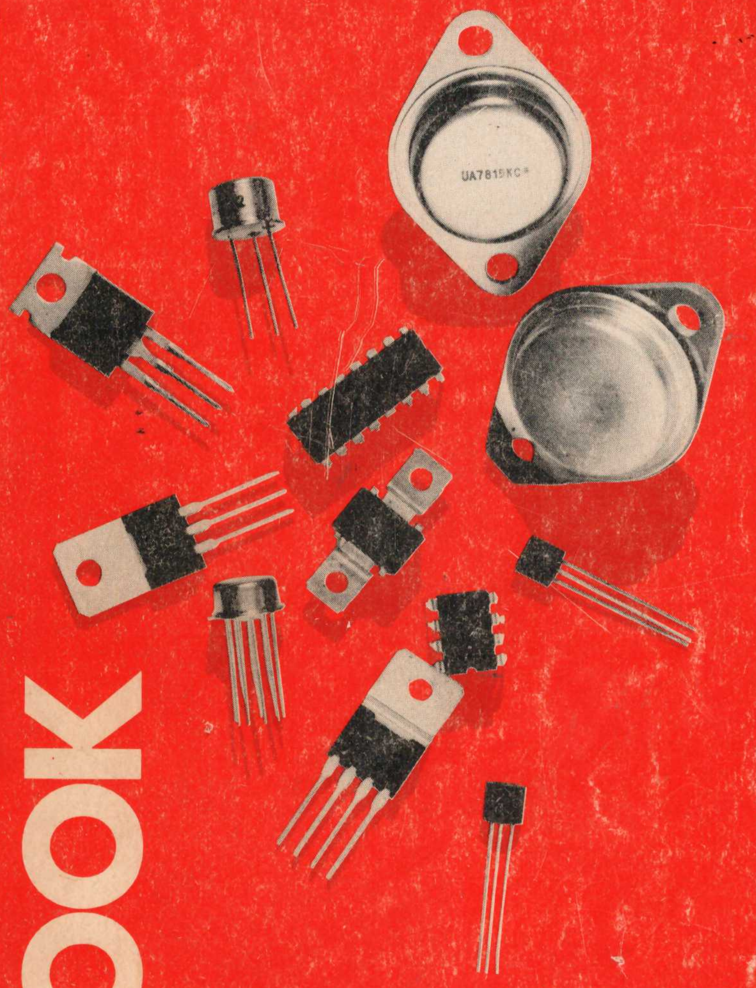
VOLTAGE REGULATOR HANDBOOK



FAIRCHILD

VOLTAGE REGULATOR HANDBOOK

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FAIRCHILD

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INTRODUCTION

Monolithic voltage regulators have been around for about a decade. A considerable effort has been devoted to linear voltage regulators by major IC manufacturers over the last few years, with recent emphasis primarily concerning 3-terminal voltage regulators.

Of the various regulators introduced in the late sixties, one device emerged as the industry standard: the μA723. A simple building block, this circuit provided low output currents (by today's standards), required several external components and a fair amount of design considerations. At last count, this product is produced by over a dozen manufacturers. The emergence of 3-terminal regulators (μA7800, μA78C, μA78M, μA78L, μA7900, μA79M) in the early seventies opened a new avenue for regulators. Circuit complexity moved from outside to inside the linear chip. Designers had at their disposal *positive* and *negative* regulators with output currents up to 3 A in a variety of packages but with a limited number of fixed output voltages. The output voltage limitation was solved by the introduction of the adjustable 4-terminal regulators (78G, 78MG, 79G, 79MG) in the mid seventies. Energy conservation programs of recent years have forced designers to be more conscious about wasted power and as a result they have looked into switching regulators. As a matter of fact, there are major switching regulator design efforts in progress at various IC manufacturers as this book goes to press.

The use of IC regulators is increasing at a rapid rate as the usage of semiconductors is widening. Today, regulators are being used in a variety of applications too numerous to list here. Fairchild is the industry leader in voltage regulators and in fact, Fairchild regulators have become industry standards.

This edition of "The Voltage Regulator Applications Handbook" significantly different in format, covers a larger selection of products and applications than the 1974 edition and is intended to familiarize the designer with the various regulators available from Fairchild as well as helping him select the correct regulator circuit for his application. At the front of this book is a complete regulator selection guide supplemented by an industry cross reference. Chapter 1 describes the various blocks used in regulators as well as the circuit descriptions of the individual regulators. Chapter 2 covers testing procedures and reliability programs. Chapter 3 is devoted to regulator applications, and includes several important precautions required in the design of regulator circuits. Chapter 4 offers power supply design assistance, such as the selection of transformer, rectifier and filter capacitors. Chapter 5 is devoted to power transistors and Chapter 6 outlines the thermal considerations necessary with IC regulators. Technical specification for all Fairchild regulators make up Chapter 7. Definitions, packaging, mounting hardware and ordering information are found in Section 8.

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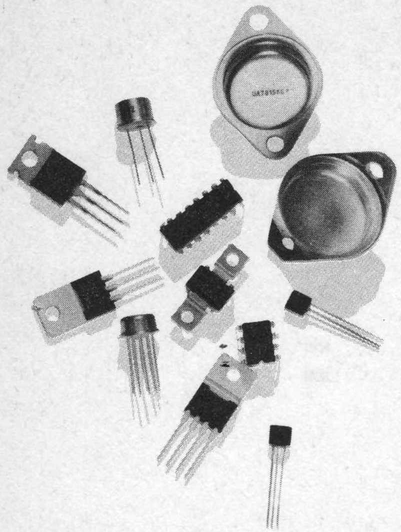


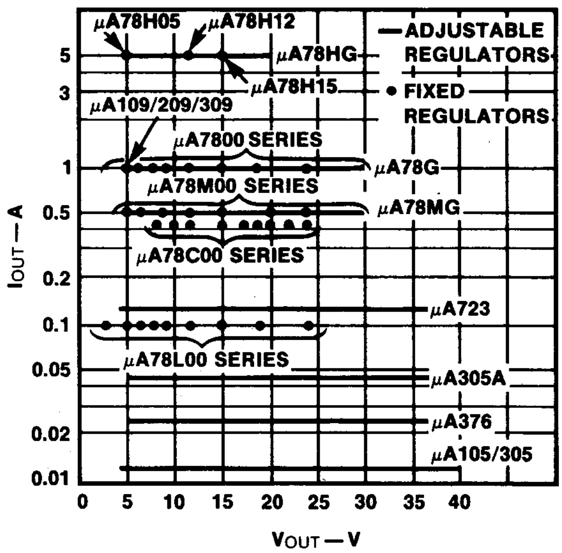
VOLTAGE REGULATOR SELECTION

VOLTAGE REGULATOR SELECTION

The selection of the proper regulator is not a simple decision and very much depends on the system requirements and the limitations imposed by the system. There are no set rules; the selection process may vary from one application to another and even from one designer to the next. The following steps are recommended as a guide:

1. Determine the required output voltage V_{OUT}, output voltage tolerance, and maximum output current $I_{OUT(max)}$. These three parameters somewhat narrow the selection. For instance, a system requirement of 1% output voltage tolerance may preclude the 3-terminal regulators since these devices are specified with a 5% tolerance over the operating temperature range unless a special selection is made.

2. Using the Quick Selection Guide below and the Selection Guide by Output Current along with *Table 6.2*, make an initial selection.



Quick Selection Guide

3. Determine the required input voltage such that

$$V_{IN(max)} > V_{IN} > V_{OUT(max)} + V_{DO(max)} + \Delta V_L + V_{R(pk)}$$

where:

$V_{IN(max)}$ = Maximum allowable input voltage

V_{IN} = Regulator input voltage under load

$V_{OUT(max)}$ = Maximum output voltage of the regulator

$V_{DO(max)}$ = Maximum dropout voltage

ΔV_L = Maximum line voltage change

$V_{R(pk)}$ = Peak ripple voltage.

4. If a filtered dc supply is not available, refer to Chapter 4 for the power-supply design.

5. If a filtered supply is available, or if the selected voltage gives an input-output voltage differential greater than 7 V, check the safe-area characteristics of the device chosen on the "Peak Output Current as a Function of Input-Output Differential Voltage" graph from the data sheet to ensure that sufficient load current is available from the regulator with the chosen input voltage.

6. If the current available is insufficent, either lower the input voltage, choose a device with a higher rating or use a booster circuit (see Chapter 3).

7. Determine the maximum ambient temperature, $T_{A(max)}$, and select an operating junction temperature equal to or less than $T_{J(max)}$, keeping in mind that the lower the operating junction temperature, the higher the reliability but the greater the heat-sinking requirement.

8. From Chapter 6, Thermal Considerations, determine the heat sink requirement for the selected regulator.

VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	(°C/W) Max		Packages	Data Sheet Page
										θ_{JC}	θ_{JA}		
µA104	Adjustable Negative	-8 -50	-0.015 -40	0.012	0.1	0.1	5	60	2	50	190	TO-100	7-123
µA105	Adjustable Positive	8.5 50	4.5 30	0.012	0.06	0.1	2	60	3	 40	190 190	MINI DIP TO-99	7-117
µA109[1]	Fixed Positive	7 35	4.7 5.3	1	1	2	4.2		2	5.5	45	TO-3	7-47
µA209[2]	Fixed Positive	7 35	4.7 5.3	1	1	2	4.2		2	5.5	45	TO-3	7-47
µA304	Adjustable Negative	-8 -40	-0.035 -30	0.02	0.1	0.2	5	60	3	50	190	TO-100	7-123
µA305	Adjustable Positive	8.5 40	4.5 30	0.012	0.06	0.1	2	60	3	 40	190 190	MINI DIP TO-99	7-117
µA305A	Adjustable Negative	8.5 50	4.5 40	0.045	0.06	0.4	2		3	 40	190 190	MINI DIP TO-99	7-117
µA309	Fixed Positive	7 35	4.8 5.2	1	2	2	5.2		2	5.5	45	TO-3	7-51
µA376	Adjustable Positive	9 40	5 37	0.025	0.05	0.5	2.5		3	 40	190 190	MINI DIP TO-99	7-117
µA723	Precision	9.5 40	2 37	0.125	0.5	0.2	4	58	3	50	190 160 190	TO-100 C DIP P DIP	7-110
µA7805	Fixed Positive	7 35	4.8 5.2	1	1	1	8	62	2.5	5 5.5	65 45	TO-220 TO-3	7-34
µA7806	Fixed Positive	8 35	5.75 6.25	1	1	1	8	59	2.5	5 5.5	65 45	TO-220 TO-3	7-34
µA7808	Fixed Positive	10 35	7.7 8.3	1	1	1	8	56	2.5	5 5.5	65 45	TO-220 TO-3	7-34
µA7812	Fixed Positive	14 35	11.5 12.5	1	1	1	8	55	2.5	5 5.5	65 45	TO-220 TO-3	7-34
µA7815	Fixed Positive	17 35	14.4 15.6	1	1	1	8	54	2.5	5 5.5	65 45	TO-220 TO-3	7-34
µA7818	Fixed Positive	20 35	17.3 18.7	1	1	1	8	53	2.5	5 5.5	65 45	TO-220 TO-3	7-34
µA7824	Fixed Positive	26 40	23 25	1	1	1	8	50	2.5	5 5.5	65 45	TO-220 TO-3	7-34
µA7885	Fixed Positive	10.5 35	8.2 8.8	1	1	1	8	54	2.5	5 5.5	65 45	TO-220 TO-3	7-34

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

[1]T_J = -55°C to 150°C
[2]T_J = -25°C to 150°C

VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	(°C/W) Max		Packages	Data Sheet Page
										θ_{JC}	θ_{JA}		
µA78C08	Fixed Positive	11 35	7.7 8.3	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C10	Fixed Positive	13 35	9.6 10.4	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C12	Fixed Positive	15 35	11.5 12.5	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C15	Fixed Positive	18 35	14.4 15.6	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C17	Fixed Positive	20 35	16.3 17.7	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C18	Fixed Positive	21 35	17.3 18.7	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C20	Fixed Positive	23 40	19.2 20.8	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C22	Fixed Positive	25 40	21.1 22.9	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C24	Fixed Positive	27 40	23 25	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78C82	Fixed Positive	11.2 35	7.9 8.5	0.5	1	0.5	6	46	3	8	80	Power* Watt	7-14
µA78CB	Fixed Positive		13.3 14.4	2			8	50	3	5 5.5	65 45	TO-220 TO-3	7-54
µA78G	Adjustable Positive	7.5 4	5 30	1	0.75	1	5	62	3	8 6	80 47	Power* Watt TO-3	7-90
µA78H05	Fixed Positive	8.5 20	4.8 5.2	5	1	2	10	60	3.5	2.5	38	TO-3	7-60
µA78H05A	Fixed Positive	25	5	5	1	1	10	60	2.2	2.5	38	TO-3	7-60
µA78H12	Fixed Positive	15.5 20	11.5 12.5	5	1	2	10	60	3.5	2.5	38	TO-3	7-60
µA78H15	Fixed Positive		14.4 15.6							2.5	38	TO-3	7-60
µA78HG	Adjustable Positive	8.5 25	5 20	5	1	1	10	60	3.5	2.5	38	TO-3	7-60

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

*Similar to TO-202

VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	(°C/W) Max θ_{JC}	(°C/W) Max θ_{JA}	Packages	Data Sheet Page
μA78L05	Fixed Positive	7.2 30	4.8 5.2	0.1	2	1	3.8	49	2.2	40	190 180	TO-39 TO-92	7-3
μA78L09	Fixed Positive	11.2 30	8.64 9.36	0.1	2	1	4	43	2.2	40	190 180	TO-39 TO-92	7-3
μA78L12	Fixed Positive	14.2 30	11.5 12.5	0.1	2	1	6	42	2.2	40	190 180	TO-39 TO-92	7-3
μA78L15	Fixed Positive	17.2 35	14.4 15.6	0.1	2	1	6	39	2.2	40	190 180	TO-39 TO-92	7-3
μA78L18	Fixed Positive	20.2 35	17.3 18.9	0.1	2	1	3		2.2	40	190 180	TO-39 TO-92	7-3
μA78L24	Fixed Positive	26.2 40	23.1 24.9	0.1	2	1	3		2.2	40	190 180	TO-39 TO-92	7-3
μA78L26	Fixed Positive	4.3 30	2.5 2.7	0.1	2	1	5.5	43	2.2	40	190 180	TO-39 TO-92	7-3
μA78L62	Fixed Positive	8.4 30	5.95 6.45	0.1	2	1	3.9	46	2.2	40	190 180	TO-39 TO-92	7-3
μA78L82	Fixed Positive	10.4 30	7.9 8.5	0.1	2	1	4	44	2.2	40	190 180	TO-39 TO-92	7-3
μA78M05	Fixed Positive	7.5 35	4.8 5.2	0.5	1	1	6	6.2	2.2	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
μA78M06	Fixed Positive	8.5 35	5.75 6.25	0.5	1	1	6	59	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
μA78M08	Fixed Positive	10.5 35	7.7 8.3	0.5	1	1	6	56	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
μA78M12	Fixed Positive	14.5 35	11.5 12.5	0.5	1	1	6	55	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
μA78M15	Fixed Positive	17.5 35	14.4 15.6	0.5	1	1	6	54	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
μA78M20	Fixed Positive	22.5 40	19.0 21	0.5	1	1	6	53	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22
μA78M24	Fixed Positive	26.5 40	23 25	0.5	1	1	6	50	2.3	5 25 8	70 185 80	TO-220 TO-39 Power Watt*	7-22

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VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	(°C/W) Max		Packages	Data Sheet Page
										θ_{JC}	θ_{JA}		
µA78MG	Adjustable Positive	7.5 40	5 30	0.5	0.75	1	5	62	3	25 11 8	185 80 80	TO-39 MINI DIP Power Watt*	7-102
µA78P05	Fixed Positive	25	5	10	1	1	10	60	2.5	2	38	TO-3	TBA
µA78S40	Switching	2.5 40	1.3 40	1.5			2	100			160 190	C DIP P DIP	7-128
µA7905	Fixed Negative	-7.3 -35	-4.8 -5.2	1	1	1	2	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
µA7906	Fixed Negative	-8.3 -35	-5.75 -6.25	1	1	1	2	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
µA7908	Fixed Negative	-10.3 -35	-7.7 -8.3	1	1	1	2	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
µA7912	Fixed Negative	-14.5 -35	-11.5 -12.5	1	1	1	3	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
µA7915	Fixed Negative	-17.6 -35	-14.4 -15.6	1	1	1	3	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
µA7918	Fixed Negative	-20.7 -35	-17.3 -18.7	1	1	1	3	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
µA7924	Adjustable Negative	-27 -40	-23 -25	1	1	1	3	54	2.3	5.5 5	45 65	TO-3 TO-220	7-78
µA79G	Adjustable Negative	-7 -40	-2.23 -30	1	1	1	2	50	2.3	8 6	80 47	Power Watt* TO-3	7-90
µA79HG	Adjustable Negative	-7 -40	-2.25 -24	5	1	1	5	50	2	2	38	TO-3	7-98
µA79M05	Fixed Negative	-7.5 -35	-4.8 -5.2	0.5	1	1	2	54	1	5 25	70 185	TO-220 TO-39	7-66
µA79M06	Fixed Negative	-7.35 -35	-5.75 -6.25	0.5	1	1	2	54	1	5 25	70 185	TO-220 TO-39	7-66
µA79M08	Fixed Negative	-9.4 -35	-7.7 -8.3	0.5	1	1	2	54	1	5 25	70 185	TO-220 TO-39	7-66
µA79M12	Fixed Negative	-13.6 -35	-11.5 -12.5	0.5	1	1	3	54	1	5 25	70 185	TO-220 TO-39	7-66
µA79M15	Fixed Negative	-16.7 -35	-14.4 -15.6	0.5	1	1	3	54	1	5 25	70 185	TO-220 TO-39	7-66
µA79M20	Fixed Negative	-22.1 -40	-19 -20	0.5	1	1	3.5	54	1	5 25	70 185	TO-220 TO-39	7-66

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

*Similar to TO-202

VOLTAGE REGULATOR SELECTION GUIDE BY DEVICE NUMBER

DEVICE	Function and Polarity	Input Voltage Range (V)	Output Voltage Range (V)	Output Current Max (A)	Line Regulation (%)	Load Regulation (%)	Quiescent Current (mA)	Ripple Rejection Min (dB)	Dropout Voltage Max (V)	(°C/W) Max θ_{JC}	(°C/W) Max θ_{JA}	Packages	Data Sheet Page
µA79M24	Fixed Negative	-26.1 -40	-23 -25	0.5	1	1	3.5	54	1	5 25	70 185	TO-220 TO-39	7-66
µA79MG	Adjustable Negative	-7 -30	-2.23 -30	0.5	1	1	2.5	50	2.3	25 11 8	185 80 80	TO-39 MINI DIP Power Watt*	7-102
SH123	Fixed Positive	20	5	3	2	2	10	60	2.2	2.5	38	TO-3	7-58
SH223	Fixed Positive	20	5	3	2	2	10	60	2.2	2.5	38	TO-3	7-58
SH323	Fixed Positive	20	5	3	2	2	10	60	2.2	2.5	38	TO-3	7-58
SH1605	Switching	40	2.5 20	5			30 (TYP)			3.5	1.5	TO-3	TBA
SH1705	Fixed Positive	25	5	5	1	1	10		2.2	2.5	38	TO-3	TBA

NOTE: Only commercial part numbers are listed. Military, automotive and industrial temperature range devices are available upon request. Refer to specific data sheet for details.

