 200mW
TO-99 Can 300mW
Operating Temperature Range .... 0°C to +70°C
Storage Temperature .... −65°C to +150°C
Lead Temperature (Soldering, 10sec) .... 300°C

NOTE: *Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

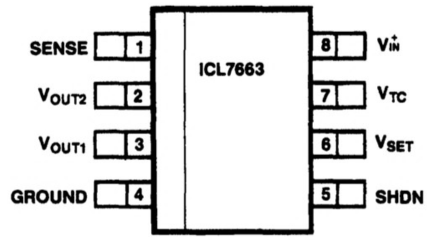
ICL7663 Positive Regulator



(outline dwg PA, JA)



(outline dwg TV)



(outline dwg BA)

Figure 2: Pin Configurations

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NOTE: All typical values have been characterized but are not tested.

ICL7663 ELECTRICAL CHARACTERISTICS

$V_{IN}^+ = 9V$, $V_{OUT} = 5V$, $T_A = +25°C$, unless otherwise specified. See Test Circuit Figure 3.

Symbol	Parameter	Test Conditions	Limits			Units
			Min	Typ	Max	
V_{IN}	Input Voltage	$T_A = +25°C$ $0°C \le T_A \le +70°C$	1.5 1.6		16.0 16.0	V
I_Q	Quiescent Current	$\left\{ \begin{array}{l} R_L = \infty \\ 1.4V \le V_{OUT} \le 8.5V \end{array} \right\}$ $V_{IN} = 16V$ $V_{IN} = 9V$		4.0 3.5	12 10	μA
V_{SET}	Reference Voltage		1.2	1.3	1.4	V
$\frac{\Delta V_{SET}}{\Delta T}$	Temperature Coefficient	$8.5V < V_{IN} < 9V$		±200		ppm
$\frac{\Delta V_{SET}}{V_{SET} \Delta V_{IN}}$	Line Regulation	$2V < V_{IN} < 9V$		0.03		%/V
I_{SET}	V_{SET} Input Current			±0.01	10	nA
I_{SHDN}	Shutdown Input Current			±0.01	10	nA
V_{SHDN}	Shutdown Input Voltage	V_{SHDN}HI: Both V_{OUT} Disabled V_{SHDN}LO: Both V_{OUT} Enabled	1.4		 0.3	V
I_{SENSE}	Sense Pin Input Current			0.01	10	nA
V_{CL}	Sense Pin Input Threshold Voltage	$V_{CL} = V_{OUT2} - V_{SENSE}$ (Current-Limit Threshold)		0.7		V
R_{SAT}	Input-Output On-Resistance (Note 3)	$V_{IN} = 2V$ $V_{IN} = 9V$ $V_{IN} = 15V$		200 70 50		Ω
$\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$	Load Regulation	$\Delta I_{OUT1} = 100\mu A$ @ $V_{OUT1} = 5V$ $\Delta I_{OUT2} = 10mA$ @ $V_{OUT2} = 5V$		2.0 1.0		Ω
I_{OUT2}	Available Output Current (V_{OUT2})	$V_{IN} = 3V$ $V_{OUT} = V_{SET}$ $V_{IN} = 9V$ $V_{OUT} = 5V$ $V_{IN} = 15V$ $V_{OUT} = 5V$	10 25 40			mA
V_{TC}	Negative-Tempco Output (Note 4)	Open-Circuit Voltage		0.9		V
I_{TC}		Maximum Sink Current	0	8	2.0	mA
$\frac{\Delta V_{TC}}{\Delta T}$	Temperature Coefficient of V_{TC} Output	Open Circuit		+2.5		mV/°C
$I_{L(min)}$	Minimum Load Current	(Includes V_{SET} Divider)	1.0			μA

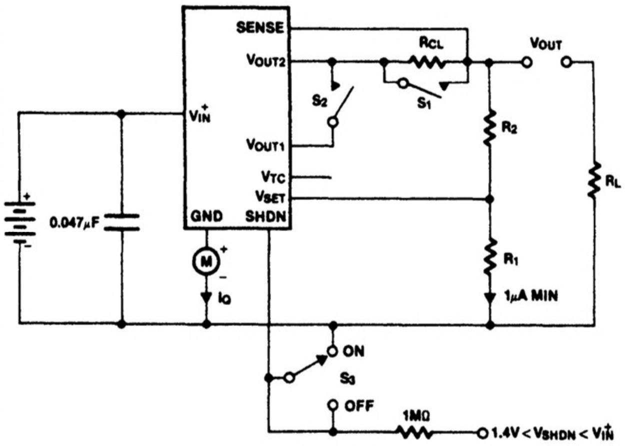
NOTES: 1. Connecting any terminal to voltages greater then (V_{IN}^+ +0.3V) or less than (GND−0.3V) may cause destructive device latchup. It is recommended that no inputs from sources operating on external power supplies be applied prior to ICL7663 power-up.

