3.0 A Positive Voltage Regulators

MC78T00 Series

THREE–AMPERE POSITIVE FIXED VOLTAGE REGULATORS

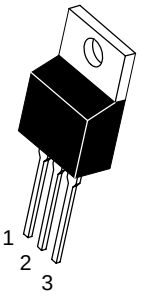
SEMICONDUCTOR TECHNICAL DATA

This family of fixed voltage regulators are monolithic integrated circuits capable of driving loads in excess of 3.0 A. These three–terminal regulators employ internal current limiting, thermal shutdown, and safe–area compensation. Devices are available with improved specifications, including a 2% output voltage tolerance, on AC–suffix 5.0, 12 and 15 V device types.

Although designed primarily as a fixed voltage regulator, these devices can be used with external components to obtain adjustable voltages and currents. This series of devices can be used with a series–pass transistor to supply up to 15 A at the nominal output voltage.

- Output Current in Excess of 3.0 A
- Power Dissipation: 25 W
- No External Components Required
- Output Voltage Offered in 2% and 4% Tolerance*
- Thermal Regulation is Specified
- Internal Thermal Overload Protection
- Internal Short Circuit Current Limiting
- Output Transistor Safe–Area Compensation

T SUFFIX
PLASTIC PACKAGE
CASE 221A



Pin 1. Input
2. Ground
3. Output

Heatsink surface is connected to Pin 2.

DEVICE TYPE/NOMINAL OUTPUT VOLTAGE

MC78T05	5.0 V	MC78T12	12 V
MC78T08	8.0 V	MC78T15	15 V

ORDERING INFORMATION

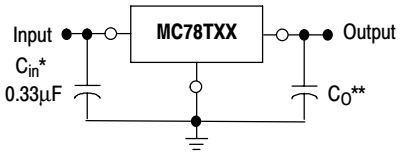
Device	V_O Tol.	Operating Temperature Range	Package
MC78TXXCT MC78TXXACT	4% 2%*	T_J = 0° to +125°C	Plastic Power
MC78TXXBT# MC78TXXABT#	4% 2%*	T_J = –40° to +125°C	Plastic Power

XX Indicates nominal voltage.

* 2% regulators available in 5, 12 and 15 V devices.

\# Automotive temperature range selections are available with special test conditions and additional tests. Contact your local ON Semiconductor sales office for information.

Simplified Application



A common ground is required between the input and the output voltages. The input voltage must remain typically 2.2 V above the output voltage even during the low point on the input ripple voltage.

XX these two digits of the type number indicate voltage.

* C_{in} is required if regulator is located an appreciable distance from power supply filter. (See Applications Information for details.)

** C_O is not needed for stability; however, it does improve transient response.

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January, 2002 – Rev. 3
Publication Order Number:
MC78T00/D

MAXIMUM RATINGS (T_A = +25°C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Input Voltage (5.0 V – 12 V) (15 V)	V_I	35 40	Vdc
Power Dissipation and Thermal Characteristics Plastic Package (Note 1) T_A = +25°C Thermal Resistance, Junction–to–Air T_C = +25°C Thermal Resistance, Junction–to–Case	 P_D $R_{\theta JA}$ P_D $R_{\theta JC}$	 Internally Limited 65 Internally Limited 2.5	 °C/W °C/W
Storage Junction Temperature	T_{stg}	+150	°C
Operating Junction Temperature Range (MC78T00C, AC)	T_J	0 to +125	°C

NOTES: 1. Although power dissipation is internally limited, specifications apply only for $P_O \le P_{max}$, P_{max} = 25 W.

ELECTRICAL CHARACTERISTICS (V_{in} = 10 V, I_O = 3.0 A, 0°C ≤ T_J ≤ 125°C, $P_O \le P_{max}$ [Note 1], unless otherwise noted.)