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VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Voltage V (Typ)	Temperature (1)	Line Regulation mV (Max)	Load Regulation mV (Max)	Ripple Rejection dB (Min)	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V (Typ)	Page
Fixed Positive 100 mA										
1	**μA78L26**	2.6	C, V	100	50	43	5.5	4.8 to 35	2.2	**7-3**
2	**μA78L05**	5.0	C, V	150	60	41	5.5	7.2 to 35	2.2	**7-3**
3	**μA78L62**	6.2	C, V	175	80	40	5.5	8.4 to 35	2.2	**7-3**
4	**μA78L82**	8.2	C, V	175	80	39	5.5	10.4 to 35	2.2	**7-3**
5	**μA78L09**	9.0	C, V	188	90	38	5.5	11.2 to 35	2.2	**7-3**
6	**μA78L12**	12	C, V	250	100	37	6.0	14.2 to 35	2.2	**7-3**
7	**μA78L15**	15	C, V	300	150	34	6.0	17.2 to 35	2.2	**7-3**
8	**μA78L18**	18	C, V	300	170	33	6.0	20.2 to 40	2.2	**7-3**
9	**μA78L24**	24	C, V	300	200	31	6.0	26.2 to 40	2.2	**7-3**
Fixed Positive 500 mA										
10	**μA78M05**	5.0	M	50	50	62	6.0	8.0 to 35	2.5	**7-22**
11	**μA78M05**	5.0	C	100	100	62	6.0	7.5 to 35	2.5	**7-22**
12	**μA78M06**	6.0	M	60	60	59	6.0	9.0 to 35	2.5	**7-22**
13	**μA78M06**	6.0	C	100	120	59	6.0	8.5 to 35	2.5	**7-22**
14	**μA78M08**	8.0	M	60	80	56	6.0	11 to 35	2.5	**7-22**
15	**μA78M08**	8.0	C	100	160	56	6.0	10.5 to 35	2.5	**7-22**
16	**μA78C08**	8.0	C, V	100	80	46	6.0	11 to 35	3.0	**7-14**
17	**μA78C10**	10	C	100	100	55	6.0	13 to 35	3.0	**7-14**
18	**μA78M12**	12	M	60	120	55	6.0	15 to 35	2.5	**7-22**
19	**μA78M12**	12	C, V	100	240	55	6.0	14.5 to 35	2.5	**7-22**
20	**μA78C12**	12	C	100	120	46	6.0	15 to 35	3.0	**7-14**
21	**μA78M15**	15	M	60	150	54	6.0	18 to 35	2.5	**7-22**
22	**μA78M15**	15	C	100	300	54	6.0	17.5 to 35	2.5	**7-22**

1 Operating junction temperature range:
C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Voltage V (Typ)	Temperature (1)	Line Regulation mV (Max)	Load Regulation mV (Max)	Ripple Rejection dB (Min)	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V (Typ)	Page
Fixed Positive 500 mA (Cont'd)										
1	**μA78C15**	15	C	100	150	46	6.0	18 to 35	3.0	7-14
2	**μA78C17**	17	C	100	170	52	6.0	20 to 35	3.0	7-14
3	**μA78C18**	18	C	100	180	46	6.0	21 to 35	3.0	7-14
4	**μA78M20**	20	M	60	200	53	6.0	23 to 40	2.5	7-22
5	**μA78M20**	20	C	100	400	53	6.0	22.5 to 40	2.5	7-22
6	**μA78C20**	20	C	100	200	46	6.0	23 to 40	3.0	7-14
7	**μA78C22**	22	C	100	220	53	6.0	24.5 to 40	2.5	7-14
8	**μA78M24**	24	M	60	240	50	6.0	27 to 40	2.5	7-22
9	**μA78M24**	24	C	100	480	50	6.0	26.5 to 40	2.5	7-22
10	**μA78C24**	24	C	100	240	46	6.0	27 to 40	3.0	7-14
Fixed Negative 500 mA										
11	**μA79M05**	-5.0	M	50	100	54	2.0	-7.5 to -35	2.5	7-22
12	**μA79M05**	-5.0	C	50	100	54	2.0	-7.3 to -35	2.3	7-22
13	**μA79M06**	-6.0	M	60	120	54	2.0	-8.5 to -35	2.5	7-22
14	**μA79M06**	-6.0	C	60	120	54	2.0	-8.3 to -35	2.3	7-22
15	**μA79M08**	-8.0	M	80	160	54	2.0	-10.5 to -35	2.5	7-22
16	**μA79M08**	-8.0	C	80	160	54	2.0	-10.3 to -35	2.3	7-22
17	**μA79M12**	-12	M	80	240	54	3.0	-14.5 to -35	2.5	7-22
18	**μA79M12**	-12	C	80	240	54	3.0	-14.3 to -35	2.3	7-22
19	**μA79M15**	-15	M	80	240	54	3.0	-17.5 to -35	2.5	7-22
20	**μA79M15**	-15	C	80	240	54	3.0	-17.3 to -35	2.3	7-22
21	**μA79M20**	-20	M	80	300	54	3.5	-22.5 to -40	2.5	7-22
22	**μA79M20**	-20	C	80	300	54	3.5	-22.3 to -40	2.3	7-22
23	**μA79M24**	-24	M	80	300	54	3.5	-26.5 to -40	2.5	7-22
24	**μA79M24**	-24	C	80	300	54	3.5	-26.3 to -40	2.3	7-22

1. Operating junction temperature range:
C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Voltage V (Typ)	Temperature (1)	Line Regulation mV (Max)	Load Regulation mV (Max)	Ripple Rejection dB (Min)	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V (Typ)	Page
Fixed Positive 1.0 A										
1	**μA7805**	5.0	M	50	50	68	6.0	8.0 to 35	3.0	7-34
2	**μA7805**	5.0	C	100	100	62	8.0	7.5 to 35	2.5	7-34
3	**μA309**	5.0	C	50	100	—	10	—	—	7-51
4	**μA109**	5.0	M	50	100	—	10	—	—	7-47
5	**μA209**	5.0	V	50	100	—	10	—	—	7-47
6	**μA7806**	6.0	M	60	60	65	6.0	9.0 to 35	3.0	7-34
7	**μA7806**	6.0	C	120	120	59	8.0	8.5 to 35	2.5	7-34
8	**μA7808**	8.0	M	80	80	62	6.0	11 to 35	3.0	7-34
9	**μA7808**	8.0	C	160	160	56	8.0	10.5 to 35	2.5	7-34
10	**μA7885**	8.5	M	85	85	60	6.0	11.5 to 35	3.0	7-34
11	**μA7885**	8.5	C	170	170	54	8.0	11 to 35	2.5	7-34
12	**μA7812**	12	M	120	120	61	6.0	15 to 35	3.0	7-34
13	**μA7812**	12	C	240	240	55	8.0	14.5 to 35	2.5	7-34
14	**μA7815**	15	M	150	150	60	6.0	18 to 35	3.0	7-34
15	**μA7815**	15	C	300	300	54	8.0	17.5 to 35	2.5	7-34
16	**μA7818**	18	M	180	180	59	6.0	21 to 35	3.0	7-34
17	**μA7818**	18	C	360	360	53	8.0	20.5 to 35	2.5	7-34
18	**μA7824**	24	M	240	240	56	6.0	27 to 40	3.0	7-34
19	**μA7824**	24	C	480	480	50	8.0	26.5 to 40	2.5	7-34
Fixed Negative 1.0 A										
20	**μA7905**	-5.0	M	50	50	54	2.0	-7.8 to -35	2.8	7-78
21	**μA7905**	-5.0	C	100	100	54	2.0	-7.3 to -35	2.3	7-78
22	**μA7906**	-6.0	M	60	60	54	2.0	-8.8 to -35	2.8	7-78
23	**μA7906**	-6.0	C	120	120	54	2.0	-8.3 to -35	2.3	7-78
24	**μA7908**	-8.0	M	80	80	54	2.0	-10.8 to -35	2.8	7-78

1 Operating junction temperature range:
C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Voltage V (Typ)	Temperature (1)	Line Regulation mV (Max)	Load Regulation mV (Max)	Ripple Rejection dB (Min)	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V (Typ)	Page
Fixed Negative 1.0 A (Cont'd)										
1	**μA7908**	-8.0	C	160	160	54	2.0	-10.3 to -35	2.3	7-78
2	**μA7912**	-12	M	120	120	54	3.0	-14.8 to -35	2.8	7-78
3	**μA7912**	-12	C	240	240	54	3.0	-14.3 to -35	2.3	7-78
4	**μA7915**	-15	M	150	150	54	3.0	-17.8 to -35	2.8	7-78
5	**μA7915**	-15	C	300	300	54	3.0	-17.3 to -35	2.3	7-78
6	**μA7918**	-18	M	180	180	54	3.0	-20.8 to -35	2.8	7-78
7	**μA7918**	-18	C	360	360	54	3.0	-20.3 to -35	2.3	7-78
8	**μA7924**	-24	M	240	240	54	3.0	-26.8 to -40	2.8	7-78
9	**μA7924**	-24	C	480	480	54	3.0	-26.3 to -40	2.3	7-78
Fixed Positive 2.0 A										
10	**μA78CB**	13.8	C	150	150	50	8.0	17 to 25	2.5	7-54
Fixed Positive 3.0 A										
11	**SH123**	5.0	M	25	100	—	20	7.5 to 20	2.5	7-58
12	**SH223**	5.0	M	25	100	—	20	7.5 to 20	2.5	7-58
13	**SH323**	5.0	C	25	100	—	20	7.5 to 20	2.5	7-58
Fixed Positive 5.0 A										
14	**μA78H05**	5.0	C, M	120	50	60	10	8.5 to 25	3.5	7-60
15	***μA78H05A**	5.0	C, M	25	50	60	10	7.8 to 2.5	2.3	TBA
16	**μA78H12**	12	C	—	120	60	10	15.5 to 25	3.5	7-60
17	**μA78H15**	15	C	30	30	60	10	18.5 to 25	—	7-60
Fixed Positive 10 A										
18	***μA78P05**	5.0	C	25	50	60	10	7.5 to 40	2.5	TBA

1 Operating junction temperature range:
C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

* To be announced

VOLTAGE REGULATOR SELECTION GUIDE BY OUTPUT CURRENT

Item	DEVICE NO.	Output Current (mA)	Output Voltage Range V	Temperature (1)	Line Regulation $\%V_{OUT}$	Load Regulation $\%V_{OUT}$	Ripple Rejection dB	Quiescent Current mA	Input Voltage Range V	Dropout Voltage V	Page
Positive Adjustable											
1	**μA105**	12	4.5 to 30	M	0.06	0.1	1.0	2.0	8.5 to 50	3.0	**7-117**
2	**μA305**	12	4.5 to 30	C	0.06	0.1	1.0	2.0	8.5 to 40	3.0	**7-117**
3	**μA376**	25	5.0 to 37	C	0.1	0.5	1.0	2.5	9.0 to 40	3.0	**7-117**
4	**μA305A**	45	4.5 to 40	C	0.06	0.4	—	2.0	8.5 to 50	3.0	**7-117**
5	**μA723**	150	2.0 to 37	M	0.3	0.15	58	3.5	9.5 to 40	3.0	**7-110**
6	**μA723**	150	2.0 to 37	C	0.5	0.2	58	4.0	9.5 to 40	3.0	**7-110**
7	**μA78MG**	500	5.0 to 30	M	1.0	1.0	62	5.0	7.5 to 40	3.0	**7-102**
8	**μA78MG**	500	5.0 to 30	C	1.0	1.0	62	5.0	7.5 to 40	2.5	**7-102**
9	**μA78G**	1000	5.0 to 30	M	1.0	1.0	68	5.0	7.5 to 40	2.5	**7-90**
10	**μA78G**	1000	5.0 to 30	C	1.0	1.0	62	5.0	7.5 to 40	3.0	**7-90**
11	**μA78HG**	5000	5.0 to 24	C	1.0	1.0	60	10	8.5 to 25	3.5	**7-60**
Negative Adjustable											
12	**μA104**	25	-0.015 to -40	M	0.1	5mV	1.0	5.0	-8.0 to -50	2.0	**7-123**
13	**μA304**	25	-0.035 to -30	C	0.1	5mV	1.0	5.0	-8.0 to -40	2.0	**7-123**
14	**μA79MG**	500	-2.23 to -30	M	1.0	1.0	50	2.5	-7.0 to -30	2.5	**7-102**
15	**μA79MG**	500	-2.23 to -30	C	1.0	1.0	50	2.5	-7.0 to -30	2.3	**7-102**
16	**μA79G**	1000	-2.23 to -30	M	1.0	2.0	50	2.0	-7.0 to -40	2.8	**7-90**
17	**μA79G**	1000	-2.23 to -30	C	1.0	2.0	50	2.0	-7.0 to -40	2.3	**7-90**
18	**μA79HG**	5000	-2.25 to -24	C,M	1.0	1.0	50	5.0	-7.0to -40	2.0	**7-98**
Adjustable Switching Regulator											
19	**μA78S**	1500	-1.3 to -40	M	—	—	100	2.0	-2.5 to -40	—	**7-128**
20	**μA78S**	1500	-1.3 to -40	C	—	—	100	2.0	-2.5 to - 40	—	**7-128**

1 Operating junction temperature range:
C = Commercial temperature range, 0°C to +125°C; V = Vehicular & Industrial temperature range, -40°C to +125°C; M = Extended Military, -55°C to +150°C.

IC VOLTAGE REGULATORS INDUSTRY CROSS REFERENCE

Type Number	Fairchild Equivalent
MOTOROLA	
MC1723GC	μA723HC
MC1723G	μA723HM
MC1723LC	μA723DC
MC1723L	μA723DM
MC7805CK	μA7805KC
MC7805CP	μA7805UC
MC7806CK	μA7806KC
MC7806CP	μA7806UC
MC7808CK	μA7808KC
MC7808CP	μA7808UC
MC7812CK	μA7812KC
MC7812CP	μA7812UC
MC7815CK	μA7815KC
MC7815CP	μA7815UC
MC7818CK	μA7818KC
MC7818CP	μA7818UC
MC7824CK	μA7824KC
MC7824CP	μA7824UC
MC78G00CK	μA78GKC
MC78G00CT**	μA78GU1C
MC78G00K	μA78GKM
MC78L02CP	μA78L26AWC
MC78L05CP	μA78L05AWC
MC78L06CP	μA78L06AWC
MC78L08CP	μA78L82AWC
MC78L12CP	μA78L12AWC
MC78L13CP	μA78L15AWC
MC78L18CP	μA78L18AWC
MC78L24CP	μA78L24AWC
MC78M05CG	μA78M05HC
MC78M05CP	μA78M05UC
MC78M06CG	μA78M06HC
MC78M06CP	μA78M06UC
MC78M08CG	μA78M08HC
MC78M08CP	μA78M08UC
MC78M12CG	μA78M12HC
MC78M12CP	μA78M12UC
MC78M15CG	μA78M15HC
MC78M15CP	μA78M15UC
MC78M20CG	μA78M20HC
MC78M20CP	μA78M20UC
MC78M24CG	μA78M24HC
MC78M24CP	μA78M24UC
MC7905CK	μA7905KC
MC7905CP	μA7905UC
MC7906CK	μA7906KC
MC7906CP	μA7906UC
MC7908CK	μA7908KC
MC7908CP	μA7908UC
MOTOROLA (Cont'd)	
MC7912CK	μA7912KC
MC7912CP	μA7912UC
MC7915CK	μA7915KC
MC7915CP	μA7915UC
MC7924CK	μA7924KC
MC7924CP	μA7924UC
MC79G00CK	μA79GKC
MC79G00CT**	μA79GU1C
MC79G00K	μA79GKM
MLM104G	μA104HM
MLM105G	μA105HM
MLM109K	μA109KM
MLM205G	μA305HC
MLM209K	μA209KM
MLM304G	μA304HC
MLM305	μA305AHC
MLM309K	μA309KC
NATIONAL	
LM104H	μA104HM
LM105H	μA105HM
LM109K	μA109KM
LM120K-5	μA7905KM
LM120K-6	μA7906KM
LM120K-8	μA7908KM
LM120K-12	μA7912KM
LM120K-15	μA7915KM
LM120K-24	μA7924KM
LM140K-5	μA7805KM
LM140K-6	μA7806KM
LM140K-8	μA7808KM
LM140K-12	μA7812KM
LM140K-15	μA7815KM
LM140K-18	μA7818LM
LM140K-24	μA7824KM
LM209K	μA209KM
LM304H	μA304HC
LM305AH	μA305AHC
LM305H	μA305HC
LM309K	μA309KC
LM320KC-5	μA7905KC
LM320KC-6	μA7906KC
LM320KC-8	μA7908KC
LM320KC-12	μA7912KC
LM320KC-15	μA7915KC
LM320KC-24	μA7924KC
LM320MP-5*	μA79M05AUC
LM320MP-6*	μA79M06AUC
LM320MP-8*	μA79M08AUC
NATIONAL (Cont'd)	
LM320MP-12*	μA79M12AUC
LM320MP-15*	μA79M15AUC
LM320MP-24*	μA79M24AUC
LM320T-5	μA7905UC
LM320T-6	μA7906UC
LM320T-8	μA7908UC
LM320T-12	μA7912UC
LM320T-15	μA7915UC
LM320T-24	μA7924UC
LM340K-8	μA7808KC
LM340K-12	μA7812KC
LM340K-15	μA7815KC
LM340K-18	μA7818KC
LM340K-24	μA7824KC
LM340T-6	μA7806UC
LM340T-8	μA7808UC
LM340T-12	μA7812UC
LM340T-15	μA7815UC
LM340T-18	μA7818UC
LM341P-5*	μA78M05UC
LM341P-6*	μA78M06UC
LM341P-8*	μA78M08UC
LM341P-12*	μA78M12UC
LM341P-15*	μA78M15UC
LM341P-24*	μA78M24UC
LM376N	μA376TC
LM723CD	μA732DC
LM723D	μA723DM
LM723CH	μA723HC
LM723CN	μA723PC
LM723H	μA723HM
LM7805KC	μA7805KC
LM7806KC	μA7806KC
LM7808KC	μA7808KC
LM7812KC	μA7812KC
LM7815KC	μA7815KC
LM7818KC	μA7818KC
LM7824KC	μA7824KC
LM78L05ACH	μA78L05AHC
LM78L05ACZ	μA78L05AWC
LM78L06ACH	μA78L06AHC
LM78L06ACZ	μA78L06AWC
LM78L08ACH	μA78L82AHC
LM78L08ACZ	μA78L82AWC
LM78L12ACH	μA78L12AHC
LM78L12ACZ	μA78L12AWC
LM78L15ACH	μA78L15AHC
LM78L15ACZ	μA78L15AWC
LM78L18ACH	μA78L18AHC

** Not Available is VIC package
* Not a direct replacement

IC VOLTAGE REGULATORS INDUSTRY CROSS REFERENCE

Type Number	Fairchild Equivalent
NATIONAL (Cont'd)	
LM78L18ACZ	μA78L18AWC
LM78L24ACH	μA78L18AHC
LM78L24ACZ	μA78L24AWC
LM7905T	μA7905UC
LM7906T	μA7906UC
LM7908T	μA7908UC
LM7912T	μA7912UC
LM7915T	μA7915UC
LM7924T	μA7924UC
μA723CK	μA723HC
μA723F	μA723DM
μA723K	μA723HM
μA7805CDA	μA7805KC
μA7805CU	μA7805UC
μA7805DA	μA7805KM
μA7806CDA	μA7806KC
μA7806CU	μA7806UC
μA7806CDA	μA7806KM
μA7808CDA	μA7808KC
μA7808CU	μA7808UC
μA7808DA	μA7808KM
μA7812CDA	μA7812KC
μA7812CU	μA7812UC
μA7812DA	μA7812KM
μA7815CDA	μA7815KC
μA7815CU	μA7815UC
μA7815DA	μA7815KM
μA7818CDA	μA7818KC
μA7818CU	μA7818UC
μA7818DA	μA7818KM
μA7824CDA	μA7824KC
μA7824CU	μA7824UC
μA7824DA	μA7824KM
μA78GU1C	μA78GU1C
μA78L02ACDB	μA78L26AHC
μA78L02ACS	μA78L26AWC
μA78L05ACDB	μA78L05AHC
μA78L05ACS	μA78L05AWC
μA78L06ACDB	μA78L06AHC
μA78L06ACS	μA78L06AWC
μA78L08ACDB	μA78L82AHC
μA78L08ACS	μA78L82AWC
μA78L12ACDB	μA78L12AHC
μA78L12ACS	μA78L12AWC
μA78L15ACDB	μA78L15AHC
μA78L15ACS	μA78L15AWC
μA78M05CDB	μA78M05HC

Type Number	Fairchild Equivalent
SIGNETICS (Cont'd)	
μA78M05CU	μA78M05UC
μA78M05DB	μA78M05HM
μA78M06CDB	μA78M06HC
μA78M06CU	μA78M06UC
μA78M06DB	μA78M06HM
μA78M08CDB	μA78M08HC
μA78M08CU	μA78M08UC
μA78M08DB	μA78M08HM
μA78M12CDB	μA78M12HC
μA78M12CU	μA78M12UC
μA78M12DB	μA78M12HM
μA78M15CDB	μA78M15HC
μA78M15CU	μA78M15UC
μA78M15DB	μA78M15HM
μA78M20CDB	μA78M20HC
μA78M20CU	μA78M20UC
μA78M20DB	μA78M20HM
μA78M24CDB	μA78M24HC
μA78M24CU	μA78M24UC
μA78M24DB	μA78M24HM
μA78MGU1C	μA78MGU1C
μA79GU1C	μA79GU1C
μA79MGU1C	μA79MGU1C
LM109DA	μA109KM
LM209DA	μA209KM
LM309DA	μA309KC
TEXAS INSTRUMENTS	
LM104L	μA104HM
LM105L	μA105HM
LM304L	μA304HC
LM305AL	μA305AHC
LM305L	μA305HC
LM376P	μA376TC
μA723CL	μA723HC
μA723CJ	μA723DC
μA723CN	μA723PC
μA723ML	μA723HM
μA723MJ	μA723DM
μA7805CKC	μA7805KC
μA7805MKA	μA7895KM
μA7805CKC	μA7805UC
μA7806CKC	μA7806KC
μA7806MKA	μA7806KM
μA7806CKC	μA7806UC
μA7808CKA	μA7808KC
μA7808MKA	μA7808KM
μA7808CKC	μA7808UC
μA7812CKA	μA7812KC