2. Derate linearly above 50°C at 5mW/°C for minidip and 7.5mW/°C for TO-99 can.

3. This parameter refers to the on-resistance of the MOS pass transistor. The minimum input-output voltage differential at low current (under 5mA), can be determined by multiplying the load current (including set resistor current, but not quiescent current) by this resistance.

4. This output has a positive temperature coefficient. Using it in combination with the inverting input of the regulator at V_{SET}, a negative coefficient results in the output voltage. See Figure 4 for details. Pin will not source current.

NOTE: All typical values have been characterized but are not tested.



NOTES 1: S_1 when closed, disables output current limiting.

2:

S_2 Closed	S_2 Open
V_{OUT1}	V_{OUT2}

3: $V_{OUT} = \frac{R_2 + R_1}{R_1} V_{SET}$

4: I_Q quiescent current is measured at GND pin by meter M.

5: S_3 when ON, permits normal operation, when OFF, shuts down both V_{OUT1} and V_{OUT2}.

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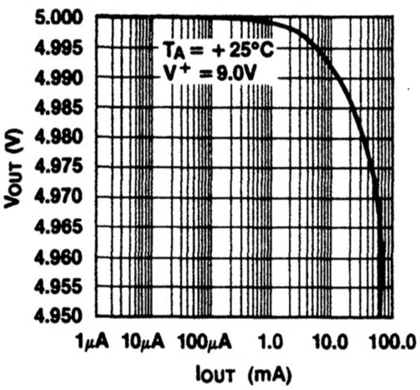
Figure 3: Test Circuit for ICL7663

TYPICAL PERFORMANCE CHARACTERISTICS

OUTPUT VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



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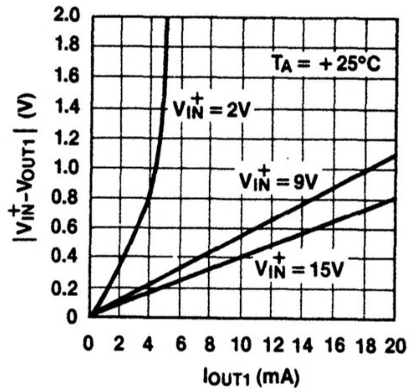
V_{OUT1} INPUT-OUTPUT DIFFERENTIAL VS OUTPUT CURRENT



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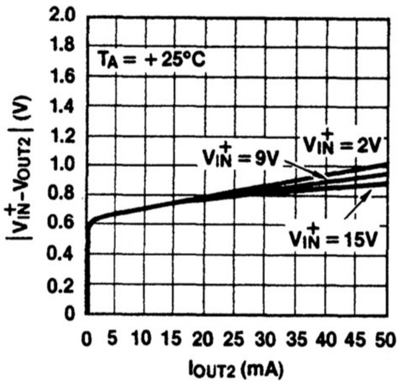
V_{OUT2} INPUT-OUTPUT DIFFERENTIAL VS OUTPUT CURRENT



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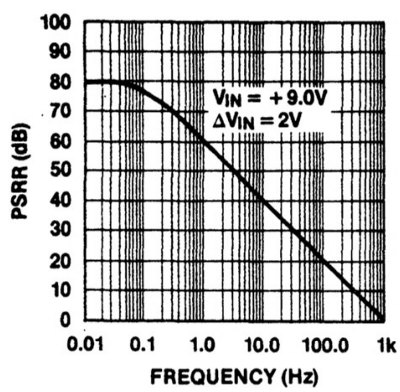
INPUT POWER SUPPLY REJECTION RATIO



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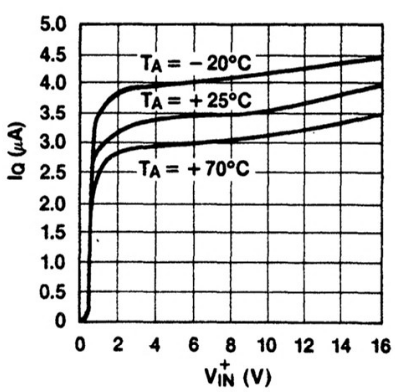
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



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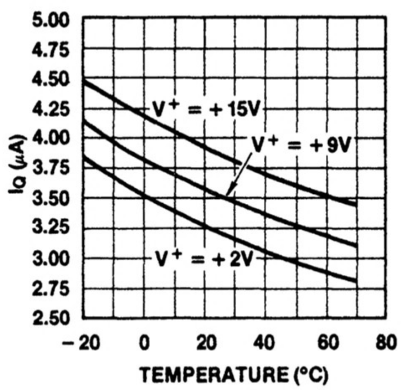
QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE



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NOTE: All typical values have been characterized but are not tested.