Characteristics	Symbol	MC78T05AC			MC78T05C			Unit
		Min	Typ	Max	Min	Typ	Max	
Output Voltage (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A; 5.0 mA ≤ I_O ≤ 2.0 A, 7.3 Vdc ≤ V_{in} ≤ 20 Vdc)	V_O	 4.9 4.8	 5.0 5.0	 5.1 5.2	 4.8 4.75	 5.0 5.0	 5.2 5.25	Vdc
Line Regulation (Note 2) (7.2 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 5.0 mA, T_J = +25°C; 7.2 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 1.0 A, T_J = +25°C; 8.0 Vdc ≤ V_{in} ≤ 12 Vdc, I_O = 3.0 A, T_J = +25°C; 7.5 Vdc ≤ V_{in} ≤ 20 Vdc, I_O = 1.0 A)	Reg_{line}	–	3.0	25	–	3.0	25	mV
Load Regulation (Note 2) (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A)	Reg_{load}	 – –	 10 15	 30 80	 – –	 10 15	 30 80	mV
Thermal Regulation (Pulse = 10 ms, P = 20 W, T_A = +25°C)	Reg_{therm}	–	0.001	0.01	–	0.002	0.03	$\%V_O/W$
Quiescent Current (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A)	I_B	 – –	 3.5 4.0	 5.0 6.0	 – –	 3.5 4.0	 5.0 6.0	mA
Quiescent Current Change (7.2 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 5.0 mA, T_J = +25°C; 5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C; 7.5 Vdc ≤ V_{in} ≤ 20 Vdc, I_O = 1.0 A)	ΔI_B	–	0.3	1.0	–	0.3	1.0	mA
Ripple Rejection (8.0 Vdc ≤ V_{in} ≤ 18 Vdc, f = 120 Hz, I_O = 2.0 A, T_J = 25°C)	RR	62	75	–	62	75	–	dB
Dropout Voltage (I_O = 3.0 A, T_J = +25°C)	$V_{in}–V_O$	–	2.2	2.5	–	2.2	2.5	Vdc
Output Noise Voltage (10 Hz ≤ f ≤ 100 kHz, T_J = +25°C)	V_n	–	10	–	–	10	–	$\mu V/V_O$
Output Resistance (f = 1.0 kHz)	R_O	–	2.0	–	–	20	–	mΩ
Short Circuit Current Limit (V_{in} = 35 Vdc, T_J = +25°C)	I_{SC}	–	1.5	–	–	1.5	–	A
Peak Output Current (T_J = +25°C)	I_{max}	–	5.0	–	–	5.0	–	A
Average Temperature Coefficient of Output Voltage (I_O = 5.0 mA)	TCV_O	–	0.2	–	–	0.2	–	mV/°C

NOTES: 1. Although power dissipation is internally limited, specifications apply only for $P_O \le P_{max}$, P_{max} = 25 W.
2. Line and load regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

ELECTRICAL CHARACTERISTICS (V_{in} = 13 V, I_O = 3.0 A, 0°C ≤ T_J ≤ 125°C, P_O ≤ P_{max} [Note 1], unless otherwise noted.)

Characteristics	Symbol	MC78T08C			Unit
		Min	Typ	Max	
Output Voltage (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A; 5.0 mA ≤ I_O ≤ 2.0 A, 10.4 Vdc ≤ V_{in} ≤ 23 Vdc)	V_O	 7.7 7.6	 8.0 8.0	 8.3 8.4	Vdc
Line Regulation (Note 2) (10.3 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 5.0 mA, T_J = +25°C 10.3 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 1.0 A, T_J = +25°C 11 Vdc ≤ V_{in} ≤ 17 Vdc, I_O = 3.0 A, T_J = +25°C 10.7 Vdc ≤ V_{in} ≤ 23 Vdc, I_O = 1.0 A)	Reg_{line}	–	4.0	35	mV
Load Regulation (Note 2) (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A)	Reg_{load}	 – –	 10 15	 30 80	mV
Thermal Regulation (Pulse = 10 ms, P = 20 W, T_A = +25°C)	Reg_{therm}	–	0.002	0.03	$\%V_O/W$
Quiescent Current (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A)	I_B	 – –	 3.5 4.0	 5.0 6.0	mA
Quiescent Current Change (10.3 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 5.0 mA, T_J = +25°C; 5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C; 10.7 Vdc ≤ V_{in} ≤ 23 Vdc, I_O = 1.0 A)	ΔI_B	–	0.3	1.0	mA
Ripple Rejection (11 Vdc ≤ V_{in} ≤ 21 Vdc, f = 120 Hz, I_O = 2.0 A, T_J = 25°C)	RR	60	71	–	dB
Dropout Voltage (I_O = 3.0 A, T_J = +25°C)	$V_{in}–V_O$	–	2.2	2.5	Vdc
Output Noise Voltage (10 Hz ≤ f ≤ 100 kHz, T_J = +25°C)	V_n	–	10	–	$\mu V/V_O$
Output Resistance (f = 1.0 kHz)	R_O	–	2.0	–	mΩ
Short Circuit Current Limit (V_{in} = 35 Vdc, T_J = +25°C)	I_{SC}	–	1.5	–	A
Peak Output Current (T_J = +25°C)	I_{max}	–	5.0	–	A
Average Temperature Coefficient of Output Voltage (I_O = 5.0 mA)	TCV_O	–	0.3	–	mV/°C

NOTES: 1. Although power dissipation is internally limited, specifications apply only for P_O ≤ P_{max}, P_{max} = 25 W.
2. Line and load regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

ELECTRICAL CHARACTERISTICS (V_{in} = 17 V, I_O = 3.0 A, 0°C ≤ T_J ≤ 125°C, P_O ≤ P_{max} [Note 1], unless otherwise noted.)