Type Number	Fairchild Equivalent
TEXAS INSTRUMENTS (Cont'd)	
μA7812MKA	μA7812KM
μA7812CKC	μA7812UC
μA7815CKA	μA7815KC
μA7815MKA	μA7815KM
μA7815CKC	μA7815UC
μA7818CKC	μA7818KC
μA7818MKA	μA7818KM
μA7818CKC	μA7818UC
μA7824CKC	μA7824KC
μA7824MKM	μA7824KM
μA7824CKC	μA7824UC
μA78GC	μA78GU1C
μA78L02ACLP	μA78L26AWC
μA78L05ACLP	μA78L05AWC
μA78L06ACLP	μA78L62AWC
μA78L08ACLP	μA78L82AWC
μA78L12ACLP	μA78L12AWC
μA78L15ACLP	μA78L15AWC
μA78M05CKC	μA78M05UC
μA78M05CLA	μA78M05KC
μA78M05MLA	μA78M05KM
μA78M06CKC	μA78M06UC
μA78M06CLA	μA78M06KC
μA78M06MLA	μA78M06KM
μA78M08CKC	μA78M08UC
μA78M08CLA	μA78M08KC
μA78M08MLA	μA78M08KM
μA78M12CKC	μA78M12UC
μA78M12CLA	μA78M12KC
μA78M12MLA	μA78M12KM
μA78M15CKC	μA78M15UC
μA78M15CLA	μA78M15KC
μA78M15MLA	μA78M15KM
μA78M20CKC	μA78M20UC
μA78M20CLA	μA78M20KC
μA78M20MLA	μA78M20KM
μA78M24CKC	μA78M24UC
μA78M24CLA	μA78M24KC
μA78M24MLA	μA78M24KM
μA78MGC	μA78MGU1C
μA7905CKA	μA7905KC
μA7905CKC	μA7905UC
μA7905MKA	μA7905KM
μA7906CKA	μA7906KC
μA7906CKC	μA7906UC
μA7906MKA	μA7906KM
μA7908CKA	μA7908KC
μA7908CKC	μA7908UC
μA7908MKA	μA7908KM

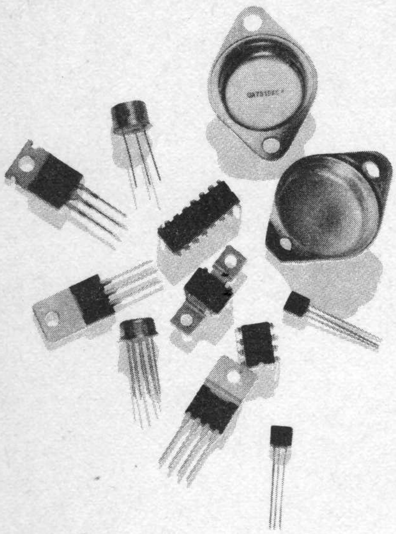
IC VOLTAGE REGULATORS INDUSTRY CROSS REFERENCE

Type Number	Fairchild Equivalent	Type Number	Fairchild Equivalent	Type Number	Fairchild Equivalent
TEXAS INSTRUMENTS (Cont'd)		**TEXAS INSTRUMENTS** (Cont'd)		**TEXAS INSTRUMENTS** (Cont'd)	
μA7912CKA	μA7912KC	μA79M05CKC	μA79M05AUC	SN52109LA***	μA109KM
μA7912CKC	μA7912UC	μA79M06CKC	μA79M06AUC	SN52723J	μA723DM
μA7912MKA	μA7912KM	μA79M08CKC	μA79M08AUC	SN52723L	μA723HM
μA7915CKA	μA7915KC	μA79M12CKC	μA79M12AUC	SN72304L	μA304HC
μA7915CKC	μA7915UC	μA79M15CKC	μA79M15AUC	SN72305L	μA305HC
μA7915MKA	μA7915KM	μA79M20CKC	μA79M20AUC	SN72305AL	μA305AHC
μA7924CKA	μA7924KC	μA79M24CKC	μA79M24AUC	SN72309LA***	μA309KC
μA7924CKC	μA7924UC	μA79MGC	μA79MGU1C	SN72376P	μA376TC
μA7924MKA	μA7924KM	SN52104L	μA104HM	SN72723J	μA723DC
μA79GC	μA79GU1C	SN52105L	μA105HM	SN72723L	μA723HC
				SN72723N	μA723PC

Voltage Regulators to be Announced

TEXAS INSTRUMENTS	FAIRCHILD EQUIVALENT
TL430	μA430
NATIONAL SEMICONDUCTORS	**FAIRCHILD EQUIVALENT**
LM117	μA117
LM317	μA317
LM320	μA320
LM340	μA340

***Available in TO-5 type can only



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IC VOLTAGE REGULATORS

Chapter 1

IC VOLTAGE REGULATORS

IC regulators have eliminated the tedious and repetitive task of designing power supply circuits. Today, the designer has a wide choice of fixed or adjustable series-type regulators with either positive or negative output voltages from 2.6 to 30 V and current capabilities from 10 mA to 2 A, as well as an increasing number of switching regulators. Built-in protection circuits improve reliability and make IC regulators virtually immune to failure modes normally encountered when dealing with discrete voltage regulators. This chapter describes the internal circuit features of series-type regulators and the circuit description of the various series regulators offered by Fairchild followed by switching regulator theory and a description of the 78S40 switching regulator.

1

INTERNAL CIRCUIT FEATURES

Figure 1-1 shows a block diagram of a typical series-type IC voltage regulator in which an error amplifier compares a reference voltage V_{REF} with a fraction of the output voltage derived from the feedback resistors R_A and R_B. The error amplifier provides the necessary base drive to the series-pass element to maintain a constant output voltage level regardless of changes in input voltage or output current levels.

To assure a stable reference immune to line voltage and temperature variations, the voltage reference is usually fed from a constant current source. If the current source is not self-starting, some type of start-up circuit must be used. In addition to these basic blocks, most regulators have protection circuits to guard against accidental shorts, excessive input-output differentials and thermal overloads.

Voltage Reference Circuit

The voltage reference is the most important part of the regulator since any abnormality observed in the reference will also be seen at the output. Therefore, it must be stable, free of noise, and must have a low temperature drift. It should also be reproducible with little variation in absolute value from device to device. Zener reference and band-gap or differential V_{BE} are the most widely used references in regulators with the band-gap type the less noisy of the two.

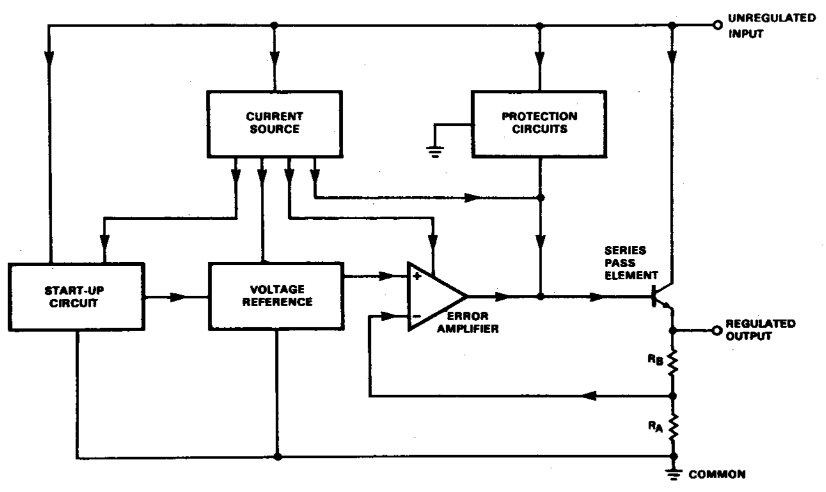


Fig. 1-1 Block Diagram of a Series-Type Voltage Regulator

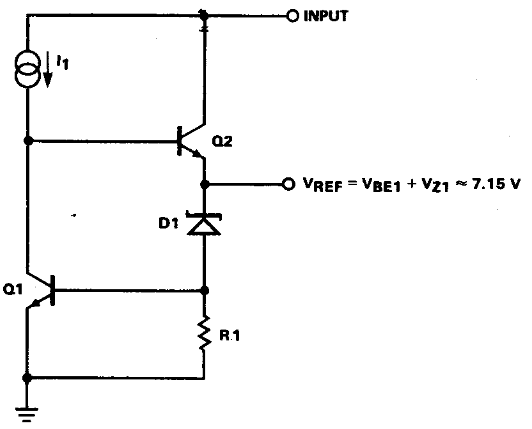


Fig. 1-2 μA723 Reference

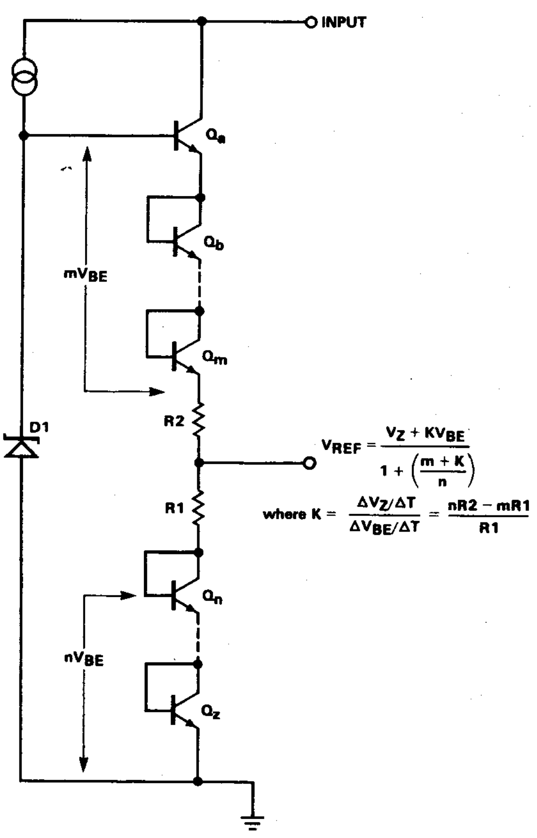


Fig. 1-3 Zener Voltage Reference Compensation Technique Using Several Base-Emitter Diodes

Zener References

The μA723, the μA78C00 series, the negative series μA7900 regulators as well as the μA104/105 have Zener voltage reference elements. There are various ways of obtaining the required temperature stability but the basic principles are the same. The technique is to compensate the positive temperature coefficient of a Zener diode with the negative coefficient of a base-emitter diode or diodes.

Figure 1-2 shows the voltage reference used in the μA723 regulator. The current through the Zener diode D1 is set by resistor R1. The temperature coefficient of the Q1 base-emitter voltage V_{BE1} is determined by Q1 collector current, which is set by the current source I_1. The lower the value of I_1 the higher the temperature coefficient of V_{BE1}. Therefore, I_1 is set to cancel the positive temperature coefficient of D1, thus yielding a nominal reference of about 7.15 V.

Another Zener-derived reference is shown in *Figure 1-3*. Here, temperature compensation is achieved via a string of diodes; m represents the number of diodes in the top portion of the circuit and n represents the number in the bottom portion. The junction of R2 and transistor Qm has a positive temperature coefficient, while the junction of R1 and Qn has a negative temperature coefficient. The reference point V_{REF} is selected to give a temperature stable reference.

$$V_{REF} = [\,V_Z - (m\,V_{BE} + n\,V_{BE})\,]\,\frac{R1}{R1 + R2} + n\,V_{BE} \tag{1-1}$$

And simplifying

$$V_{REF} = \frac{R1\,V_Z + (n\,R2 - m\,R1)\,V_{BE}}{R1 + R2} \tag{1-2}$$

For a temperature stable reference

$$\frac{\Delta V_{REF}}{\Delta T} = 0$$

1

Assuming resistors R1 and R2 have the same temperature coefficient

$$\frac{\Delta V_{REF}}{\Delta T} = \frac{R1 + (n\,R2 - m\,R1)}{R1 + R2} \tag{1-3}$$

To achieve a stable reference, therefore

$$R1\,\frac{\Delta V_Z}{\Delta T} = -\,(n\,R2 - m\,R1)\,\frac{\Delta V_{BE}}{\Delta T} \tag{1-4}$$

or

$$\frac{R1}{R2} = \frac{n}{m + K} \tag{1-5}$$

where

$$K = \frac{-\dfrac{\Delta V_Z}{\Delta T}}{\dfrac{\Delta V_{BE}}{\Delta T}} = \frac{n\,R2 - m\,R1}{R1} \tag{1-6}$$

Substituting these values of K and $\frac{R1}{R2}$ in *Equation 1-2*

$$V_{REF} = \frac{V_Z + KV_{BE}}{1 + \dfrac{(m + K)}{n}} \tag{1-7}$$

Both of these Zener-derived voltage references offer some advantages. The circuit in *Figure 1-2* provides a higher reference voltage, approximately 7.15 V, which is buffered. Therefore, the user can draw some current out of the reference terminal without appreciably affecting the reference. The circuit in *Figure 1-3* is more complex but it offers a wide range of low voltage references. This reference has a high output impedance since it is not buffered, therefore no current can be drawn out without degrading the regulator.

Band-Gap References

Each of the μA7800, μA78M and μA78L positive regulators has a band-gap voltage reference derived from the predictable temperature, current and voltage relationship in a base-emitter junction. To obtain a temperature-compensated reference voltage, the positive temperature coefficient of the emitter-base voltage differential between two transistors, operated at different current densities, is added to the negative temperature coefficient of the emitter-base voltage (see *Figure 1-4a*). Transistor Q1 operates at a considerably higher current density than Q2. The base-emitter differential voltage ΔV_{BE} appears across R3. Transistor Q2 is a gain stage and thus develops a voltage drop across R2 that is proportional to the drop

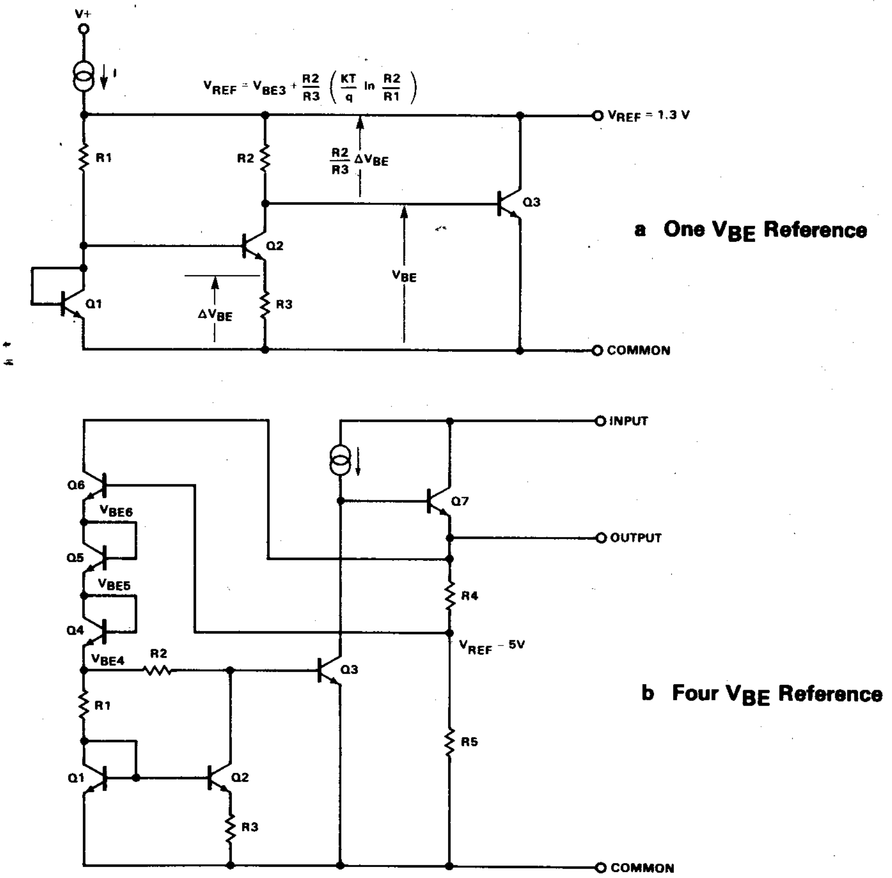


Fig. 1-4 Band-gap or Differential V_{BE} Voltage References

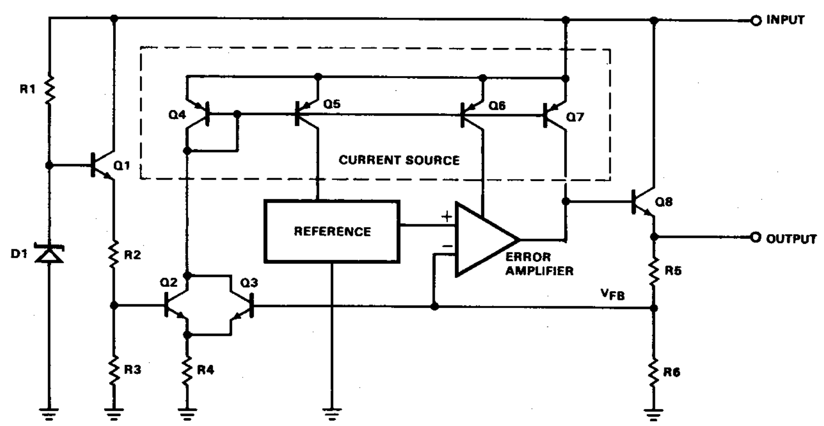


Fig. 1-5 Typical Regulator Start-Up Circuit

across R3. Transistor Q3 provides additional gain and adjusts the reference voltage V_{REF} to a value equal to the Q3 base-emitter drop plus the voltage across R2. The reference voltage can thus be expressed as

$$V_{REF} = V_{BE3} + V_{R2} = V_{BE3} + \frac{R2}{R3} \Delta V_{BE} + I_{B3} R2 \tag{1-8}$$

Neglecting the drop due to the Q3 base current

$$V_{REF} \cong V_{BE3} + \frac{R2}{R3} \frac{kT}{q} \ln \frac{J1}{J2} \tag{1-9}$$

where J = Current density; T = ° Kelvin; k = Boltzmann constant; q = Electron Charge

To obtain a temperature stable reference, $\Delta V_{REF}/\Delta T$ must be set to zero, or

$$\frac{\Delta V_{REF}}{\Delta T} = \frac{\Delta V_{BE3}}{\Delta T} + \frac{R2}{R3} \frac{k}{q} \ln \frac{J1}{J2} = 0 \tag{1-10}$$

Assuming $V_{BE1} = V_{BE3}$, the following must be satisfied

$$\frac{\Delta V_{BE3}}{\Delta T} = -\frac{R2}{R3} \frac{k}{q} \ln \frac{J1}{J2} = -\frac{R2}{R3} \frac{k}{q} \ln \frac{R2}{R1} \tag{1-11}$$

where $\Delta V3_{BE3}/\Delta T$ is the negative temperature coefficient of the Q3 base-emitter voltage, k/q ln J1/J2 is the positive temperature coefficient of the base-emitter differential voltage of Q1 and Q2.

Therefore, by selecting the resistor ratios R2/R3 and R2/R1, a temperature compensated reference of about 1.3 V is obtained. This reference is used in the μA78L00-series regulators.

To obtain a higher voltage reference, additional diodes can be added in series as shown in *Figure 1-4b*. The reference then becomes:

$$V_{REF} = V_{BE3} + V_{BE4} + V_{BE5} + V_{BE6} + \frac{R2}{R3} \frac{kT}{q} \ln \frac{R2}{R1} \tag{1-12}$$

Resistors R1, R2 and R3 are selected so that the reference voltage is constant over the temperature range and also has a nominal value of 5 V at room temperature. This reference is used in the μA7800/78M00-series positive regulators.

Current Sources

Stable current sources can easily be realized in monolithic circuits by taking advantage of the good matching and tracking capability of monolithic components. Also, the IC designer can add as many active devices as necessary without significantly increasing die area. A variety of current sources can be designed by scaling emitter areas, thus removing much of the dependence on absolute resistor values.

Operation of the reference circuit at a constant current level reduces fluctuations due to line-voltage variations in the reference voltage and therefore in the output. The error amplifier is operated at a constant current to reduce line-voltage induced errors or offsets at the output. The drive for the output stage is also made constant to insure device operation over the intended line voltage and temperature ranges. In addition, the use of constant currents throughout the regulator causes the quiescent current to remain relatively constant with line voltage and temperature variations.