DETAILED DESCRIPTION

The ICL7663 is a CMOS integrated circuit which contains all the functions of a voltage regulator plus protection circuitry on a single monolithic chip. Referring to the functional diagram (Figure 1), it can be seen that it contains a bandgap-type voltage reference of 1.3 Volts. This voltage, therefore, is the lowest output voltage the regulator can control. Error amplifier A drives a P-channel pass transistor which is sufficient for low (under about 5mA) currents. The high current output is passed by an NPN bipolar transistor connected as a follower. This configuration gives more gain and lower output impedance.

Logic-controlled shutdown is implemented via an MOS transistor of the appropriate polarity. Current-sensing is achieved with comparator C, which functions with the V_{OUT2} line. Finally, the positive regulator has an output (V_{TC}) from a buffer amplifier (B), which can be used to generate programmable-temperature-coefficient output voltages.

The amplifiers, reference and comparator circuitry all operate at bias levels well below 1μA to achieve the extremely low quiescent current. This does limit the dynamic response of the circuit, however, and transients are best dealt with outside the regulator loop.

BASIC OPERATION

The ICL7663 is designed to regulate battery voltages in the 5V to 15V region at maximum load currents of about 5mA to 30mA. Although intended as a low power device, power dissipation limits must be observed. For example, the power dissipation in the case of a 10V supply regulated down to 2V with a load current of 30mA clearly exceeds the power dissipation rating of the minidip: $(10-2)(30)(10^{-3}) = 240$mW. The test circuit illustrates proper use of the device.

CMOS devices generally require two precautions: every input pin must go somewhere, and maximum values of applied voltages and current limits must be rigorously observed. Neglecting these precautions may lead to, at the least, incorrect or non-operation, and at worst, destructive device failure. To avoid the problem of latchup, do not apply inputs to any pins before supply voltage is applied.

NOTE: All typical values have been characterized but are not tested.

Input Voltages — The regulator accepts working inputs of 1.4V to 18V. When power is applied, the rate-of-rise of the input may be hundreds of volts per microsecond. This is potentially harmful to the regulator, where internal operating currents are in the nanoampere range. The 0.047μF capacitor on the device side of the switch will limit inputs to a safe level around 2V/μs. Use of this capacitor is suggested in all applications. In severe rate-of-rise cases, it may be advisable to use an RC network on the SHutDowN pin to delay output turn-on. Battery charging surges, transients, and assorted noise signals should be kept from the regulator by RC filtering, zener protection, or even fusing.

Output Voltages — The resistor divider R_2/R_1 is used to scale the reference voltage, V_{SET}, to the desired output using the formula $V_{OUT} = (1 + R_2/R_1)\ V_{SET}$. Suitable arrangements of these resistors, using a potentiometer, enables exact values for V_{OUT} to be obtained. Because of the low leakage current of the V_{SET} terminal, these resistors can be tens of megohms for minimum additional quiescent drain current. However, *some* load current is required for proper operation, so for extremely low-drain applications it is necessary to draw at least 1μA. This can include the current for R_2 and R_1.

Output voltages up to nearly the V_{IN} supply may be obtained at low load currents, while the low limit is the reference voltage. The minimum input-output differential in each regulator is obtained using the V_{OUT1} terminal.

Output Currents — For the ICL7663, low output currents of less than 5mA are obtained with the least input-output differential from the V_{OUT1} terminal (connect V_{OUT2} to V_{OUT1}). Where higher currents are needed, use V_{OUT2} (V_{OUT1} should be left open in this case).

High output currents can be obtained only as far as package dissipation allows. It is strongly recommended that output current-limit sensing be used in such cases.

Current-Limit Sensing — The on-chip comparator (C in the block diagrams) permits shutdown of the regulator output in the event of excessive current drain. As the test circuit shows, a current-limiting resistor, R_{CL}, is placed in series with V_{OUT2}, and the SENSE terminal is connected to the load side of R_{CL}. When the current through R_{CL} is high enough to produce a voltage drop equal to V_{CL} (0.7V) the voltage feedback is bypassed and the regulator output will be limited to this current. Therefore, when the maximum load current (I_{LOAD}) is determined, simply divide V_{CL} by I_{LOAD} to obtain the value for R_{CL}.