Characteristics	Symbol	MC78T12AC			MC78T12C			Unit
		Min	Typ	Max	Min	Typ	Max	
Output Voltage (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A, 5.0 mA ≤ I_O ≤ 2.0 A, 14.5 Vdc ≤ V_{in} ≤ 27 Vdc)	V_O	 11.75 11.5	 12 12	 12.25 12.5	 11.5 11.4	 12 12	 12.5 12.6	Vdc
Line Regulation (Note 2) (14.5 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 5.0 mA, T_J = +25°C; 14.5 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 1.0 A, T_J = +25°C; 16 Vdc ≤ V_{in} ≤ 22 Vdc, I_O = 3.0 A, T_J = +25°C; 14.9 Vdc ≤ V_{in} ≤ 27 Vdc, I_O = 1.0 A)	Reg_{line}	–	6.0	45	–	6.0	45	mV
Load Regulation (Note 2) (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A)	Reg_{load}	 – –	 10 15	 30 80	 – –	 10 15	 30 80	mV
Thermal Regulation (Pulse = 10 ms, P = 20 W, T_A = +25°C)	Reg_{therm}	–	0.001	0.01	–	0.002	0.03	$\%V_O/W$
Quiescent Current (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A)	I_B	 – –	 3.5 4.0	 5.0 6.0	 – –	 3.5 4.0	 5.0 6.0	mA
Quiescent Current Change (14.5 Vdc ≤ V_{in} ≤ 35 Vdc, I_O = 5.0 mA, T_J = +25°C; 5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C; 14.9 Vdc ≤ V_{in} ≤ 27 Vdc, I_O = 1.0 A)	ΔI_B	–	0.3	1.0	–	0.3	1.0	mA
Ripple Rejection (15 Vdc ≤ V_{in} ≤ 25 Vdc, f = 120 Hz, I_O = 2.0 A, T_J = 25°C)	RR	57	67	–	57	67	–	dB
Dropout Voltage (I_O = 3.0 A, T_J = +25°C)	$V_{in} – V_O$	–	2.2	2.5	–	2.2	2.5	Vdc
Output Noise Voltage (10 Hz ≤ f ≤ 100 kHz, T_J = +25°C)	V_n	–	10	–	–	10	–	$\mu V/V_O$
Output Resistance (f = 1.0 kHz)	R_O	–	2.0	–	–	20	–	mΩ
Short Circuit Current Limit (V_{in} = 35 Vdc, T_J = +25°C)	I_{SC}	–	1.5	–	–	1.5	–	A
Peak Output Current (T_J = +25°C)	I_{max}	–	5.0	–	–	5.0	–	A
Average Temperature Coefficient of Output Voltage (I_O = 5.0 mA)	TCV_O	–	0.5	–	–	0.5	–	mV/°C

NOTES: 1. Although power dissipation is internally limited, specifications apply only for P_O ≤ P_{max}, P_{max} = 25 W.
2. Line and load regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

ELECTRICAL CHARACTERISTICS (V_{in} = 20 V, I_O = 3.0 A, 0°C ≤ T_J ≤ 125°C, P_O ≤ P_{max} [Note 1], unless otherwise noted.)

Characteristics	Symbol	MC78T15AC			MC78T15C			Unit
		Min	Typ	Max	Min	Typ	Max	
Output Voltage (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A; 5.0 mA ≤ I_O ≤ 2.0 A, 17.5 Vdc ≤ V_{in} ≤ 30 Vdc)	V_O	 14.7 14.4	 15 15	 15.3 15.6	 14.4 14.25	 15 15	 15.6 15.75	Vdc
Line Regulation (Note 2) (17.6 Vdc ≤ V_{in} ≤ 40 Vdc, I_O = 5.0 mA, T_J = +25°C; 17.6 Vdc ≤ V_{in} ≤ 40 Vdc, I_O = 1.0 A, T_J = +25°C; 20 Vdc ≤ V_{in} ≤ 26 Vdc, I_O = 3.0 A, T_J = +25°C; 18 Vdc ≤ V_{in} ≤ 30 Vdc, I_O = 1.0 A)	Reg_{line}	–	7.5	55	–	7.5	55	mV
Load Regulation (Note 2) (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A)	Reg_{load}	 – –	 10 15	 30 80	 – –	 10 15	 30 80	mV
Thermal Regulation (Pulse = 10 ms, P = 20 W, T_A = +25°C)	Reg_{therm}	–	0.001	0.01	–	0.002	0.03	%V_O/W
Quiescent Current (5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C) (5.0 mA ≤ I_O ≤ 3.0 A)	I_B	 – –	 3.5 4.0	 5.0 6.0	 – –	 3.5 4.0	 5.0 6.0	mA
Quiescent Current Change (17.6 Vdc ≤ V_{in} ≤ 40 Vdc, I_O = 5.0 mA, T_J = +25°C; 5.0 mA ≤ I_O ≤ 3.0 A, T_J = +25°C; 18 Vdc ≤ V_{in} ≤ 30 Vdc, I_O = 1.0 A)	ΔI_B	–	0.3	1.0	–	0.3	1.0	mA
Ripple Rejection (18.5 Vdc ≤ V_{in} ≤ 28.5 Vdc, f = 120 Hz, I_O = 2.0 A, T_J = 25°C)	RR	55	65	–	55	65	–	dB
Dropout Voltage (I_O = 3.0 A, T_J = +25°C)	V_{in}–V_O	–	2.2	2.5	–	2.2	2.5	Vdc
Output Noise Voltage (10 Hz ≤ f ≤ 100 kHz, T_J = +25°C)	V_n	–	10	–	–	10	–	μV/V_O
Output Resistance (f = 1.0 kHz)	R_O	–	2.0	–	–	20	–	mΩ
Short Circuit Current Limit (V_{in} = 40 Vdc, T_J = +25°C)	I_{SC}	–	1.0	–	–	1.0	–	A
Peak Output Current (T_J = +25°C)	I_{max}	–	5.0	–	–	5.0	–	A
Average Temperature Coefficient of Output Voltage (I_O = 5.0 mA)	TCV_O	–	0.6	–	–	0.6	–	mV/°C