Start-up Circuit

Certain current sources in regulator circuits are derived from the regulated output and, as a result, are not self-starting. They, therefore, require some additional circuits to initiate and maintain the flow of current independent of output conditions. *Figure 1-5* shows a typical start-up circuit. Zener diode D1 and the emitter-follower transistor Q1 provide a fixed voltage at the base of Q2 through the divider network of R2 and R3. When power is first applied to the circuit, collector and base currents of Q4 flow through Q2. Once Q4 conducts, Q5, Q6 and Q7 also conduct and a regulated output is obtained. Normally, the bias at the base of Q2 is set to a level lower than the reference voltage. Thus, when a regulated output is obtained, Q3 turns on and Q2 turns off, diverting the collector and base currents of Q4 through the Q3 collector. The feedback voltage V_{FB}, the base-emitter voltage of Q3, and R4 set the pnp current sources Q4, Q5, Q6 and Q7.

Protection Circuits

Protective circuits are added on chip to improve reliability and to make regulators immune to certain types of overloads. They protect the regulators against short circuit conditions (current limit), against excessive input-output voltage differential conditions (safe area limit) and against excessive junction temperatures (thermal limit).

Current Limit or Short-Circuit Protection

The most commonly used protection scheme is current limiting for guarding the output series-pass transistor against excessive output currents or short circuit conditions (see *Figure 1-6*). With low input-output conditions when Zener diode D1 is not conducting, there is no current flowing through R1. The current limiting transistor Q2, then, senses the voltage drop across the current limiting resistor R3. As the output current increases, the drop across R3 increases; and, as a result, the Q2 base-emitter voltage increases until Q2 begins to conduct thereby removing the base drive of the series-pass transistor Q1. No additional output current can be pulled out since any increase in the output current will cause Q2 to conduct harder. This current-limit circuit has a slight disadvantage, *i.e.,* the voltage developed across R3 adds to the regulator drop-out voltage and degrades the load regulation and output impedance.

A simple way of getting around this problem is to pre-bias the base of the current-limit transistor Q2 with a fraction of the base-emitter voltage of the series-pass transistor Q1 via R6 and R7 as shown in *Figures 1-7a* and *b*. In these three current-limit schemes, the output current decreases with increasing temperature since the base-emitter voltage of the current-limit transistor Q2 is the threshold for preventing the flow of additional regulator output current.

Temperature-independent short-circuit current can be achieved with a slight increase in circuit complexity. *Figure 1-7c* shows the circuit used in the μA79M00-series negative regulators to obtain temperature independent peak output current. At low to medium output current levels, Q4 is on and Q5 and Q6 are off. When the voltage drop across R3 reaches a predetermined level, Q4 begins to turn off and current is diverted to Q5, which in turn causes Q6 to turn on. Q1 and consequently Q2 base currents are thus diverted and the output current is prevented from increasing any further. By proper choice of R1:R2 and emitter area ratio of Q4 and Q5, the peak current is set to be independent of temperature.

Safe Operating Area (SOA) Protection*

Safe area protection is included in IC regulators to protect the series-pass transistor against excessive power dissipation by reducing the collector current as the collector-emitter voltage is increased (*Figure 1-6*). When the input-output voltage differential exceeds the breakdown voltage differential of Zener diode D1, current flows from the input to the output through D1, R1, R2 and R3. The voltage drop across R3 and, therefore, the Q2 base voltage become a function of not only the output current but also the input-output voltage differential. Hence, maximum output current is available when the input-output voltage differential is less than the D1 breakdown voltage. The safe area protection network reduces the available output current I_{OUT} as the input-output differential $\Delta(V_{IN}-V_{OUT})$ increases at a rate determined by

$$\frac{\Delta I_{OUT}}{\Delta(V_{IN} - V_{OUT})} = -\frac{R2}{R1\,R3} \tag{1-13}$$

*See Chapter 5

The safe area protection network thus reduces the available output current as the input-output differential increases and limits the regulator operation to within the safe operating area of the series-pass transistor. Note that the safe area protection network is lumped in with the short circuit protection network and consequently both have the same temperature characteristics.

When selecting a regulator to operate with high input voltage or with high input-output voltage differential, it must be remembered that output current *decreases* with *increased* input-output voltage differential. Under heavy load and high input-voltage conditions, the safe area protection circuit may cause a high

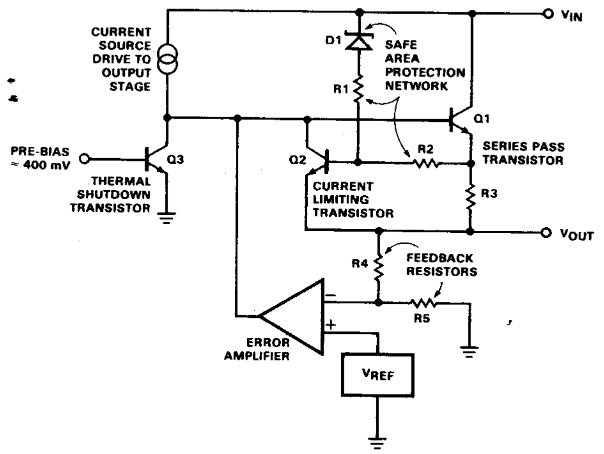


Fig. 1-6 Basic Regulator Protection Circuit

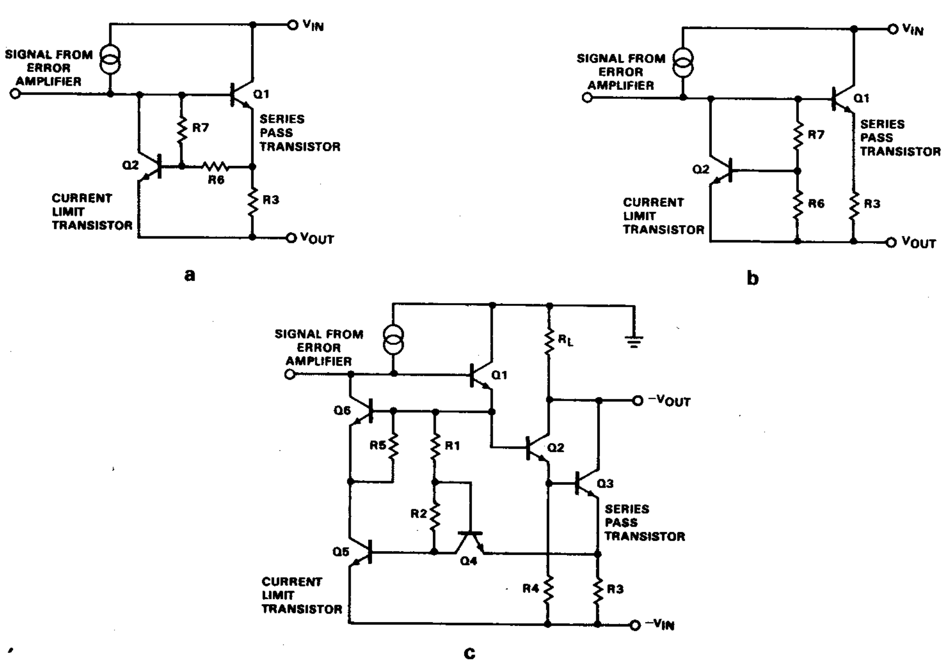


Fig. 1-7 Alternate Current Limit Circuits

output voltage device to latch up after a momentary short, since the input voltage becomes the input-output differential during the short. The regulator may not be able to supply as much current after the fault condition as before. Latching will not damage the regulator; interrupting the power, reducing the load current or the input voltage momentarily will restore normal operation.

Thermal Overload Protection

A discrete regulator usually relies on current limiting for overload protection since there is no practical way to sense junction temperature in a separate series-pass transistor. The dominant failure mechanism of this type of regulator, then, is excessive heating of the series-pass transistor. In a monolithic regulator, the series-pass transistor is contained within the thermal overload-protection circuit where its maximum junction temperature is limited, independent of input voltage, type of overload or degree of package heat sinking. It is, therefore, considerably more effective than current limiting by itself. An added bonus to combined thermal and current overload protection is that a higher output current level under normal conditions can be considered, since there is no excessive regulator heating when a load fault occurs.

The base-emitter junction of a transistor placed as close as practical to the series-pass transistor is used to sense the chip temperature. The thermal shutdown transistor Q3 in *Figure 1-6* is normally biased below its activation threshold so that it does not affect normal operation of the circuit. However, if the chip temperature rises above its maximum limit due to an overload, inadequate heat sinking or other condition, the thermal shutdown transistor turns on, removing the base drive to the output transistor Q1 and shutting down the regulator to prevent any further chip heating.

Error Amplifier

The error amplifier in a regulator can be a simple gain stage or can consist of several amplifier stages depending on the regulator performance. It is an operational amplifier used in a negative feedback mode where the reference is connected to the non-inverting input while the feedback signal from the regulated output is divided down through a pair of feedback resistors (R4 and R5 in *Figure 1-6*). The output voltage in this type of feedback configuration is

$$V_{OUT} = V_{REF} \frac{A}{\beta(1 + A)}$$

where A is the amplifier gain and β is the fraction of the output feedback or $\beta = \frac{R5}{R4+R5}$

Improved line and load regulation in regulators results from higher gain. As the amplifier gain is increased, the output impedance drops and the regulator performance improves. Since the error amplifier has a high gain, the output voltage equation can be written as follows.

$$V_{OUT} = \frac{V_{REF}}{\beta} = V_{REF} \frac{R4 + R5}{R5}$$

It is obvious that the lowest output voltage possible with this configuration is when R4 = 0 which results when $V_{OUT} = V_{REF}$ (unity gain). To obtain a wide range of regulated output voltage, then, a low value of V_{REF} is an advantage. However, to obtain a high output voltage from a low reference, the feedback ratio β must be low (in other words, high value of R4). As the loop gain decreases the regulator performance degrades, affecting such parameters as line and load regulation and output impedance.

The error amplifier, like an op amp, requires some compensation for stability. Most regulators have on-chip compensation and, depending on the type or the application, may require additional external compensation. Excessive compensation, however, causes the error amplifier gain to fall off at high frequencies, thus deteriorating regulator performance.

Series-Pass Element

The maximum input voltage and the maximum output current of the regulator determine the size of the series-pass transistor. In the higher output current devices, such as the μA7800 and the μA7900 series, the output transistor and its metallization pattern occupy nearly half of the die area.

One of the benefits of including the series-pass transistor on the chip is that the integrated circuit needs only three terminals, hence, an ordinary transistor power package can be used. Another important advantage is that thermal as well as current overload protection can be incorporated on the chip in close proximity to the series-pass device.

CIRCUIT DESCRIPTIONS OF SERIES REGULATORS

Certain portions of the various regulator circuits are common to one group within the regulator family. For instance, the μA7800 and the μA78M00 series are identical except for their series-pass transistors. The 4-terminal adjustable regulators are identical to their 3-terminal counterparts (the μA78G and μA7800, μA79G and μA7900, etc.) except for the feedback resistors. The following descriptions of the various regulator circuits, fixed-voltage devices followed by the adjustable types, are arbitrarily arranged in order of increasing device terminals. The positive versions are followed by the negative counterparts. A selection guide and short form data are provided in Chapter 2.

1

Positive 3-Terminal Regulators

The positive 3-terminal regulators cover the largest range of output current, from 100 mA to 5 A, output voltages from 2.6 to 24 V, and are available in a variety of packages.

μA78L00 Series

The μA78L00 series is the simplest of the 3-terminal regulators (*Figure 1-8*). It is capable of delivering 100 mA output current and is available in nine output voltages ranging from 2.6 to 24 V and two popular packages, metal TO-39 and plastic TO-92. The start-up circuit, comprised of Zener diode D1, transistor Q10 and resistors R14, R15, R16, provides a bias level that is less than the reference at the Q11 base. Collector and base currents of Q6 flow through Q11 at the instant the power is turned on. When the device reaches regulation, the reference causes Q8 to turn on thereby diverting the current from Q11.

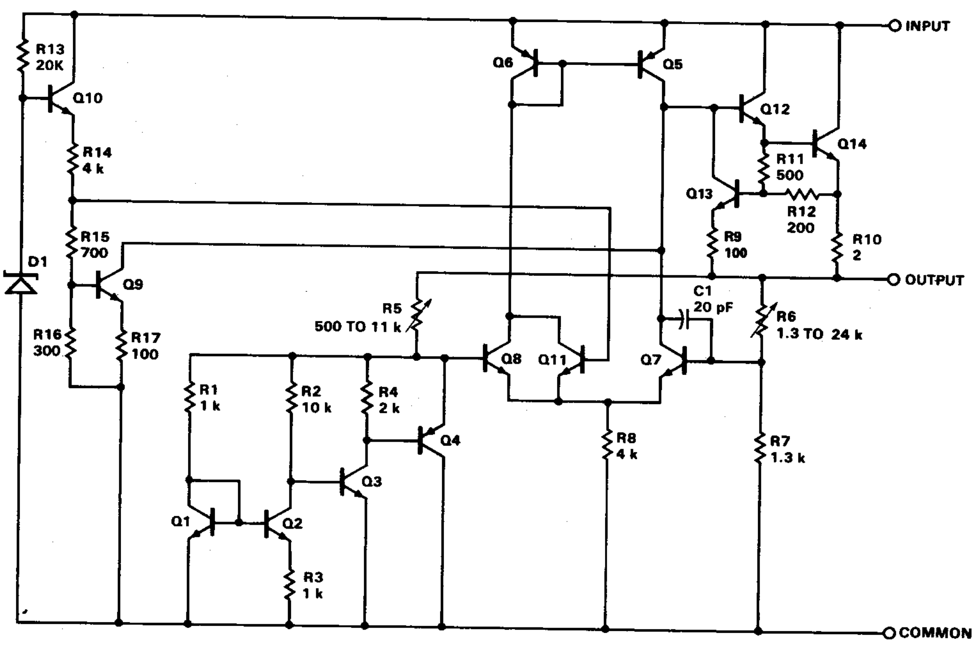


Fig. 1-8 μA78L00 Equivalent Circuit

The output voltage also provides a constant current of about 2 mA to the reference through resistor R5. The voltage reference is a band-gap type with a nominal value of 1.3 V consisting of Q1 through Q4 and R1 through R4. The error amplifier is a differential pair consisting of Q7 and Q8 with active pnp loads, Q5 and Q6, for high gain. The current through the error amplifier is set by the reference voltage, the base-emitter drop of Q8, and R8. The feedback resistors, R6 and R7, determine the output voltage.

Capacitor C1 is included on the chip for stability. The output stage uses a Darlington consisting of Q12 and Q14. Thermal-shutdown transistor Q9, which is physically placed near Q14, is pre-biased from the start-up circuit at approximately 400 mV at 25°C and limits the chip temperature to a safe value under overload conditions. Short-circuit protection is achieved by Q13 which is pre-biased by a fraction of the base-emitter voltage of the series-pass transistor. It should be noted that the µA78L00 series does not need safe-area protection because the series-pass transistor is designed to handle the short circuit current at the maximum input voltage. This may appear as an overdesign but, when dealing with current levels this low, the die area needed to include safe area protection would be greater than the area used to overdesign the series-pass transistor.

µA78C00 Series

The µA78C00 series is a low cost regulator intended mainly for consumer applications. It is capable of delivering 0.5 A current and is available in popular output voltages to 24 V in the Power Watt package, (similar to TO-202). ***Figure 1-9*** **shows the equivalent circuit of the µA78C00 regulator. The reference is derived from Zener diode D1 and compensated by the base-emitter voltage of the error amplifier Q4. Additional gain is provided by Q7 and Q8 to the Darlington-connected emitter-follower output stage of Q10 and Q11. The output stage is compensated by capacitor C1. A positive start-up condition is ensured by FET transistor Q1 to provide base current to transistors Q2 and Q5. Q2 Q5 and Q6 then form a positive feedback loop which raises the base voltage of Q2 until the reference Zener D1 conducts. Thermal overload protection is achieved by transistor Q3. The bias to the base-emitter voltage of Q3 is derived from D1 via Q2 and the divider network of R1 and R2. At high junction temperatures, Q3 turns on and removes the drive to the output stage. Current limit transistor Q9 protects the device against accidental shorts by sensing the voltage drop across R7 while Zener diode D2 along with Q9 and resistors R5, R6, and R7 limit the power dissipation to a safe value.**

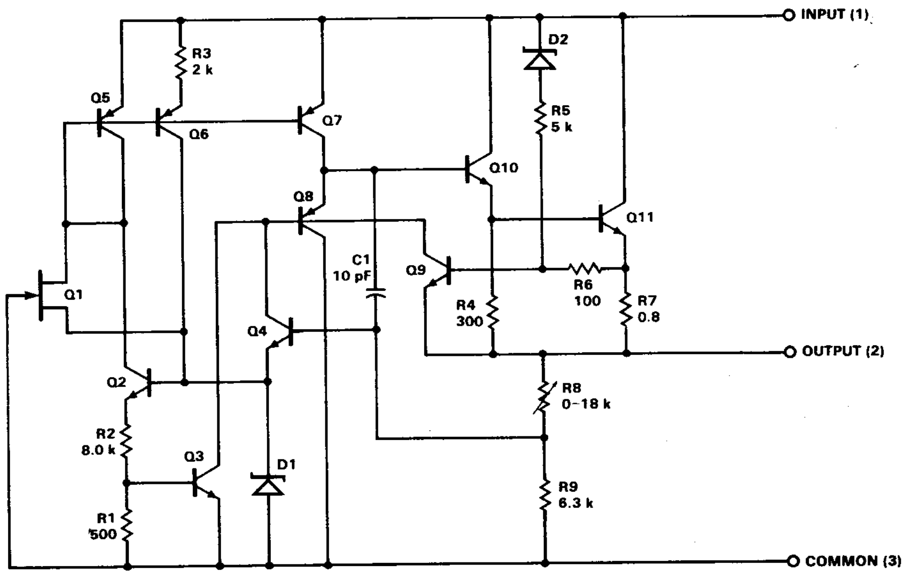


Fig. 1-9 µA78C00 Equivalent Circuit

μA78M00/μA7800 Series

The μA78M00 and the μA7800 regulators are schematically identical (*Figure 1-10*); they differ only in maximum current capability, 0.5 A and 1 A respectively. Component value differences (R9, R11, R16) are shown with the μA7800 value in parenthesis. Transistors Q1 through Q7 and their associated resistors constitute a temperature compensated reference of 5 V. The Darlington configuration, Q3 and Q4, is the error amplifier lumped into the voltage reference. The error amplifier gain is increased by the pnp transistor Q11 which acts as a buffer to drive the active collector load formed by the pnp current-source transistor pair, Q8 and Q9.

The current through Q8 and Q9 is set up by the current through resistor R1. During regulator turn on, the current in R1 flows first through transistor Q13, part of the start-up circuit containing Zener diode D1, transistors Q12 and Q13, and resistors R5, R6 and R7. After the device is in regulation, Q13 is biased off and the regulator takes over setting the current in R1, which then flows through Q5 and Q10.

Thermal protection is provided by transistor Q14 with the base clamped by the resistive divider string, R5, R6 and R7, in the start-up circuit. At a junction temperature of about 175°C, Q14 turns on and removes the base current to the output stage, thus turning the series-pass transistor Q17 off and preventing further increase in chip temperature.

The short-circuit protection transistor Q15 is pre-biased from the base-emitter voltage drop of the series-pass transistor Q17 via resistors R12 and R21. As the output current increases, the drop across R11 increases, causing the base voltage of Q15 to increase also. When the output current reaches the preset level, Q15 begins to turn on, shunting the base current of the output stage and preventing any further increase in output current.

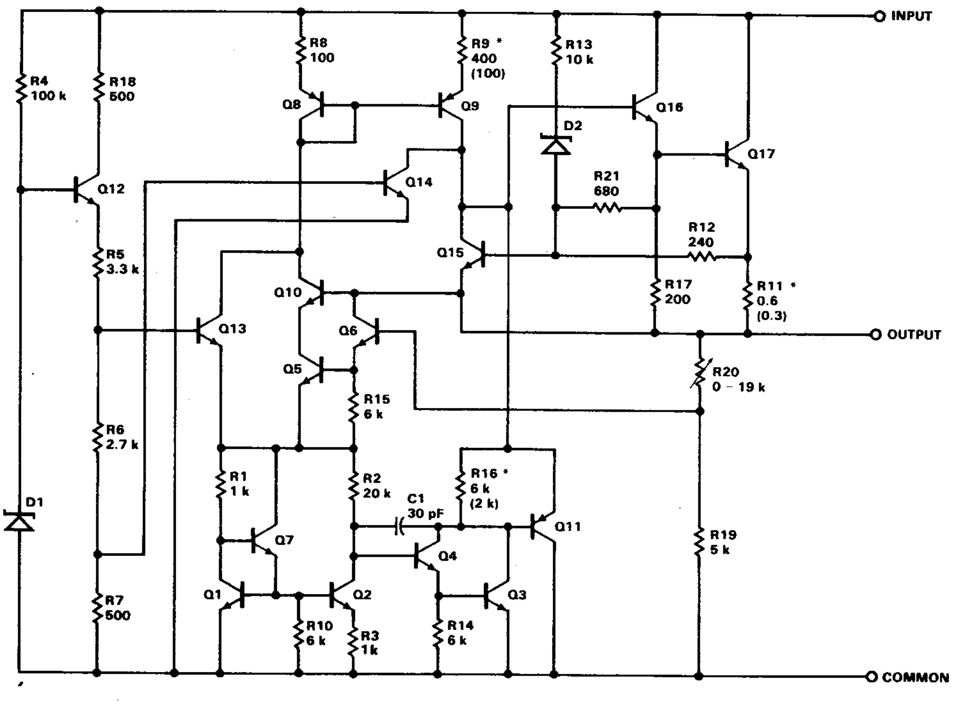


Fig. 1-10 μA78M00 (μA7800*) Equivalent Circuit

Safe-area protection, accomplished via resistors R11, R12, R13, Zener diode D2 and Q15, limits the instantaneous power through the series-pass transistor to a safe value by decreasing the maximum regulator current as the input-output voltage differential is increased.