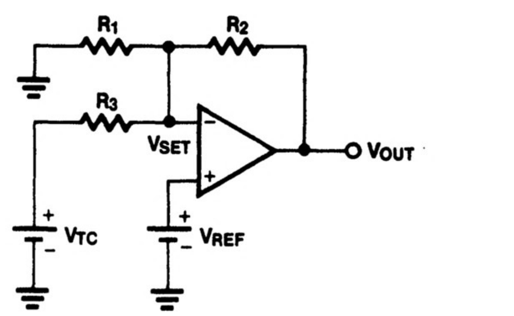
Logic-Controllable Shutdown — When equipment is not needed continuously (e.g., in remote data-acquisition systems), it is desirable to eliminate its drain on the system until it *is* required. This usually means switches, with their unreliable contacts. Instead, the ICL7663 can be shut down by a logic signal, leaving only I_Q (under 4μA) as a drain on the power source. Since this pin must not be left open, it should be tied to ground if not needed. A voltage of less than 0.3V will keep the regulator ON, and a voltage level of more than 1.4V but less than V_{IN}^{+} will turn the outputs OFF. If there is a possibility that the control signal could exceed the regulator input (V_{IN}^{+}), the current from this signal should be limited to 100μA maximum by a high-value (1MΩ) series resistor. This situation may occur when the logic signal originates from a system powered separately from that of the regulator.

Additional Circuit Precautions — The regulator has poor rejection of voltage fluctuations from AC sources above 10Hz or so. To prevent the output from responding (where this might be a problem), a reservoir capacitor across the load is advised. The value of this capacitor is chosen so that the regulated output voltage reaches 90% of its final value in 20ms. From

$$I = C\frac{\Delta V}{\Delta t},\ C = I_{OUT}\frac{(20 \times 10^{-3})}{0.9V_{OUT}} = 0.022\frac{I_{OUT}}{V_{OUT}}.$$

In addition, where such a capacitor is used, a current-limiting resistor is also suggested (see **"Current-Limit Sensing"**).

Producing Output Voltages With Negative Temperature Coefficients — The ICL7663 has an additional output which is 0.9V relative to GND and has a tempco of +2.5mV/°C. By applying this voltage to the inverting input of amplifier A (i.e., the V_{SET} pin), output voltages having negative TC may be produced. The TC of the output voltage is controlled by the R_2/R_3 ratio (see Figure 4 and its design equations).



$$\text{EQ.1: } V_{OUT} = V_{SET}(1 + \frac{R_2}{R_1}) + \frac{R_2}{R_3}(V_{SET} - V_{TC})$$

$$\text{EQ.2: TC } V_{OUT} = -\frac{R_2}{R_3}(TCV_{TC}) \text{ in mV/°C}$$

WHERE: $V_{SET} = 1.3V$

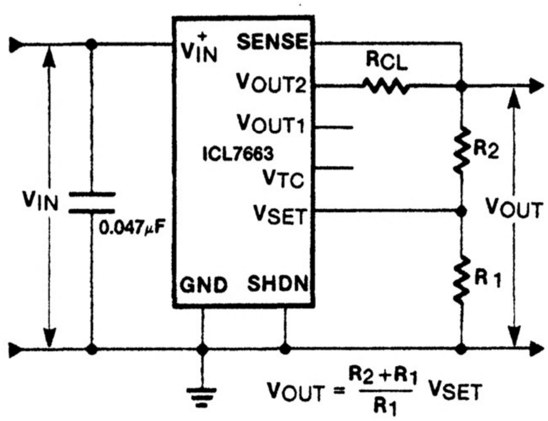
$V_{TC} = 0.9V$

$TCV_{TC} = +2.5mV/°C$

Figure 4: Generating Negative Temperature Coefficients

NOTE: All typical values have been characterized but are not tested.

APPLICATIONS



$$V_{OUT} = \frac{R_2 + R_1}{R_1} V_{SET}$$

$$I_{CL} = \frac{0.7V}{R_{CL}}$$

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Figure 5: Basic Application of ICL7663 as Positive Regulator with Current Limit

NOTE: All typical values have been characterized but are not tested.

ICL7663B ADDENDUM TO THE ICL7663 DATASHEET

This Addendum to the standard ICL7663 datasheet describes changes and/or modifications to the DC Operating characteristics applicable to the ICL7663B devices. The following table indicates those limits to which the ICL7663B is tested and/or guaranteed operational.