NOTES: 1. Although power dissipation is internally limited, specifications apply only for P_O ≤ P_{max}, P_{max} = 25 W.
2. Line and load regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty cycle is used.

VOLTAGE REGULATOR PERFORMANCE

The performance of a voltage regulator is specified by its immunity to changes in load, input voltage, power dissipation, and temperature. Line and load regulation are tested with a pulse of short duration (< 100μs) and are strictly a function of electrical gain. However, pulse widths of longer duration (> 1.0 ms) are sufficient to affect temperature gradients across the die. These temperature gradients can cause a change in the output voltage, in addition to changes caused by line and load regulation. Longer pulse widths and thermal gradients make it desirable to specify thermal regulation.

Thermal regulation is defined as the change in output voltage caused by a change in dissipated power for a specified time, and is expressed as a percentage output voltage change per watt. The change in dissipated power can be caused by a change in either the input voltage or the load current. Thermal regulation is a function of IC layout and die attach techniques, and usually occurs within 10 ms of a change in power dissipation. After 10 ms, additional changes in the output voltage are due to the temperature coefficient of the device.

Figure 1 shows the line and thermal regulation response of a typical MC78T05AC to a 20 W input pulse. The variation of the output voltage due to line regulation is labeled ① and the thermal regulation component is labeled ②. Figure 2 shows the load and thermal regulation response of a typical MC78T05AC to a 20 W load pulse. The output voltage variation due to load regulation is labeled ① and the thermal regulation component is labeled ②.