The μA7800 and μA78M00 are available in popular fixed output voltage options ranging from 5 to 24 V. The output voltages are internally fixed during manufacture by selection of the feedback resistor ratio of R19 and R20. The μA78M00 series is available in the metal TO-39 and plastic TO-220 while the μA7800 series is packaged in the metal TO-3 and plastic TO-220.

μA109 Series

The μA109 series includes the μA109, μA209 and μA309 3-terminal regulators with fixed output voltages of 5 V and 1 A output current capabilities. Schematically, the circuit is identical to that of the μA7805 (*Figure 1-10*) except for R12 which is a 180 Ω resistor; device operation is the same. The lower value of R12 increases the peak output current and changes the characteristics of the safe-area circuit so that the device can deliver higher output current for the same input-output voltage. The μA109 operates over the full military temperature range while the μA209 is for industrial-temperature operation. The μA309 is the relaxed version. All are packaged in the TO-3.

μA78CB, 13.8 V, 2 A Positive Regulator

The μA78CB is a positive 13.8 V 2 A regulator available in metal TO-3 and plastic TO-220 packages. It has the same features as the μA7800 series with 20 W dissipation capability. Schematically, it is identical to the μA7800 of *Figure 1-10* except for the short-circuit sense resistor R11 which is 0.2 Ω to set the peak current over 3 A at 25°C, and the feedback resistor R20 which is 8 k to set the output voltage to a nominal value of 13.8 V. The device is intended as a fixed 13.8 V regulator for home-base CB stations, and as an automotive power supply for driving accessories directly from the AC line through a transformer, a full wave rectifier and a filter capacitor.

μA78H00 Series

The μA78H00 series are hybrid regulators with 5 A output current capability with all the inherent characteristics of the monolithic 3-terminal regulators, *i.e.,* full thermal overload, short-circuit and safe-area protection. The 78H00s are constructed using state-of-the-art hybrid circuit technology and are packaged in hermetically sealed TO-3s providing 50 W power dissipation. They are available with 5, 12 and 15 V options. Each regulator consists of a μA78M00 monolithic chip driving a discrete series-pass element Q1 and two short-circuit detection transistors Q2 and Q3 *(Figure 1-11).* A beryllium-oxide substrate is used in conjuction with an isothermal layout to optimize the thermal characteristics of the device and still maintain electrical isolation between the various chips. This ensures nearly ideal thermal transfer between the series-pass device Q1 and the temperature sensing circuit within the μA78M00, thus providing the thermal-limiting feature to the regulator. Output voltage V_{OUT} is derived from the μA78M00 chip which also provides the basic blocks for the regulator as well as serving as buffer and driver for the series-pass element. When a load is placed across the output terminals, the load current supplied by the μA78M00 is sensed by resistor R2 which then develops a voltage drop that forward biases the emitter-base junction of Q1. At this time, the μA78M00 begins to supply base current to Q1 which supplies the bulk of the load current (≈95%) during operation.

The output circuit is designed so that the worst-case current requirement of the Q1 base added to the current through R2 always remains below the current-limit threshold of the μA78M00. Resistor R1 in conjuction with Q2 and Q3 make up a current sense and limit circuit to protect the series-pass device from excessive current drain. As the output current begins to increase, the voltage drop across R1 starts to forward bias the Q3 emitter-base junction. As Q3 conducts, its collector current flows through the Q2 base; thus Q2 begins to conduct and therefore shunts away some of the current available to the Q1 base. This process continues until a natural state of electrical equilibrium is reached, at which time 78H00 is in a current-limit mode of operation. Capacitor C1 provides frequency stability by adding a pole in the output-circuit transfer function that lowers the overall loop gain below the critical levels at high frequencies.

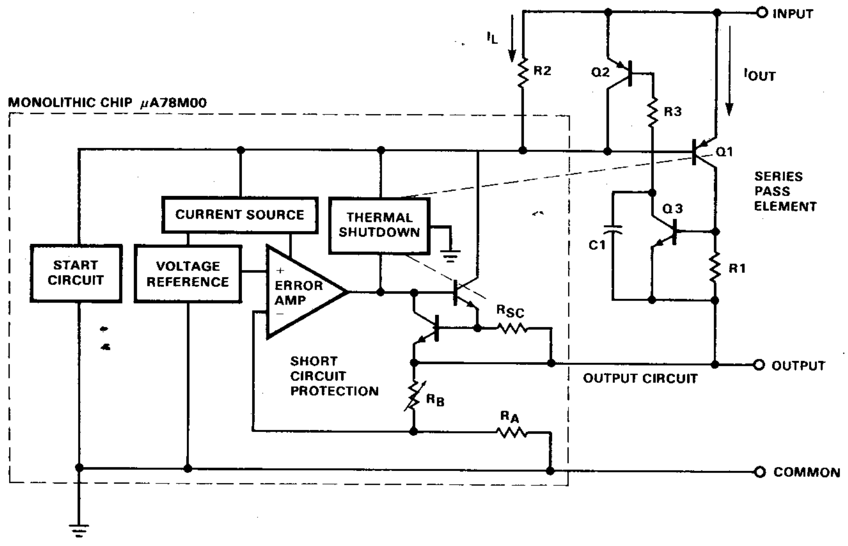


Fig. 1-11 78H00 Block Diagram

Safe area protection is achieved by brute force. The series-pass transistor is capable of handling the short-circuit current at the maximum input voltage rating of the 78H00. Output voltage sensing is performed at the device output pin so that the error amplifier can correct for any output voltage errors caused by finite impedances in the output circuit such as lead bonds and metal traces.

Negative 3-Terminal Regulators

The negative 3-terminal regulators are the complements of the positive regulators discussed above. They are available in the same output voltage options, have the same protective features, and can be used in combination with positive regulators or by themselves. They are available with 0.5 A output current (μA79M00) in TO-39 and TO-220 packages, and 1 A output (μA7900) in TO-3 and TO-220 packages.

μA79M00 Series

The equivalent circuit for the μA79M00 series is shown in *Figure 1-12*. The start-up circuit consists of Zener diode D1 and transistors Q1 and Q2. Once the regulator starts, transistor Q2 is turned off and the reference Zener diode D2 is biased from a current source transistor Q7 whose current is set by the Zener reference D2, Q3, Q4 and the reference resistors R1, R2 and R20. The reference circuit has two temperature compensated levels. The lower reference is a −2.23 V derived from Zener diode D2 and transistors Q3 and Q4. This reference is used in the 5 to 8 V output options. Higher output voltage options use a −6.2 V reference derived from D2, Q6, Q7 and their associated resistors. Note that a fraction of the Q6 base-emitter voltage obtained from R3 and R4 compensates for the positive temperature coefficient of Zener diode D2. The purpose of the two voltage references is to allow a wide output voltage range without a sacrifice in device performance as explained in the Error Amplifier section.

The voltage reference circuit also provides the bias for the error amplifier consisting of Q10 through Q13 via Q9 and R8. The error amplifier is a differential pair with an active load, Q14 and Q15. The reference input (−2.23 V or −6.20 V) to the error amplifier is applied to the base of Q10 (non-inverting input) while the error voltage is applied from the feedback network of R24 and R25 to the base of Q11 (inverting input). The output of the error amplifier is fed to the series-pass transistor Q20 via Q17, R12 and Q18. Frequency compensation of the error amplifier is accomplished with resistors R9, R10 and capacitors C1 and C2. In addition, an external capacitor (from output to ground) is necessary since the series-pass transistor is operating in the common-emitter mode.

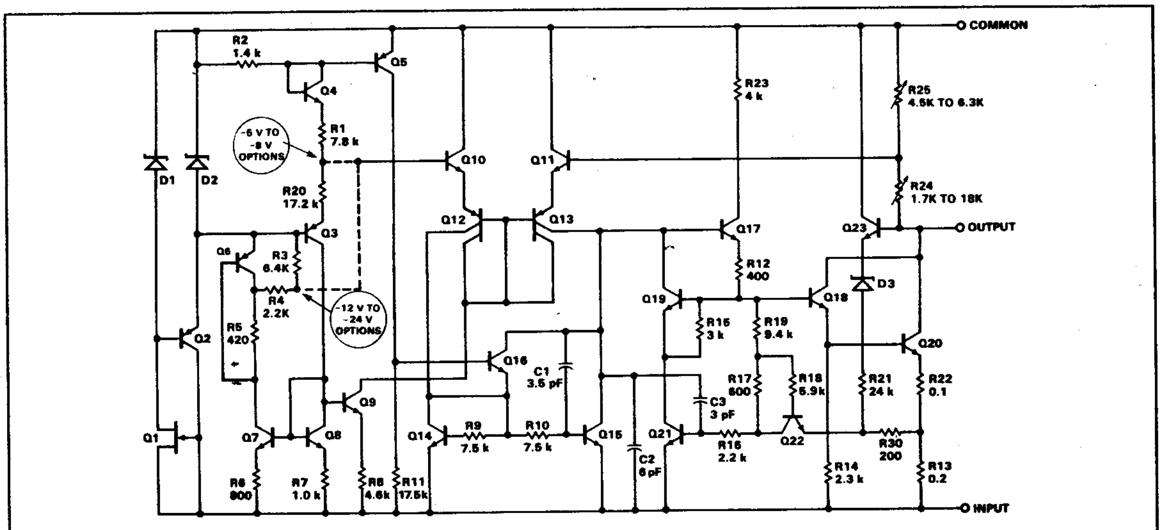


Fig. 1-12 μA79M00 Equivalent Circuit

The μA79M00 series has three protective circuits. Short-circuit protection is provided by sensing the voltage drop across R13. When this drop exceeds 130 mV, transistor Q22 is biased off and Q19 and Q21 are turned on, shunting base drive from Q17 via Q19. As explained earlier in this chapter, the short circuit current is made nearly temperature independent by selecting the area ratio of Q21 and Q22 and the resistance ratio of R17 and R19. R16, R18 and C3 provide compensation for the short-circuit protection circuit, preventing oscillations during short circuit conditions. Thermal overload protection is provided by Q5, Q16, R2 and R11. When the V_{BE} of Q5 decreases sufficiently with rising temperature, Q16 is turned on and current is shunted from Q17. Finally, the safe-area protection circuit, formed by Q23, D3 and resistors R21 and R30, detects the collector-to-emitter voltage of the series-pass transistor Q20 and decreases the maximum available regulator current as the input-output differential voltage is increased.

μA7900 Series

The μA7900 series is very similar to the μA79M00 series except for the short circuit protection scheme (*Figure 1-13*). By removing Q22 and its associated resistors from the μA79M00, the peak output current of the μA7900 is made temperature dependent with a negative temperature coefficient just like the positive 3-terminal regulators.

Positive Adjustable Regulators

Although versatile and easy to use, the 3-terminal regulator has one drawback – the output voltage is internally fixed, thereby limiting the user to around a half-dozen popular output voltages. Applications requiring variable or non-standard output voltages dictate the use of either external components with the 3-terminal devices at a sacrifice in performance or multi-terminal devices at an increase in complexity.

μA78MG/μA78G/μA78HG Positive Adjustable 4-Terminal Regulators

The 4-terminal regulator has solved the dilemma by offering all of the unique features of it 3-terminal counterpart along with an adjustable output determined by an external resistor ratio. The equivalent circuit diagram of the μA78MG/μA78G regulators in *Figure 1-14* is identical to that of the μA78M00/μA7800 series in *Figure 1-10* except that the feedback resistors are omitted and the base of Q6 is brought out as the Control terminal. Component value differences (R9, R11, R16) are shown with the 78G values in parentheses. The μA78MG is a 0.5 A device while the μA78G is a 1 A device. The output current capability can be increased substantially by the use of one or more external transistors. With an available control or feedback terminal and two external resistors, the designer can set the output voltage anywhere from 5 to 30V. The μA78MG is available in the Power Watt, (similar to TO-202) the power mini DIP or the 4-lead TO-39 package. The μA78G is offered in the Power Watt (similar to TO-202) and the 4-lead TO-3 packages.

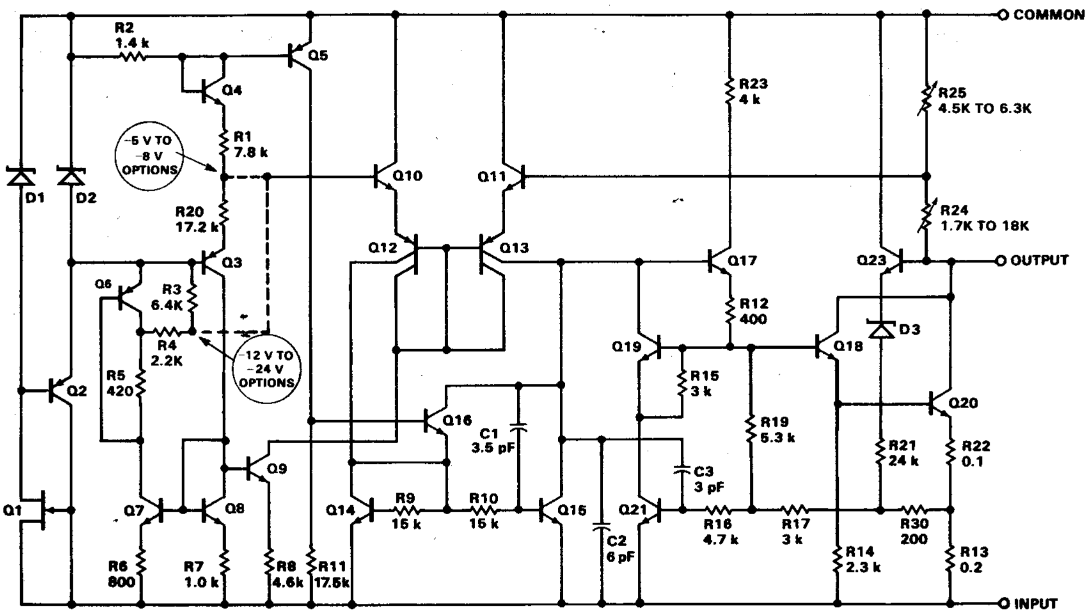


Fig. 1-13 μA7900 Equivalent Circuit

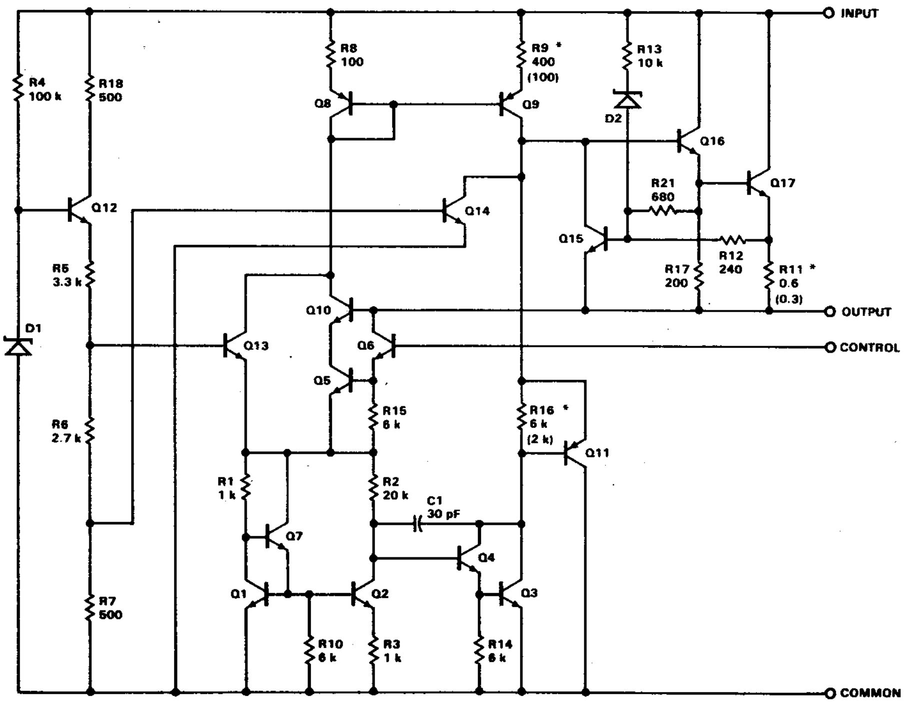


Fig. 1-14 μA78MG (μA78G*) Equivalent Circuit

The 78HG hybrid 4-terminal adjustable regulator with 5 A output current capability is schematically identical to the 78H00 series *(Figure 1-11)* except that the feedback resistors RA and RB are omitted and the inverting input of the error amplifier is brought out as the control terminal. The regulator consists of a μA78MG monolithic chip driving a discrete series-pass transistor Q1 and two short-circuit detection transistors Q2 and Q3. Just as the 78H00 series, the 78HG has all the inherent characteristics of the monolithic regulators and is constructed using state-of-the-art hybrid circuit technology. It is packaged in the 4-lead TO-3 package and is capable of 50 W power dissipation.

μA723 Precision Regulator

The μA723, commonly regarded as a universal building block *(Figure 1-15)* in power supply design, is available in the 14-lead ceramic or plastic DIP and the 10-lead TO-100 and has the following features.

- Internally generated reference voltage directly available in buffered form.
- Both inputs of the error amplifier available for use with other than positive grounded configurations.
- Collector of the internal series-pass device available at a separate lead (V_C).
- Voltage level shifting available (V_Z output) through an internal Zener diode (14-lead DIP version only).
- Adjustable output voltage from 2 to 37 V.
- Output current to 150 mA with no external pass transistor.

Bias supplies for the entire circuit are obtained by first generating a stabilized voltage with respect to the V+ line across Zener diode D1, which is supplied with a constant current from FET Q1. The Zener voltage is then used to drive the bias voltage that controls the current sources to the rest of the regulator. The basic voltage reference elements are Zener diode D2 and the Q6 base-emitter voltage. Q4 and Q5 provide current as well as buffering to D2 so that current may be taken from the reference terminal for certain applications. Resistor R7 and MOS capacitor C1 are included on the chip to eliminate the need for external compensation of the reference loop. Note that the full 7.1 V of the reference need not be tied to the error amplifier. For applications requiring output voltages less than 7.1 V, a fraction of the reference can be taken to the non-inverting input of the error amplifier by merely adding a pair of resistors to divide down the reference.

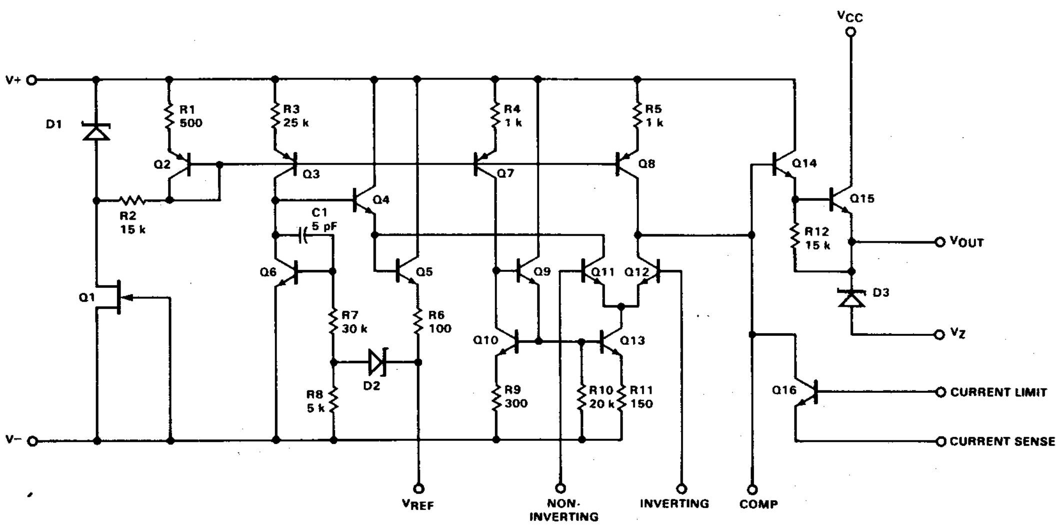


Fig. 1-15 μA723 Precision Voltage Regulator Equivalent Circuit

The error amplifier consists of the differential pair Q11 and Q12 driven by current source Q13 which is mirrored from Q7 by Q10. The active load for Q12 is a pnp current source Q8; therefore, in a balanced condition, *i.e.*, when Q11 and Q12 base voltages are equal, Q11 and Q12 collector currents are both equal. Q11 collector is returned to a stabilized voltage source in the reference supply to maintain high line rejection in the amplifier. In operation, V_{REF}, or a voltage derived from V_{REF}, is applied to the noninverting input (Q11 base) and a voltage proportional to the required output voltage is applied to the inverting input, Q12 base. When the feedback loop is closed via the μA723 output stage and an external series-pass transistor, if used, the two error amplifier inputs are forced into a balanced condition, thus defining the output voltage in terms of V_{REF} and the appropriate resistor ratios.