ICL7663B POSITIVE REGULATOR ORDERING INFORMATION

Positive Regulator		
ICL7663BCBA	0°C to 70°C	8-pin S.O.I.C.
ICL7663BCJA	0°C to 70°C	8-pin CERDIP
ICL7663BCPA	0°C to 70°C	8-pin MiniDIP
ICL7663BCTV	0°C to 70°C	TO-99

ABSOLUTE MAXIMUM RATINGS ICL7663B

Input Supply Voltage .... +12V
Any Input or Output Voltage (Note 1) Terminals 1, 2, 3, 4, 5, 6, 7) .... (GND −0.3V) to (V^+_{IN} +0.3V)
Output Source Current
(Terminal 2) 50mA
(Terminal 3) 25mA
Output Sinking Current (Terminal 7) .... −10mA
Power Dissipation (Note 2)
MiniDIP 200mW
TO-99 Can 300mW

NOTE: *Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

ICL7663B OPERATING CHARACTERISTICS

$V^+_{IN} = 9V$, $V_{OUT} = 5V$, $T_A = +25°C$, unless otherwise specified.

Symbol	Parameter	Test Conditions	Limits			Units
			Min	Typ	Max	
V^+_{IN}	Input Voltage	$T_A = +25°C$ $20°C \le T_A \le +70°C$	1.5 1.6		10 10	V
I_Q	Quiescent Current	$\left\{ \begin{matrix} R_L = \infty \\ 1.4V \le V_{OUT} \le 8.5V \end{matrix} \right\}$		3.5	10	μA
V_{SET}	Reference Voltage		1.2	1.3	1.4	V
$\frac{\Delta V_{SET}}{\Delta T}$	Temperature Coefficient	$8.5V < V^+_{IN} < 9V$		±200		ppm
$\frac{\Delta V_{SET}}{V_{SET} \Delta V_{IN}}$	Line Regulation	$2V < V^+_{IN} < 9V$		0.03		%/V
I_{SET}	V_{SET} Input Current			±0.01	10	nA
I_{SHDN}	Shutdown Input Current			±0.01	10	nA
V_{SHDN}	Shutdown Input Voltage	V_{SHDN}HI: Both V_{OUT} Disabled V_{SHDN}LO: Both V_{OUT} Enabled	1.4		 0.3	V
I_{SENSE}	Sense Pin Input Current			0.01	10	nA
V_{CL}	Sense Pin Input Threshold Voltage	$V_{CL} = V_{OUT2} - V_{SENSE}$ (Current-Limit Threshold)		0.7		V
R_{SAT}	Input-Output Saturation Resistance (Note 3)	$V^+_{IN} = 2V$ $V^+_{IN} = 9V$		200 70		Ω
$\frac{\Delta V_{OUT}}{\Delta I_{OUT}}$	Load Regulation	$\Delta I_{OUT1} = 100\mu A$ @ $V_{OUT1} = 5V$ $\Delta I_{OUT2} = 10mA$ @ $V_{OUT2} = 5V$		2 1		Ω
I_{OUT2}	Available Output Current (V_{OUT2})	$V^+_{IN} = 3V$ $V_{OUT} = V_{SET}$ $V^+_{IN} = 9V$ $V_{OUT} = 5V$	10 25			mA

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NOTE: All typical values have been characterized but are not tested.

ICL7663B OPERATING CHARACTERISTICS $V^+_{IN} = 9V$, $V_{OUT} = 5V$, $T_A = +25°C$, unless otherwise specified. (Continued)

Symbol	Parameter	Test Conditions	Limits			Units
			Min	Typ	Max	
V_{TC}	Negative-Tempco Output (Note 4)	Open-Circuit Voltage		0.9		V
I_{TC}		Maximum Sink Current	0	8	2	mA
$\frac{\Delta V_{TC}}{\Delta T}$	Temperature Coefficient	Open Circuit		+2.5		mV/°C
$I_{L(min)}$	Minimum Load Current	(Includes V_{SET} Divider)			1	μA

NOTES: 1. Connecting any terminal to voltages greater than (V^+_{IN} +0.3V) or less than (GND −0.3V) may cause destructive device latchup. It is recommended that no inputs from sources operating on external power supplies be applied prior to ICL7663B power-up.

2. Derate linearly above 50°C at 5mW/°C for minidip and 7.5mW/°C for TO-99 can.
3. This parameter refers to the saturation resistance of the MOS pass transistor. The minimum input-output voltage differential at low current (under 5mA), can be determined by multiplying the load current (including set resistor current, but not quiescent current) by this resistance.
4. This output has a positive temperature coefficient. Using it in combination with the inverting input of the regulator at V_{SET}, a negative coefficient results in the output voltage. See Figure 3 for details. Pin will not source current.

NOTE: All typical values have been characterized but are not tested.