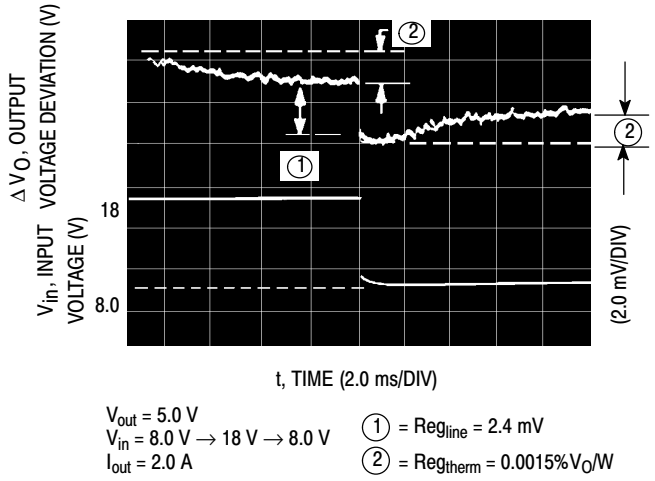


Figure 1. MC78T05AC Line and Thermal Regulation

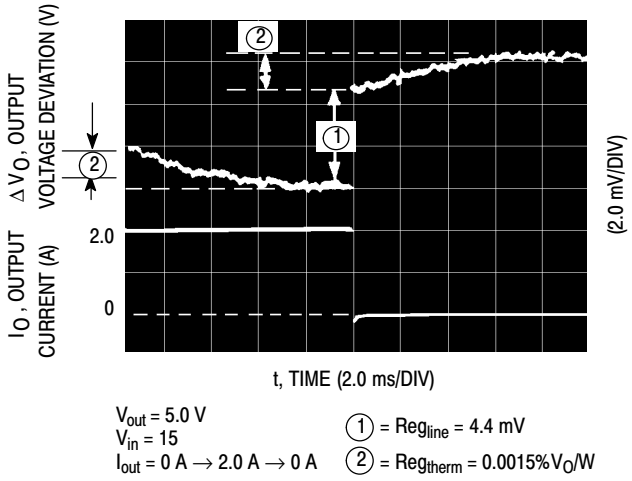
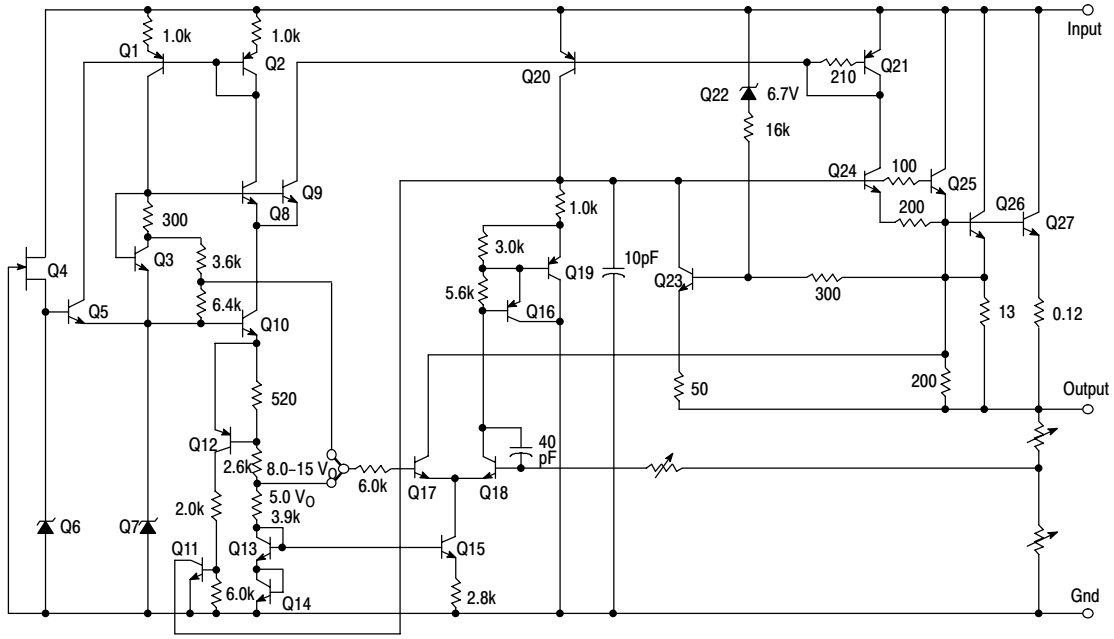