The output stage consists of a double emitter follower, Q14 and Q15, to prevent excessive loading on the Q12 collector. This, in conjunction with the high impedance of the active load, Q8, allows adequate gain to be obtained from the single stage amplifier. This also simplifies frequency compensation; a single capacitor connected from Q12 collector, Comp terminal, to either Q12 base or ground is sufficient to provide stable operation in all applications. Zener diode D3, available in the dual in-line package version only, is included for level shifting purposes.

Transistor Q16 is the current limiting transistor. When an external current-sensing resistor forward biases the Q16 base-emitter junction at a particular load-current level, the Q16 collector sinks most of the available current from the current source Q8. This cuts off the output stage and limits the output current. Note, by applying a command signal to the base, the current limiting transistor can be used to turn the regulator output voltage completely off.

μA105 Series Regulators

The μA105 series includes the μA105 and μA305, each rated with a maximum output current of 12 mA, the μA305A rated at 45 mA and the μA376 rated at 25 mA *(Figure 1-16)*. These regulators have an adjustable output voltage range as low as 4.5 V. They are packaged in the 8-lead TO-99 or 8-lead Mini Dip.

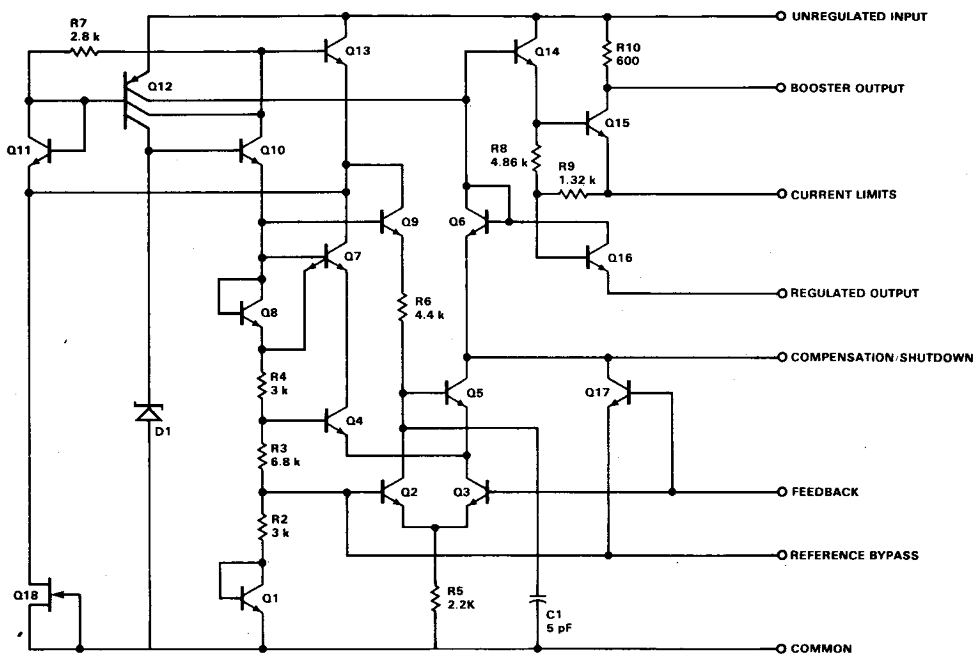


Fig. 1-16 μA105 Series Equivalent Circuit.

The μA105 voltage reference is derived from Zener diode D1 and transistors Q10, Q8 and Q1. By proper selection of R2, R3 and R4, a temperature stable reference of 1.7 V is obtained at the base of Q2. This point is accessible to the user at Reference Bypass, pin 5, so that an external capacitor can be added to bypass any noise coming from the reference Zener diode D1. Start-up of the regulator is achieved through FET Q18 and the multi-collector pnp current-source transistor Q12, which provides the bias current for the reference as well as the error amplifier and the output stage.

The differential pair, Q2 and Q3, forms the first stage of the error amplifier which has a gain of 20. The 1.7 V reference is internally tied to the non-inverting input of the error amplifier and is brought out for external bypassing of the reference. This configuration differs from that of the μA723 since it commits the reference to the non-inverting input and restricts the user to a fixed reference (1.7 V). The inverting input of the error amplifier is the base of Q3 and is brought out to the Feedback terminal. The second stage of the error amplifier consists of Q4 and Q5 with one of the collectors of Q12 as the load. In normal operation, both stages of the error amplifier are balanced over the device operating temperature range, regardless of the absolute value of components, thus giving the error amplifier a good drift characteristic. Frequency compensation is accomplished with internal capacitor C1, which prevents loop oscillations due to the high gain of the error amplifier, and an external integrating capacitor around the error amplifier, which makes the error amplifier insensitive to loading conditions.

The output stage is a double emitter follower consisting of Q14 and Q15. Transistors Q6 and Q16 perform the current-limiting function by removing the drive to the output stage when an overload condition is sensed externally between Current Limit and Regulated Output terminals. Q17 prevents latch-up that may occur with low output voltage settings. Without Q17, should Q3 saturate, it would cut off the second stage of the error amplifier, Q4 and Q5, and cause the output voltage to latch at a voltage nearly equal to the unregulated input.

Negative Adjustable Regulators

Negative regulators are not widely used as positive regulators, therefore, as one might expect, the selection is not as large. Nevertheless, sufficient options are available to cover most applications.

79MG/79G Negative Adjustable 4-Terminal Regulators

The 78MG/79G negative adjustable regulators are similar to their positive counterparts, the 78MG/78G 4-terminal adjustable regulators, and are offered in the same package options. They are derived from the μA79M00 and μA7900 respectively, using the lower of the two available references. Except for the feedback resistors, the μA79MG is schematically identical to the μA79M00 (compare *Figures 1-12* and *1-17*), and the μA79G to the μA7900 (*Figures 1-13* and *1-18*). In the μA79MG/79G, the base of Q11 is brought out as the Control terminal. Device operation is the same except that output adjustment of the μA79MG/79G is left to the user's choice of a pair of external resistors. Both the 79MG and the 79G have an adjustable output range from −30 to −2.23 V with input voltage range from −40 to −7 V. They are designed to deliver continuous load currents of up to 0.5 A for the 79MG and 1 A for the 79G.

μA104 Series Regulators

The μA104 family includes the μA104 and the μA304 regulators that can supply up to 25 mA output current without external pass transistors. The voltage reference and error amplifier circuits are designed so that the output voltage range is adjustable from 0 to −30 V for the μA304 and 0 to −40 V for the μA104. They are packaged in the 10-lead TO-100.

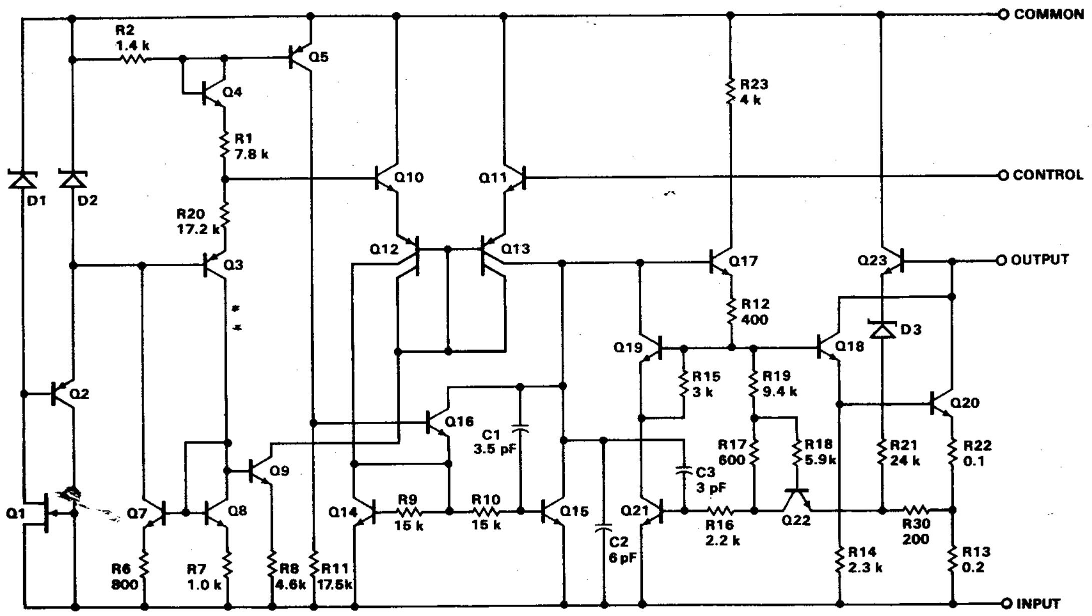


Fig. 1-17 μA79MG Equivalent Circuit

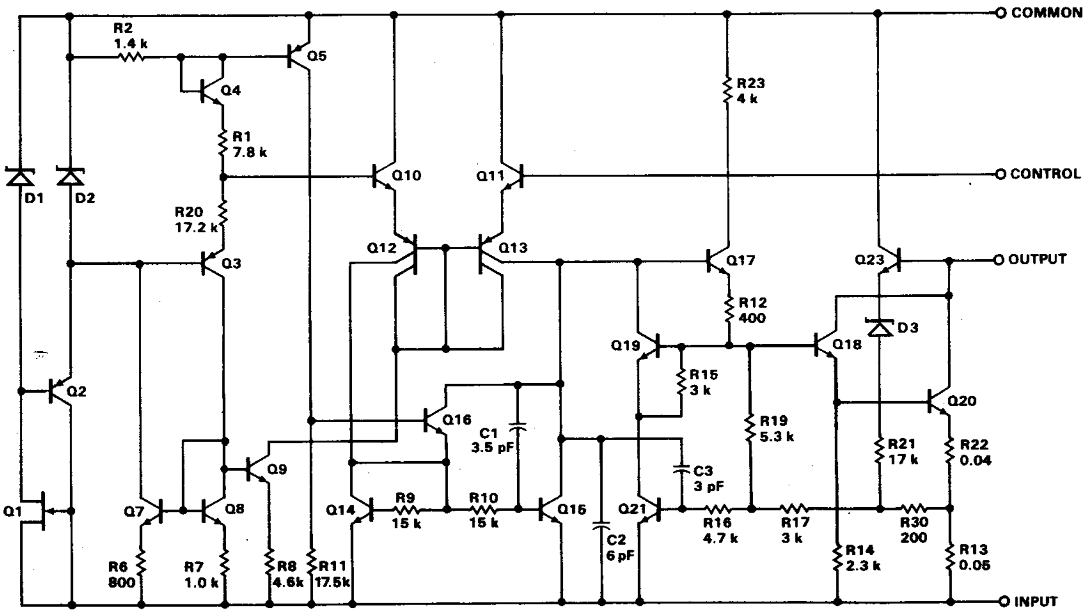


Fig. 1-18 μA79G Equivalent Circuit

Figure 1-19 shows the equivalent circuit of the μA104 family. The reference voltage between the Reference and Reference-Supply terminals is derived from Zener diode D1 and compensated by the series network, Q7, R4, Q2, Q1, Q4, Q5, and R3. This configuration yields a compensated reference of −2.4 V. When a known value resistor is placed between these two terminals, the collector currents of Q1 and Q2 can be fixed. A second resistor connected between the Common and Adjustment terminals provides the reference to the error amplifier, Q18 and Q19, through R17. Emitter-follower transistors Q18 and Q19 drive the common-base dual pnp transistor Q17. Epitaxial FET Q9 biases the current-source transistors Q12 and Q13. By using active collector loads and a triple Darlington output stage, sufficient gain is achieved to prevent the output stage from loading the input stage. R14 limits the base drive to Q23 during saturation, a condition that may occur with low input voltages. The error amplifier operates with common-mode voltages up to ground and consequently the regulator functions with output voltages to 0 V. To prevent the reference circuit from saturating with low input-output differentials, the inverting input of the error amplifier is connected through the divider network of R15 and R16 to the output. R17 matches the impedance seen by the Q19 base and also minimizes offset errors in the amplifier. Transistor Q24 is the current limiter and the current limit loop is compensated by R11 and C1.

For stable device operation, an external capacitor is required between output and common. On-chip capacitor C2 compensates for the series resistance of the external capacitor and is brought to the outside for use if additional compensation is required.

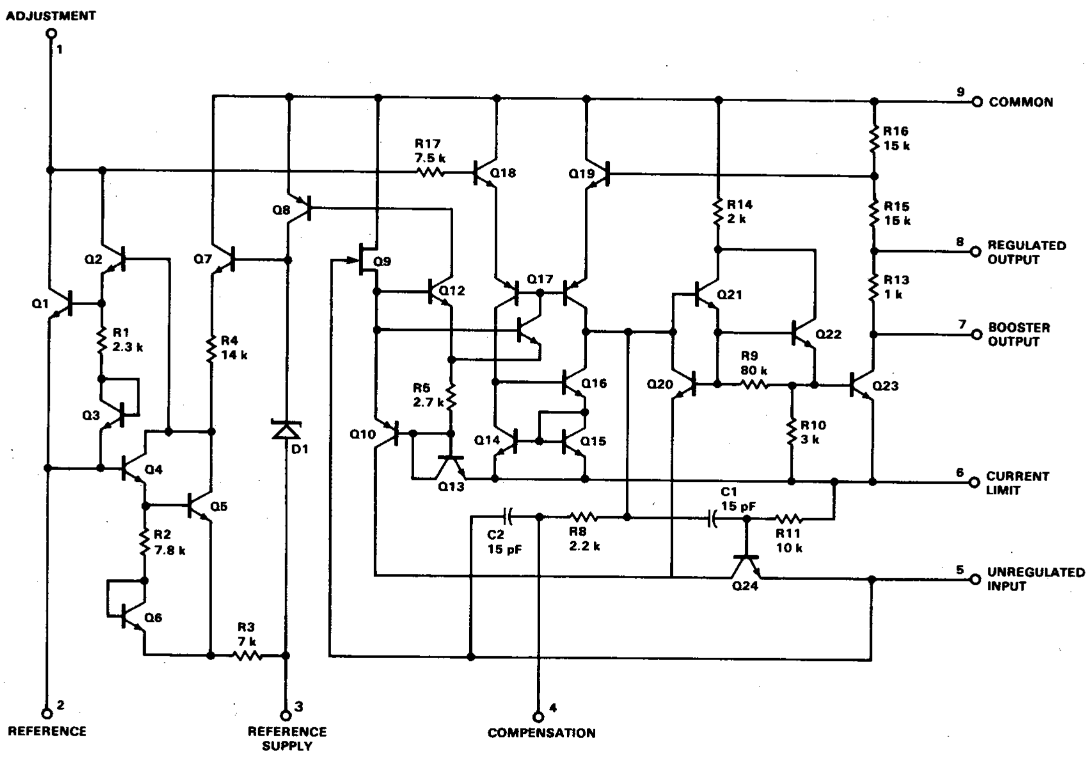


Fig. 1-19 Equivalent Circuit μA104 Series

SWITCHING REGULATORS

Series-pass regulators have dominated the power supply regulator market because they are simple, easy to use, offer high performance, and a wide range of high quality circuits is available from a number of manufacturers. Increasing concern about wasted power has caused designers to seriously consider switching regulators, which are not only much more efficient but also provide output voltages *higher or lower* than the input voltage supplied. In addition, they can provide an output voltage of the *opposite polarity.*

The switching mode voltage regulator offers the advantage of high efficiency over the more common series or shunt regulation schemes. This is particularly apparent when there is a large difference between the input voltage and the regulated output voltage. Consider, for example, a voltage regulator with 28 V input and an output of 5 V at 1 A. A conventional series regulator would require a drop of 23 V across the pass transistor. Thus, 23 W are wasted, and the efficiency is only 18%. Switching regulators, however, can be simply designed to give efficiencies greater than 75% under the same input and output restrictions.

1

Switching regulators are also useful in applications where cost, rather than efficiency, is the prime design criterion. The designer may trade the cost of a high power series pass transistor for a slight increase in circuit complexity that allows the use of lower power switching transistors.

One area of caution when using switching regulators is the generation of electromagnetic and radio frequency interference (EMI and RFI). Solutions to these problems generally revolve around the use of feed-through low pass filters isolating the lines to the regulator, and careful mechanical design to suppress radiated interference.

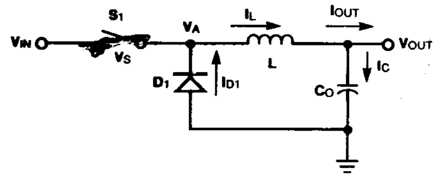
Switching regulators do have some drawbacks. They are complex, require some external components, and should be used with some degree of care. They generate noise and an output ripple, and are slower to respond to transient load conditions. However, these disadvantages can be minimized and are overshadowed by the very high efficiency (up to 90%) of switching regulators. With good control electronics, attention to timing, and some filtering, switching regulators can be used in power supply designs that provide lower operating costs and reduce power dissipation. A new integrated circuit switching regulator subsystem, the μA78S40, makes possible a variety of switching *or* series-pass regulator systems with minimum external parts.

Switching regulators are capable of storing energy and cycling on and off as necessary to supply adequate power to the load. They store energy in inductors and capacitors, which do not dissipate power. (Series-pass regulators apply the input/output differential voltage across a pass transistor, which *does* dissipate power.) Output transistors act as switches with the on/off cycle rate determined by the input/output voltages and the load current. Control circuitry monitors the output voltage and modifies timing to maintain a constant output voltage. While the regulator is off, energy is stored in an output capacitor which averages the current flow to the load. The basic modes of operation provide *increased, decreased,* or *inverted* voltage at the output from a fixed input voltage.

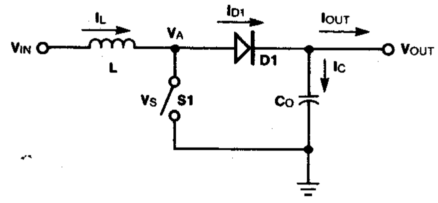
Figure 1-20 illustrates the three basic operating modes of a switching regulator. The same basic components – a switch, a diode to direct current, an inductor and a capacitor to store energy – are used for the step-down, step-up, and inverting modes.

Step-Down Regulator

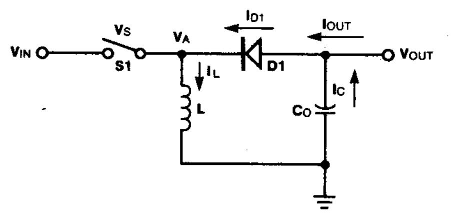
A simple step-down voltage regulator is shown in Figure 1-20a. When Switch S_1 closes, the voltage V_A rises close to V_{IN} (V_{IN}-V_S), and the voltage V_A-V_{OUT} is applied across the inductor causing the



a Step-Down Voltage Regulator



b Step-Up Voltage Regulator



c Voltage Inverter

V_{OUT} = Unregulated Output Voltage, V
V_{IN} = Unregulated Input Voltage, V
V_S = Switch Voltage, V
V_D = Diode Voltage Drop, V
i_{pk} = Peak Current in A
t_{on} = On Time in μs
t_{off} = Off Time in μs
L = Inductor in μH
C_O = Output Capacitor in μF

Fig. 1-20 Basic Operating Modes

current to increase from zero at a rate of $(V_A - V_{OUT})/L$. This current flows from the switch through the inductor and into the load and output capacitor. If the instantaneous inductor current, i_L, is less than the load current, the capacitor provides the additional current and V_{OUT} decreases slightly. When i_L exceeds the output current the remaining current flows into the capacitor, increasing V_{OUT}; i_L will increase until the switch turns off. At this instant, since the inductor current cannot change instantly, V_A falls to $-V_D$ so diode D_1 can turn on and provide the inductor current. The voltage across the inductor is now $-(V_{OUT} + V_D)$; so the inductor current will change at a rate of $-(V_{OUT} + V_D)/L$. The inductor current continues to fall toward zero until S_1 turns on again, and the cycle is repeated. The electronics in the system controls the on- and off-time of S_1 so that the average inductor current equals the output current; the average capacitor current will be zero and V_{OUT} will remain constant. The control circuit generally consists of an oscillator whose on-and off-times are set so that i_L will increase to a maximum current of I_{pk} and then decrease to zero, and a sense circuit that senses the output voltage and increases the off-time (by blocking the oscillator output) if V_{OUT} increases too high. In this type of system a maximum i_{OUT} of $I_{pk}/2$ is possible, and for i_{OUT} less then $I_{pk}/2$ the control circuit increases the off-time by an amount such that the average i_L equals i_{OUT}.