Figure 2. MC78T05AC Load and Thermal Regulation



Representative Schematic Diagram

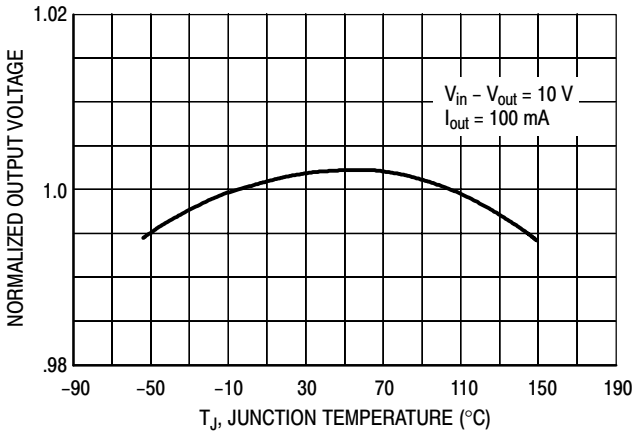


Figure 3. Temperature Stability

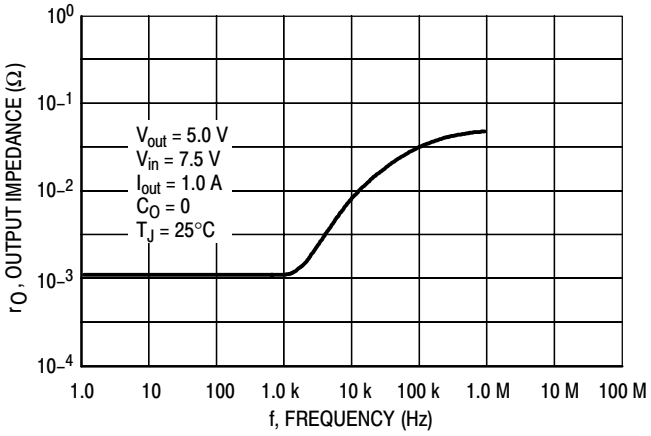


Figure 4. Output Impedance

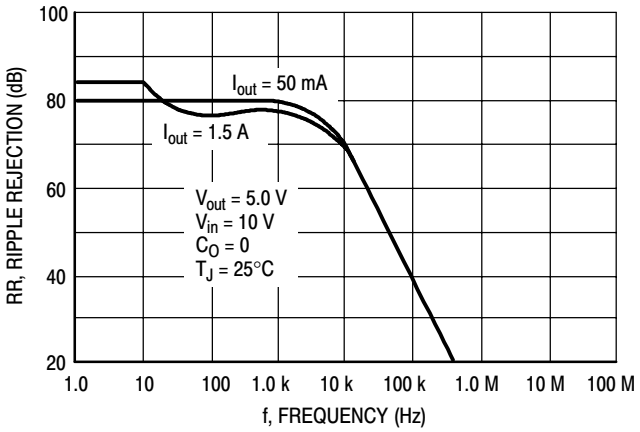


Figure 5. Ripple Rejection versus Frequency

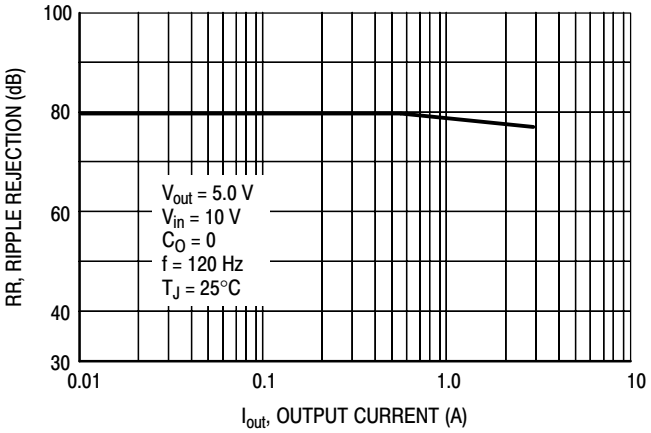


Figure 6. Ripple Rejection versus Output Current

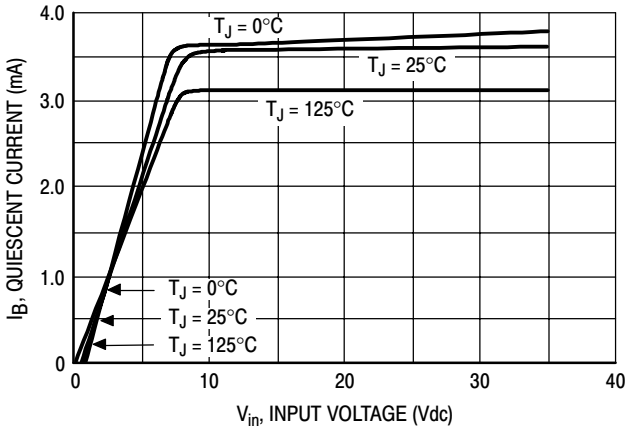


Figure 7. Quiescent Current versus Input Voltage

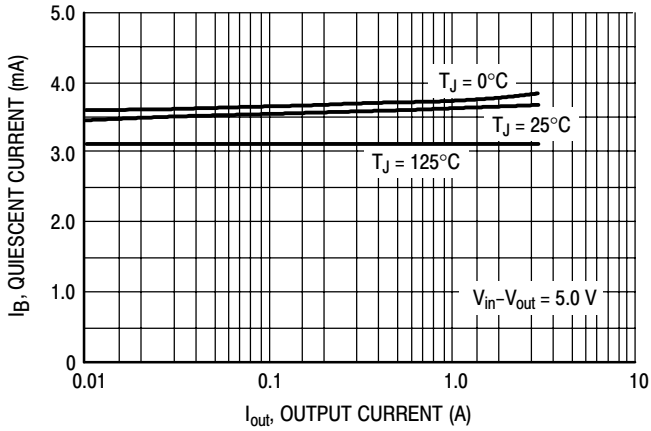


Figure 8. Quiescent Current versus Output Current

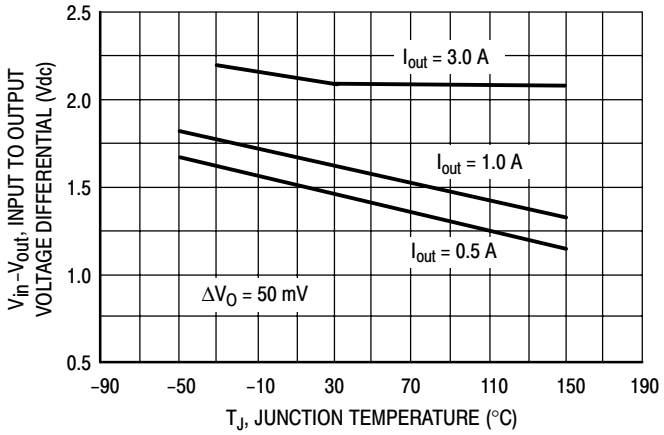


Figure 9. Dropout Voltage

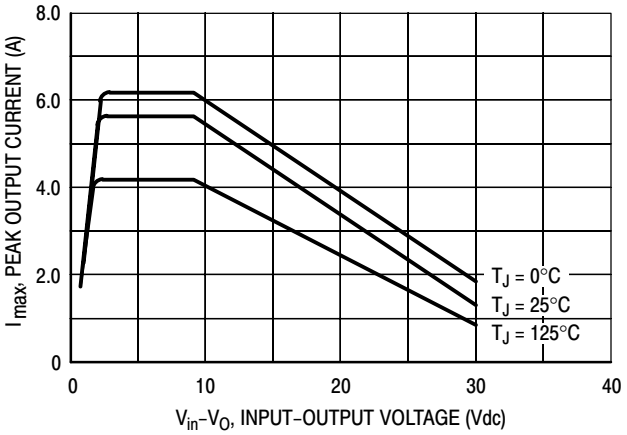


Figure 10. Peak Output Current

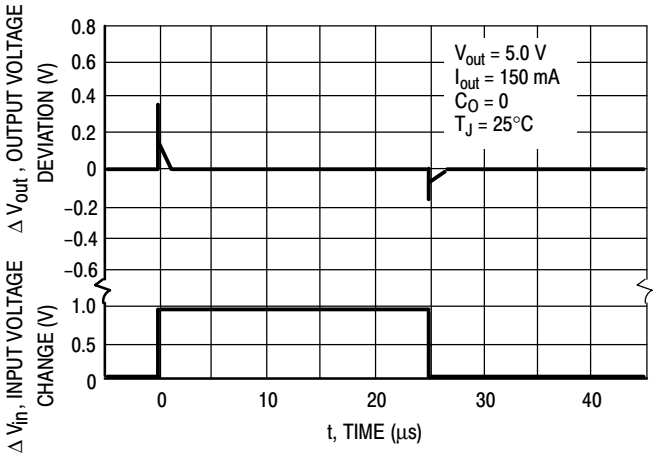


Figure 11. Line Transient Response

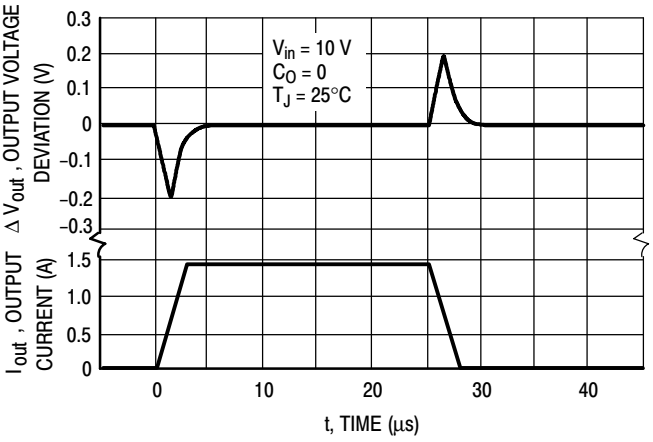


Figure 12. Load Transient Response

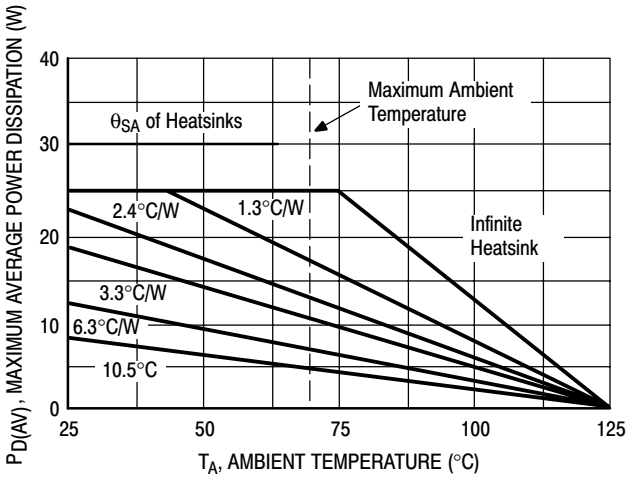


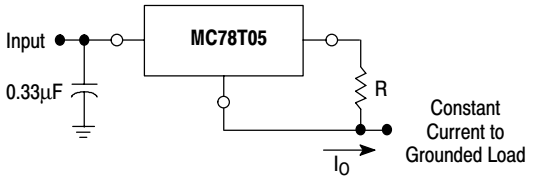
Figure 13. Maximum Average Power Dissipation for MC78T00CT, ACT

APPLICATIONS INFORMATION

Design Considerations

The MC78T00 Series of fixed voltage regulators are designed with Thermal Overload Protection that shuts down the circuit when subjected to an excessive power overload condition, Internal Short Circuit Protection that limits the maximum current the circuit will pass, and Output Transistor Safe–Area Compensation that reduces the output short circuit current as the voltage across the pass transistor is increased.

In many low current applications, compensation capacitors are not required. However, it is recommended that the regulator input be bypassed with a capacitor if the regulator is connected to the power supply filter with long wire lengths, or if the output load capacitance is large. An input bypass capacitor should be selected to provide good high frequency characteristics to insure stable operation under all load conditions. A 0.33 μF or larger tantalum, mylar, or other capacitor having low internal impedance at high frequencies should be chosen. The bypass capacitor should be mounted with the shortest possible leads directly across the regulator's input terminals. Normally good construction techniques should be used to minimize ground loops and lead resistance drops since the regulator has no external sense lead.