The peak current for a step-down regulator is determined by the input voltage, switch voltage, output voltage, inductor size, and the switch on-time, or conversely the on-time is set to give the desired peak current.

$$I_{pk} = \frac{V_{IN} - V_S - V_{OUT}}{L} \cdot t_{on}$$

In a similar manner, the off-time for i_L to drop to zero is related to I_{pk}, V_{OUT}, V_D, and L.

$$I_{pk} = \frac{V_{OUT} + V_D}{L} \bullet t_{off}$$

The ideal ratio of t_{on} to t_{off} is a function of V_{IN}, V_{OUT}, V_D, and V_S.

$$\frac{t_{on}}{t_{off}} = \frac{V_{OUT} + V_D}{V_{IN} - V_S - V_{OUT}}$$

The maximum output current for this timing is

$$I_{OUT(MAX)} = I_{pk}/2$$

the average input current is $I_{pk}/2$ times the percentage of time the switch is on.

$$I_{IN(avg)} = \frac{I_{pk}}{2} \bullet \frac{t_{on}}{t_{on} + t_{off}} = \frac{I_{pk}}{2} \bullet \frac{V_{OUT} + V_D}{V_{IN} - V_S + V_D}$$

The efficiency of this regulator is

$$\text{EFFICIENCY} = \frac{V_{OUT}}{V_{OUT} + V_D} \bullet \frac{V_{IN} - V_S + V_D}{V_{IN}}$$

If V_S and V_D go to zero the efficiency goes to 100%; therefore if V_S and V_D are small compared to V_{IN} and V_{OUT} very high efficiencies can be achieved. The ripple on the output is a function of I_P, t_{on}, t_{off} and C_O and can always be reduced by increasing C_O without affecting any other portion of the circuit.

$$V_{PEAK\ RIPPLE} = I_{pk} \bullet \frac{(t_{on} + t_{off})}{8\ C_O}$$

Step-Up Regulator

Switching regulators operating in a step-up mode, *Figure 1-20b*, provide an output voltage greater than the input voltage. In the case of a step-up regulator, when the switch closes, the applied voltage drops to almost zero ($V_A = V_S$), and voltage V_{IN}-V_S is applied across the inductor, causing the inductor current to increase linearly. Because the applied voltage is less than the output voltage, the diode is reverse-biased and current cannot flow to the output. Again, when the switch opens, the inductor current cannot change instantly, and the applied voltage changes to the total of the output voltage plus the diode voltage. At this time current can flow through the diode to the load capacitor, and the inductor current decreases at a linear rate, determined by V_{OUT}-V_D-V_{IN}. Timing adjustments control the average diode current (I_{D1}) so it is equal to the load current. The diode current can only flow during off-time, so the maximum output current is ($I_{pk}/2$) ($t_{off}/t_{on}+t_{off}$). If the load current is less than the maximum output current, off-time is increased by a dead time with no current to the output. Input current can flow during both on and off-times, so the average input current is always greater than the maximum output current.

The on-time in a step-up regulator is a function of V_{IN}, V_S, and L while t_{off} is a function of V_{IN}, V_{OUT}, V_D, and L.

$$t_{on} = \frac{I_{pk} \bullet L}{V_{IN} - V_S}$$

$$t_{off} = \frac{I_{pk} \bullet L}{V_{OUT} + V_D - V_{IN}}$$

The t_{on} to t_{off} ratio is a function of circuit voltages as is the maximum output current.

$$\frac{t_{on}}{t_{off}} = \frac{V_{OUT} + V_D - V_{IN}}{V_{IN} - V_S}$$

$$I_{OUT(MAX)} = \frac{I_{pk}}{2} \bullet \frac{V_{IN} - V_S}{V_{OUT} + V_D - V_S}$$

$$I_{IN(AVG)} = \frac{I_{pk}}{2}$$

The efficiency is also a function of V_{IN}, V_{OUT}, V_S, and V_D and approaches 100% as V_S and V_D become small compared with V_{IN} and V_{OUT}.

$$\text{EFFICIENCY} = \frac{V_{IN} - V_S}{V_{IN}} \bullet \frac{V_{OUT}}{V_{OUT} + V_D - V_S}$$

Output ripple is a function of I_{pk}, I_{OUT}, t_{off}, and C_O and can again be reduced by increasing C_O without affecting circuit performance.

$$V_{PEAK\ RIPPLE} = \frac{(I_{pk} - I_{OUT})^2}{2\, I_{pk}} \bullet \frac{t_{off}}{C_O}$$

Voltage Inverter Regulator

The basic voltage inverter is shown in Figure 1-20c. This circuit generates a negative output for a positive input. When S_1 turns on, V_A rises to V_{IN}-V_S, and this voltage is impressed on the inductor, causing current to increase at a linear rate. When S_1 turns off, the inductor current cannot change instantaneously, so V_A drops to $(-V_{OUT} - V_O)$, forward biasing D_1. Current now decays at a linear rate. i_{D1} supplies current to the output capacitor and load and its average value must be equal to the load current. Input current flows only when S_1 is on and is therefore equal to $I_{pk}/2 \bullet (t_{on}/t_{on} + t_{off})$.

The basic formulas for the voltage inverter are shown below. As in the other circuits, optimum t_{on} and t_{off} values are functions of V_{IN}, V_{OUT}, V_S, V_D, and L while the ratio of t_{on}/t_{off} is dependent only on the voltages. $I_{OUT(max)}$ is always less than $I_{pk}/2$, but then so is the average input current. Efficiency depends on input and output voltages and is basically independent of current level. Ripple can be minimized as usual by increasing the value of C_O.

$$I_{pk} = \frac{V_{IN} - V_S}{L} \cdot t_{on}$$

$$I_{pk} = \frac{|V_{OUT}| + V_D}{L} \cdot t_{off}$$

$$\frac{t_{on}}{t_{off}} = \frac{|V_{OUT}| + V_D}{V_{IN} - V_S}$$

$$I_{OUT(MAX)} = \frac{I_{pk}}{2} \cdot \frac{V_{IN} - V_S}{V_{IN} + |V_{OUT}| + V_D - V_S}$$

$$I_{IN(avg)} = \frac{I_{pk}}{2} \cdot \frac{|V_{OUT}| + V_D}{V_{IN} + |V_{OUT}| + V_D - V_S}$$

$$\text{EFFICIENCY} = \frac{V_{IN} - V_S}{V_{IN}} \cdot \frac{|V_{OUT}|}{|V_{OUT}| + V_D}$$

$$V_{PEAK\ RIPPLE} = \frac{(I_{pk} - I_{OUT})^2}{2\, I_{pk}} \cdot \frac{t_{off}}{C_O}$$

The μA78S40 Universal Regulator

In order to operate effectively in step-down, step-up, and inverting modes, a switching regulator should have several functional building blocks common to all of its operational modes, minimizing the need for external parts and maximizing its versatility. The μA78S40 universal regulator meets this goal and allows a wide variety of regulators to be built with minimum external parts. This regulator's functional blocks are illustrated in *Figure 1-21* and outlined below; design formulas are shown in Table 1-1.

- A Current-Controlled Oscillator
- A Temperature-Compensated Current-Limiting Circuit
- A Temperature-Compensated Voltage Reference
- An Error Amplifier
- A Power-Switching Circuit
- A High-Gain Amplifier

The current-controlled oscillator has drive circuitry for the transistor power switch. Oscillator frequency is set by an external capacitor so it can be varied according to application. The oscillator duty cycle is internally fixed at 8:1. A current-limiting circuit controls oscillator on-time, adjusting the duty cycle for optimum timing. This temperature-compensated current-limiting circuit senses the switching transistor current across an external resistor and modifies the oscillator on-time, limiting the peak current and protecting the switching transistors.

CHARACTERISTIC	STEP DOWN	STEP UP	INVERTING
I_{pk}	$2\,I_{OUT(max)}$	$2\,I_{OUT(max)} \bullet \frac{V_{OUT} + V_D - V_S}{V_{IN} - V_S}$	$2\,I_{OUT(max)} \bullet \frac{V_{IN} + \lvert V_{OUT}\rvert + V_D - V_S}{V_{IN} - V_S}$
R_{SC}	$0.33\ V/I_{pk}$	$0.33\ V/I_{pk}$	$0.33\ V/I_{pk}$
t_{on}	$\frac{I_{pk} \bullet L}{V_{IN} - V_S - V_{OUT}}$	$\frac{I_{pk} \bullet L}{V_{IN} - V_S}$	$\frac{I_{pk} \bullet L}{V_{IN} - V_S}$
t_{off}	$\frac{I_{pk} \bullet L}{V_{OUT} + V_D}$	$\frac{I_{pk} \bullet L}{V_{OUT} + V_D - V_{IN}}$	$\frac{I_{pk} \bullet L}{\lvert V_{OUT}\rvert + V_D}$
$\frac{t_{on}}{t_{off}}$	$\frac{V_{OUT} + V_D}{V_{IN} - V_S - V_{OUT}}$	$\frac{V_{OUT} + V_D - V_{IN}}{V_{IN} - V_S}$	$\frac{\lvert V_{OUT}\rvert + V_D}{V_{IN} - V_S}$
L	$\frac{V_{OUT} + V_D}{I_{pk}} \bullet t_{off}$	$\frac{V_{OUT} + V_D - V_{IN}}{I_{pk}} \bullet t_{off}$	$\frac{\lvert V_{OUT}\rvert + V_D}{I_{pk}} \bullet t_{off}$
$C_T(\mu F)$	$45 \times 10^{-5}\ t_{off}(\mu s)$	$45 \times 10^{-5}\ t_{off}(\mu s)$	$45 \times 10^{-5}\ t_{off}(\mu s)$
C_O	$\frac{I_{pk} \bullet (t_{on} + t_{off})}{8\,V_{ripple}}$	$\frac{(I_{pk} - I_{OUT})^2 \bullet t_{off}}{2\,I_{pk} \bullet V_{ripple}}$	$\frac{(I_{pk} - I_{OUT})^2 \bullet t_{off}}{2\,I_{pk} \bullet V_{ripple}}$
Efficiency	$\frac{V_{IN} - V_S + V_D}{V_{IN}} \bullet \frac{V_{OUT}}{V_{OUT} + V_D}$	$\frac{V_{IN} - V_S}{V_{IN}} \bullet \frac{V_{OUT}}{V_{OUT} + V_D - V_S}$	$\frac{V_{IN} - V_S}{V_{IN}} \bullet \frac{\lvert V_{OUT}\rvert}{\lvert V_{OUT}\rvert + V_D}$
$I_{IN(avg)}$ (Max load condition)	$\frac{I_{pk}}{2} \bullet \frac{V_{OUT} + V_D}{V_{IN} - V_S + V_D}$	$\frac{I_{pk}}{2}$	$\frac{I_{pk}}{2} \bullet \frac{\lvert V_{OUT}\rvert + V_D}{V_{IN} + \lvert V_{OUT}\rvert + V_D - V_S}$
V_{ripple}	$\frac{I_{pk}\ (t_{on} + t_{off})}{8\,C_O}$	$\frac{(I_{pk} - I_{OUT})^2}{2\,I_{pk}} \bullet \frac{t_{off}}{C_O}$	$\frac{(I_{pk} - I_{OUT})^2}{2\,I_{pk}} \bullet \frac{t_{off}}{C_O}$

Table 1-1. 78S40 Design Formulas

A 1.3 V temperature-compensated voltage reference source can provide up to 10 mA of current without an external pass transistor. A high-gain differential comparator disables the power switch when the output voltage becomes too high. A power Darlington switching transistor handles 1.5 A of current and can withstand up to 40 V. The switch collectors and the emitter drive are externally available to allow optimized connection of the switch. A power-switching diode handles 1.5 A of forward current and 40 V of reverse voltage.

The high-gain independent operational amplifier has 150 mA output current capability and a separate positive voltage supply connection. Its input common mode range *includes* ground. It may be connected to provide series-pass regulation or feedback control for switching regulators.

This switching regulator can operate over a wide range of power conditions, from battery power to high-voltage, high-current supplies. Low voltage requirements with minimum current drain make the regulator very useful in battery or 5 V systems. It typically operates from 2.2 to 40 V dc. At the 5 V level, the regulator draws only 2 mA. A low standby-current drain significantly improves regulator efficiency in low-power applications and greatly increases battery lifetime in battery applications. This high efficiency in low-power applications is *not* typical of other switching systems. Combined with the capability of the μA78S40 to handle up to 40 V input and provide as much as 1.5 A switching current, efficient low power operation makes the regulator performance over a wide operating range unmatched.

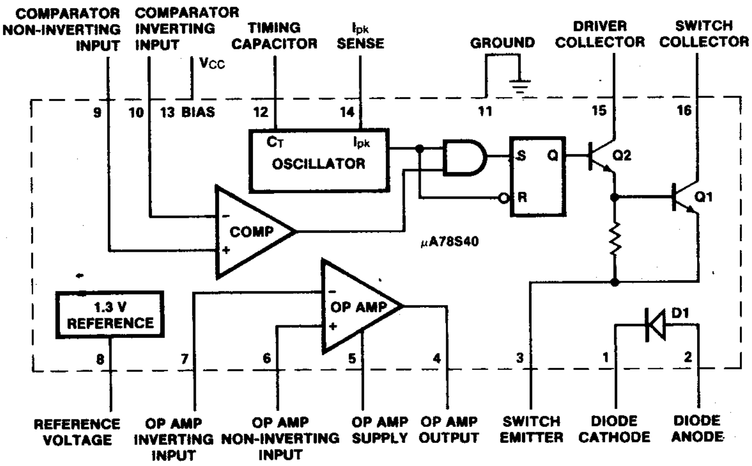


Fig. 1-21 μA78S40 Universal Regulator Partitioning

1

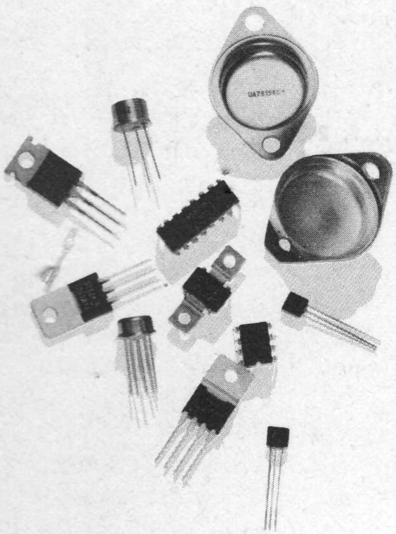
Using a versatile circuit such as this requires some care, but the benefits are well worth the attention since this IC subsystem provides the user with the flexibilty for optimizing power supply performance. A critical parameter is oscillator timing. Although the on-time/off-time ratio is internally fixed at 8:1, the user can adjust this ratio down through the proper selection of peak current, the oscillator capacitor value, the inductor value, and the input/output voltages. Peak current is determined solely by the current-limiting circuit. Selection of the timing capacitor is based on the off-time required. The user should establish the off-time and let the current-limiting circuit modify the on-time. This off-time can be set by the user for either intermittent or continous operation. For intermittent operation, the user should set the off-time equal to the time required for the inductor current to drop to zero. For continuous operation, the off-time should be set at something less than the time required for the inductor current to drop to zero. When operated in the continuous mode, average inductor current exceeds 1/2 of the peak current, making more power available at the output. However, timing is very critical (*see box on following page*), and if on-time and off-time periods are too short, switching losses can significantly reduce efficiency. With this regulator, on-time and off-time should be kept greater than 10 μs.

Switching is accomplished by a Darlington pair with the switch emitter as well as both transistor collectors available for external connection. Either the collector inputs or the emitter output can be used. If the emitter output is used, the collector inputs can be shorted, resulting in a switch voltage of 1.6 V typical. If the collector inputs are used with the emitter grounded, the user must consider the performance tradeoffs between shorting both collectors or using the switch output. System performance is affected by the input and output voltages, the output current, and the expected variations of the input voltage. If both collectors are shorted, there is no switching loss due to base current (switch voltage is typically 1.1 V). If the switch output is used, base drive through the driver is provided by connecting an external resistor to the input voltage line (switching voltage is typically 0.5 V). A switching diode in the circuit is capable of handling voltage up to 40 V and current up to 1.5 A for both step-up and step-down modes. To use the regulator for inverting applications, an external diode is required because the diode voltage drops below the circuit common.

SWITCHING REGULATOR TIMING CONSIDERATIONS

Optimization of regulator on-time and off-time depends on CIRCUIT VARIABLES such as inductance and switch and diode voltage – and on SYSTEM VARIABLES such as input/output voltages. Consider the following conditions and consequences.

- On-time too short – Inductor peak current isn't high enough, so the maximum output current is reduced. However, efficiency does not suffer.
- On-time too long, or off-time too short – Without current limiting, after several cycles the inductor current will exceed the expected peak current and continue to increase, which could lead to excessive current flow and DEVICE DESTRUCTION.
- Off-time too long – Inductor current falls to zero and stays there for some time before the switch turns on again. Consequently, average inductor current is less than half of peak current, and the available output current is reduced. However, efficiency does not suffer.
- On-time too long – Current limiting for the switch is unacceptable when the inductor current is constant at the peak current, because inductor voltage drops to zero. Therefore, switch voltage increases (to V_{IN}-V_{OUT}), creating a large efficiency loss and possibly DESTROYING the switch.
- Off-time too short with on-time adjusted by current limit – No efficiency is lost, but the inductor current does not drop to zero. Therefore, average inductor current is in excess of half of peak current, and the maximum output current exceeds half of the peak current.



TESTING AND RELIABILITY

Chapter 2
TESTING AND RELIABILITY

TESTING VOLTAGE REGULATORS

All Fairchild voltage regulators are factory-tested with automated equipment to ascertain that they meet or exceed guaranteed specifications. The testing equipment operates at relatively high speeds and automatically measures output voltage tolerances, line and load regulation, quiescent current, short-circuit current, and a long list of other voltage regulator parameters. To adequately interpret published voltage-regulator specifications, it is advisable to have some understanding of the testing as performed at Fairchild. This is also important for customer incoming inspection, as some correlation is necessary between factory testing and customer acceptance testing.

2

Individual parameter tests performed on Fairchild voltage regulators require only a few milliseconds, so a complete regulator test can be accomplished in a fraction of a second. Such short testing times mean that the device junction temperature is very close to ambient. If the devices were tested under steady-state conditions, costs would unfortunately increase, and the increased expense would be passed on to the customer. Consequently, published parameters are based on fast testing and usually specified with a constant junction temperature of 25° C. Exceptions are noted in the individual data sheet tables.

When a regulator is operated with high dissipation, however, the effect of temperature drift must be evaluated or at least considered. For example, a μA7805 1 A positive voltage regulator with a junction temperature of 25° C, a 10 V input, and a load current variation of 1.5 A has a guaranteed load regulation of less than 50 mV for military-grade units and less than 100 mV for commercial-grade units. Under steady-state testing conditions, as opposed to pulsed testing conditions, junction temperature would increase by 30° C to 55° C (based on a 4° C/W junction-to-case thermal resistance and an infinite heat sink). The μA7805 regulator has a temperature coefficient of -1.1 mV/° C, so a 30° C junction-temperature increase means an output voltage drift of -33 mV. This drift must be considered if load regulation is being measured under steady-state conditions.

Incoming inspection tests should accomodate these conditions. One approach would be to duplicate the testing procedure used by manufacturing, i.e., maintain a constant junction temperature of 25°C. If steady-state testing is performed during acceptance evaluation, a correlation between the method used in incoming inspection and the method used by Fairchild must be established. In this case, the temperature coefficients of each regulator type must be considered.

3-Terminal Regulators

Testing of 3-terminal regulators is performed at input voltages that reflect actual use conditions. The input-output voltage differential considers all of the variations associated with nominal, unregulated power supplies. For example, a 12 V regulator (μA7812) test uses a 7 V I/O voltage differential and considers the following parameters:

- Device Input-Output Voltage Differential - 2 V Nominal
- Line Voltage Reference - 10%
- Filtered Supply Ripple - 10%
- Line Regulation - 10%
- Diode Drop and Source Impedance Variations - 1 V.