The MC78T05 regulator can also be used as a current source when connected as above. In order to minimize dissipation the MC78T05 is chosen in this application. Resistor R determines the current as follows:

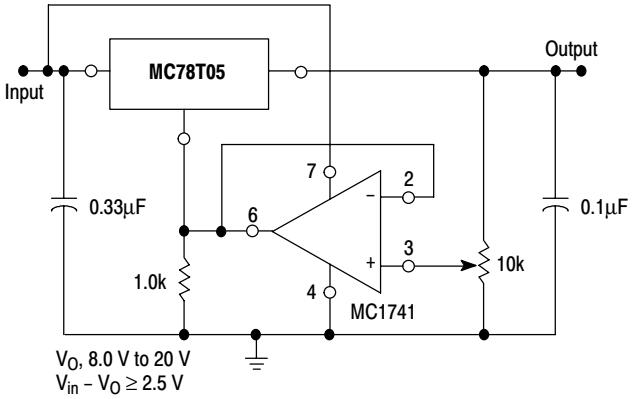
$$I_O = \frac{5.0\ V}{R} + I_B$$

$\Delta I_B \cong 0.7$ mA over line, load and Temperature changes

$I_B \cong 3.5$ mA

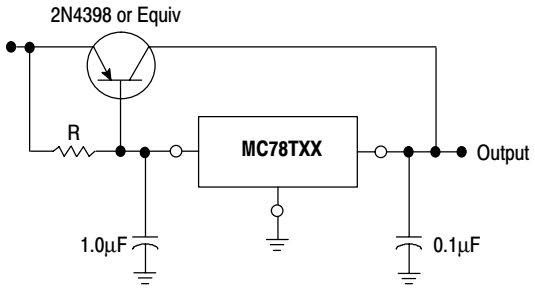
For example, a 2.0 A current source would require R to be a 2.5 Ω, 10 W resistor and the output voltage compliance would be the input voltage less 7.0 V.

Figure 14. Current Regulator



The addition of an operational amplifier allows adjustment to higher or intermediate values while retaining regulation characteristics. The minimum voltage obtainable with this arrangement is 3.0 V greater than the regulator voltage.

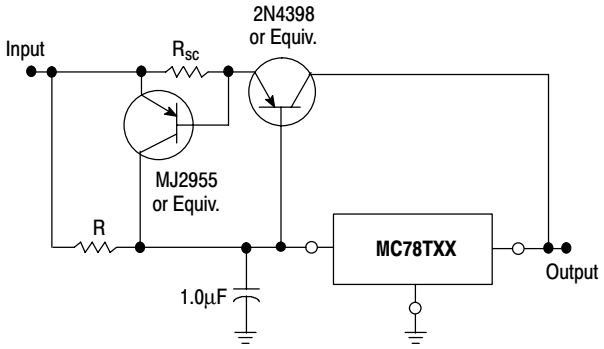
Figure 15. Adjustable Output Regulator



XX = 2 digits of type number indicating voltage.

The MC78T00 series can be current boosted with a PNP transistor. The 2N4398 provides current to 15 A. Resistor R in conjunction with the V_{BE} of the PNP determines when the pass transistor begins conducting; this circuit is not short circuit proof. Input–output differential voltage minimum is increased by the V_{BE} of the pass transistor.

Figure 16. Current Boost Regulator



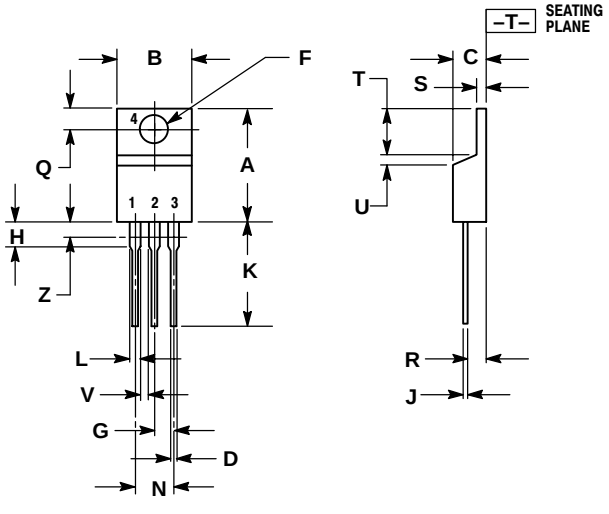
XX = 2 digits of type number indicating voltage.

The circuit of Figure 17 can be modified to provide supply protection against short circuits by adding a short circuit sense resistor, R_{SC}, and an additional PNP transistor. The current sensing PNP must be able to handle the short circuit current of the three–terminal regulator. Therefore, an eight–ampere power transistor is specified.

Figure 17. Current Boost With Short Circuit Protection

PACKAGE DIMENSIONS

T SUFFIX
PLASTIC PACKAGE
CASE 221A–09
ISSUE AA



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.570	0.620	14.48	15.75
B	0.380	0.405	9.66	10.28
C	0.160	0.190	4.07	4.82
D	0.025	0.035	0.64	0.88
F	0.142	0.147	3.61	3.73
G	0.095	0.105	2.42	2.66
H	0.110	0.155	2.80	3.93
J	0.018	0.025	0.46	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.060	1.15	1.52
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.110	2.04	2.79
S	0.045	0.055	1.15	1.39
T	0.235	0.255	5.97	6.47
U	0.000	0.050	0.00	1.27
V	0.045	---	1.15	---
Z	---	0.080	---	2.04

Notes

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