This is expressed in the following equation:

$$V_{IN} = V_{OUT(max)} + (V_{IN} - V_{OUT}) + \text{Ripple} + \text{Line Reg} + V_D = 12.6\text{ V} + 2\text{ V} + 1.46\text{ V} + 1.6\text{ V} + 1\text{ V} = 18.66\text{ V}$$

A 12 V regulator, then, is not only tested with a guard band, but the input voltage range used allows for greater variation than is present in actual operating conditions. All Fairchild 3-terminal regulator tests are based on similar practical considerations.

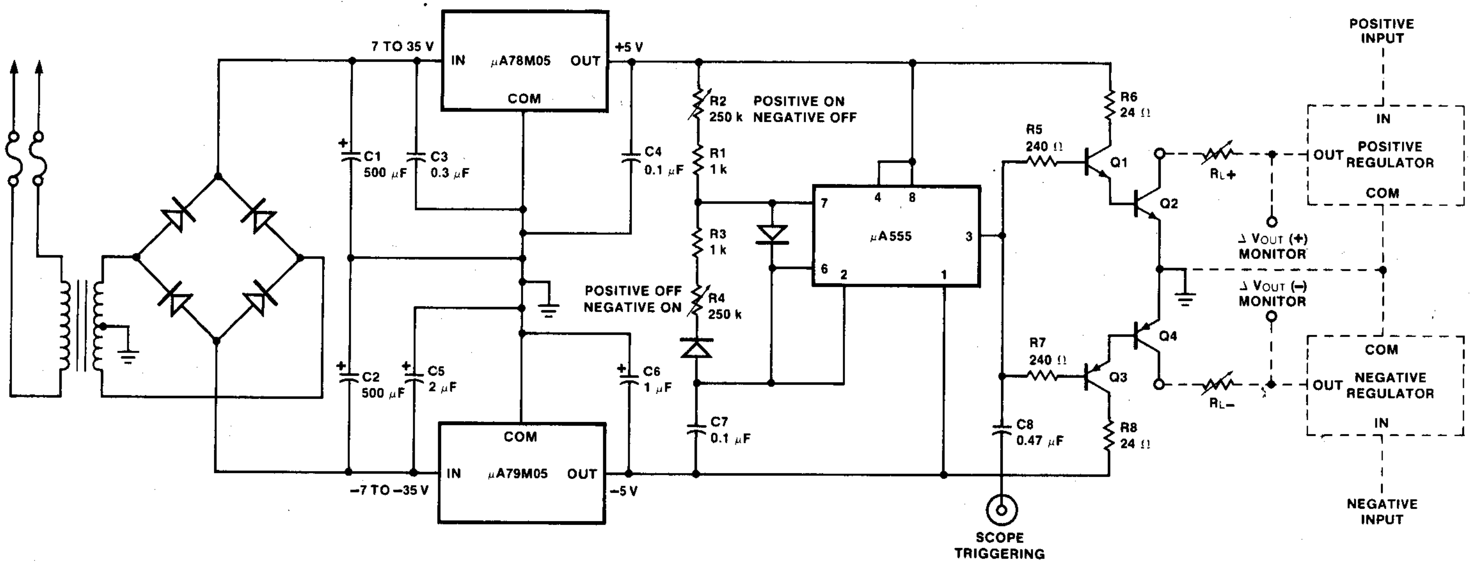


Fig. 2-1 Self-Contained Load Regulation Test Circuit for Positive or Negative Regulators

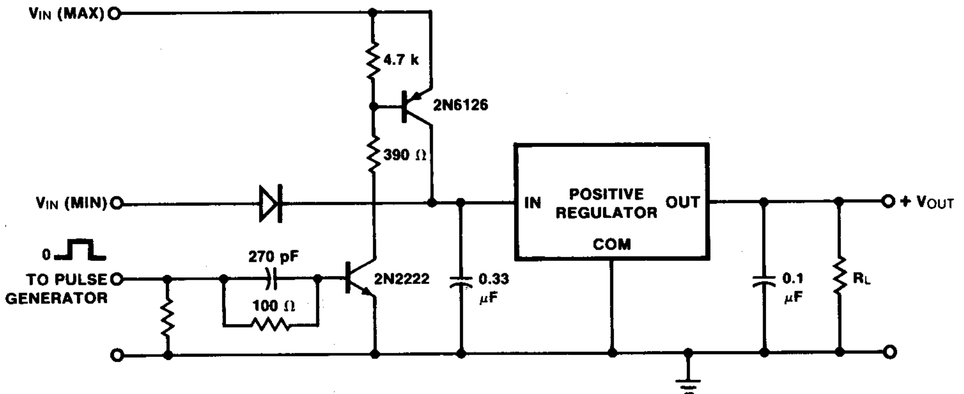
Figure 2-1 shows a self-contained load-pulsing circuit that can be used for measuring load regulation of either a positive or negative regulator. The μA555 timer operates in the astable mode as a free-running multivibrator. Transistors Q2 and Q4, along with the load resistors R_L, provide the required loading across the regulator outputs. The on and off times of Q2 and Q4 are set by potentiometers R2 and R4. Transistors Q2 and Q4 must be capable of handling the load current levels to be measured. Line regulation of positive or negative regulators can be measured using the circuits in *Figure 2-2*. Here a pulse generator switches the input voltages between $V_{IN\ (min)}$ and $V_{IN\ (max)}$ but a similar arrangement could be used by substituting a μA555 timer for the pulse generator.

Ripple Rejection

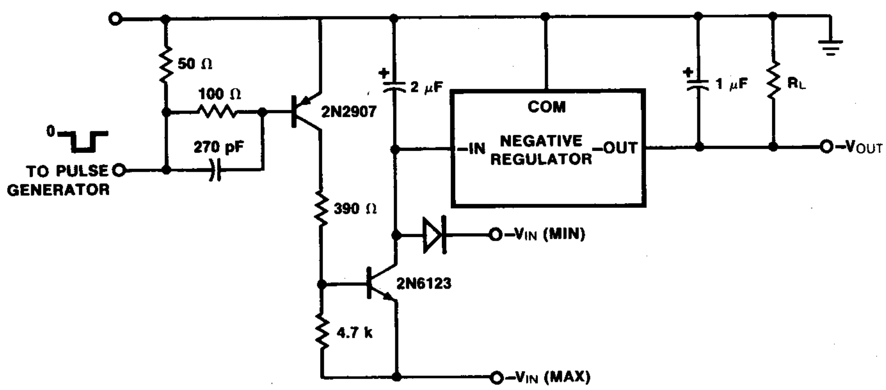
Ripple rejection is the ratio (in dB) of the regulator input ac component (or the output of the sine wave generator) to the output ac component of the device under test. Its measurement is quite straightforward.

Ripple rejection of Fairchild regulators is normally specified at a load current of 30 to 50% of the rated output of the device. This is more realistic than the 20 mA or so specified by some other manufacturers. A regulator with good ripple rejection at low output currents may not necessarily maintain this feature at moderate-to-high current levels unless special effort is made during the layout of the integrated circuit to keep the reference circuit on isotherms (equal temperature lines) and away from the heat source (series-pass element).

2



a. **For Positive Regulators**



b. **For Negative Regulators**

Fig. 2-2 Line Regulation Test Circuits

Figure 2-3 shows two simple circuits for measuring ripple rejection of positive and negative regulators. The 5k potentiometers in both circuits provide the bias necessary to produce the dc level of the input voltage to the regulator. The sine-wave generators are used to produce the ac component of the regulator input voltage.

Life Test and Burn-In (See *Figure 2-4*)
Burn-in information is provided here as a guide to perform regulator life testing. The burn-in performed by Fairchild is based on the thermal resistance of the regulator package. The power dissipation level is selected so that the junction temperature is near the maximum specified level (150° C for most products). The power level is then determined based on the chosen ambient. In general, burn-in is performed at 25° C ambient without a heat sink but it can also be done with a heat sink or a different ambient.

Example: Determine a burn-in circuit, operating at a 25° C ambient, for a μA7805 in the TO-220 package. From the data sheet:

$$\theta_{J-A} = 65°\text{C/W max}$$

$$P_D = \frac{T_{J\,(max)} - T_A}{\theta_{J\,A}} = \frac{150 - 25}{65} = 1.92\text{ W}$$

If $R_L = 30\Omega$ and the effects of I_Q are neglected,

$$P_D = (V_{IN} - V_{OUT})\frac{V_{OUT}}{R_L}$$

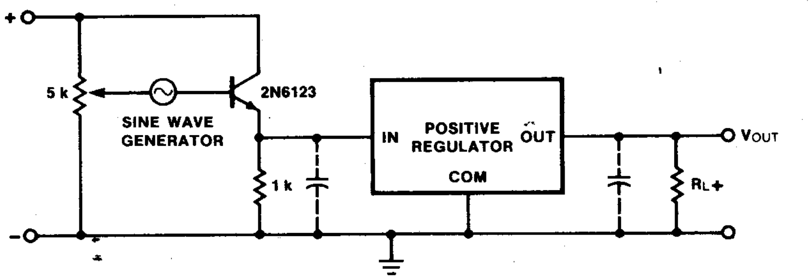
or

$$V_{IN} = P_D\left(\frac{R_L}{V_{OUT}}\right) + V_{OUT} = 16.5\text{ V}$$

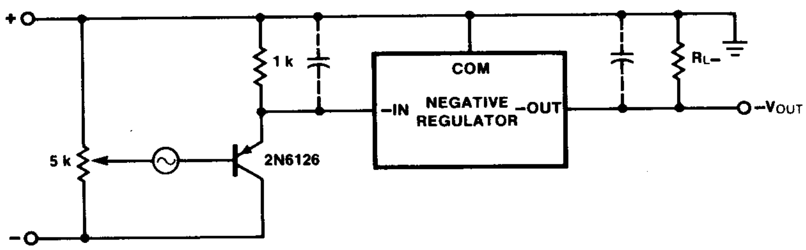
If the same circuit is used at an ambient of 125° C,

$$V_{IN} = P_D\left(\frac{R_L}{V_{OUT}}\right) + V_{OUT} = \frac{150\text{-}125}{65} \times \frac{30}{5} + 5 = 7.3\text{ V}$$

Note that the value of the load resistor chosen here (30 Ω) is arbitrary. Any other value giving output currents within the rating of the device could be used. If the burn-in is to be performed at more than one temperature, selecting a common load resistor for all temperatures and changing the input voltage to give the required power dissipations simplifies the design and construction of the burn-in fixtures.

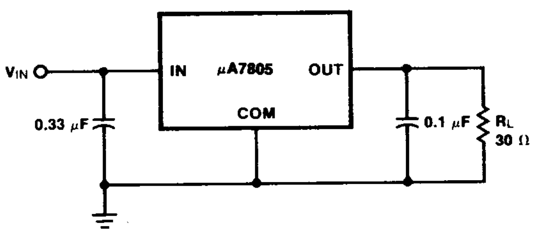


a For Positive Regulators



b For Negative Regulators

Fig. 2-3 Ripple Rejection Measurement Circuits



V_{IN} = 16.5 V FOR T_A = 25°C
V_{IN} = 7.3 V FOR T_A = 125°C
NO HEAT SINK

Fig. 2-4 Burn-In Circuit for μA7805 Regulator in TO-220 Package

2

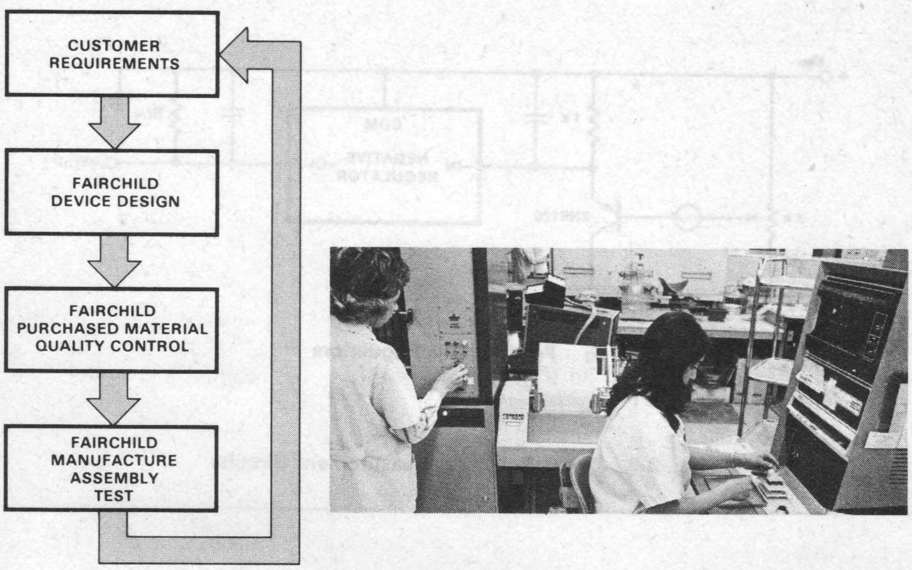
RELIABILITY

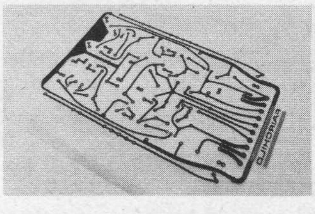
There are three basic ingredients in the manufacture of reliable voltage regulators. First, the device must be designed with the user's applications and reliability requirements in mind. Secondly, the device must be manufactured with the optimum technology for the application. Thirdly, controls must be established to assure maintenance of the quality/reliability levels established in the design of the device. Consideration is given to the reliability influence of each part of the manufacturing and testing cycle with constant feedback from internal reliability monitoring; customer feedback on the results is a vital factor. The Fairchild reliability concept can be presented as constant feedback system which begins and ends with the customer *(Figure 2-5)*.

Areas of Consideration

Device Applications and Reliability

The reliability cycle begins with the customer. His device application, environment for its usage and end-product reliability requirements are major factors in establishing the quality/reliability levels for voltage regulators. The customer is the final judge.





Customer Design Breadboard

Fig. 2-5 Customer Feedback System

Device Design
Inherent component reliability is a function of the product/process design. New Fairchild regulator designs as well as modifications or extensions of existing designs with known performance and reliability characteristics are rigorously evaluated. Three different factors in the manufacture of an IC significantly affect its reliability.

The Silicon Chip — Fairchild's design-technology capability utilizes epitaxial layer to achieve the desired electrical parameter characteristics. The surface influences long-term gain and voltage/leakage stability. The metallization determines mechanical integrity and current distribution.

Chip Assembly — The process and materials used to assemble the chip and package must preserve the inherent reliability of the chip and be inherently reliable to withstand thermal, mechanical and electrical stresses.

The Package — The package must effectively transfer heat from the chip to the outside world and protect the chip during handling and use.

2

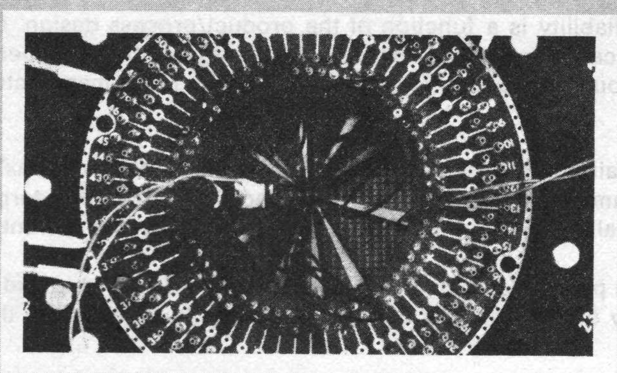
Incoming Quality Control (IQC)
All purchased materials for Fairchild voltage regulators are controlled through central specification control, product engineering, and reliability and quality assurance (R&QA) located in Mountain View. Materials are purchased and inspected per control documents using three IQC methods.

Direct visual and mechanical inspection
Functional testing
Composition analysis utilizing chemical and x-ray techniques from both internal and external sources.

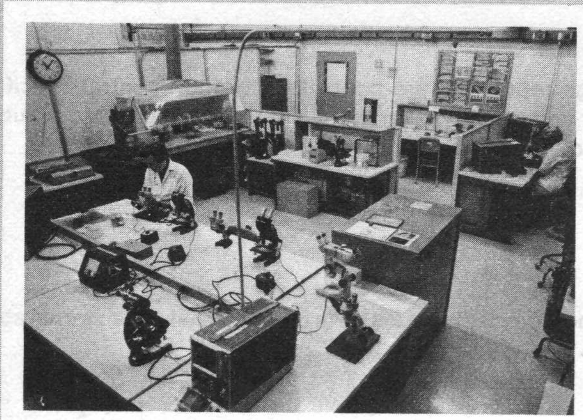
In addition to centralized IQC, each manufacturing facility has a local, fully equipped IQC department. These facilities concentrate on cleanliness, plating quality and functionality. A computer file is made on each vendor's performance and quarterly reports are generated and analyzed.

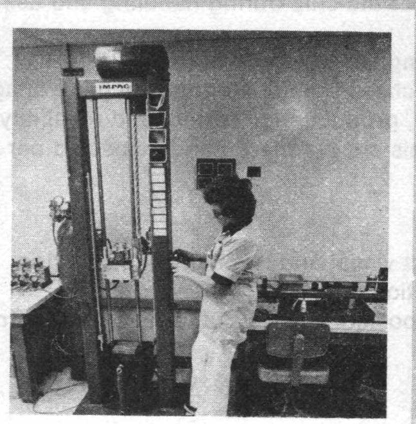
Wafer Manufacture
All wafers used to fabricate Fairchild voltage regulators are made at Fairchild. This includes crystal pulling, slicing, polishing and epitaxial layer growth. Fairchild voltage-regulator designs rely on accurate control of thickness and resistivity over a three-inch diameter wafer. All critical operations have laminar-flow clean-air hoods directly over the work areas. Wafer fabrication is essentially a series of masking and furnace cycles in which geometries are defined and impurities (dopants) introduced to form emitter, base and resistor regions. Daily controls are maintained on furnace temperatures to within $\pm 1°$ C. Resistivities (ρ_S) of diffused layers are recorded on every run. Each masking step defines a new portion of the device geometry. A post develop inspection is performed to assure that each wafer has been properly exposed and chemically developed before final etching. When the masking and etching procedures are completed, a final inspection assures that the geometry is properly aligned, etched and cleaned. Following each production masking step, a sample inspection is performed by quality control inspectors to verify correct process implementation.

After masking and diffusion, the metallization process completes wafer manufacture. Fairchild uses electron-beam evaporation techniques to deposit gold and aluminum. Deposits are controlled through utilization of automated process sequencing,which includes an automatic thickness controller. Every run is gated through a first optical (1st opt.) inspection before it leaves the wafer fabrication area. Cleanliness, mask alignment, metal adherence (front and back) and general workmanship are inspected.

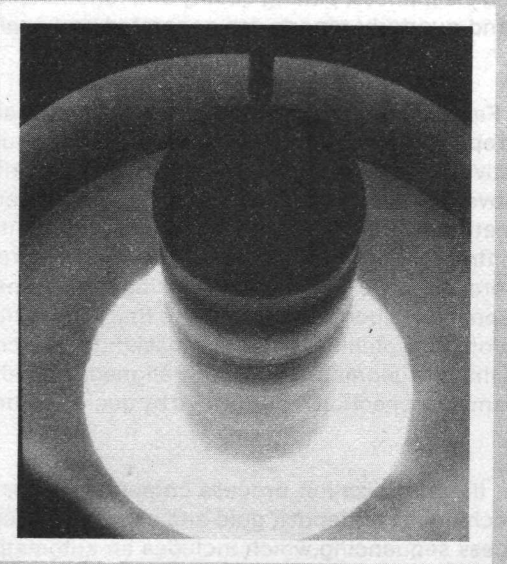


Wafer Probing





IQC Area



Crystal Puller

Wafer Testing
Before the wafers are scribed and broken into dice for assembly onto headers or shipment to a customer as probed dice, they are electrically sorted. Each wafer is automatically probed with multiple tests to duplicate or correlate the dice to the final product test requirements. Rejected dice are ink marked and later scrapped. A final quality control gate is performed before the probed wafers can be forwarded to assembly.

Device Assembly
After the wafers are scribed and broken, a second optical (2nd opt.) QC inspection is performed. The dice are inspected for wafer fabrication (handling) damage, as well as for defects which may cause assembly problems or result in latent reliability problems.

Monitors are performed on both assembly equipment and operators. Machines are shut down if defect control limits are exceeded and suspect material is rejected and 100% screened. Key items inspected are die orientation, voids under die, proper bond formation, wirepull strength and cleanliness.

2

A third optical (3rd opt.) gate is performed prior to final device sealing. If rejected, the lot is 100% screened by production and resubmitted to QC. Accepted lots are sent to the final seal operation, where the packages are monitored for weld strength and hermeticity (except plastic packages).

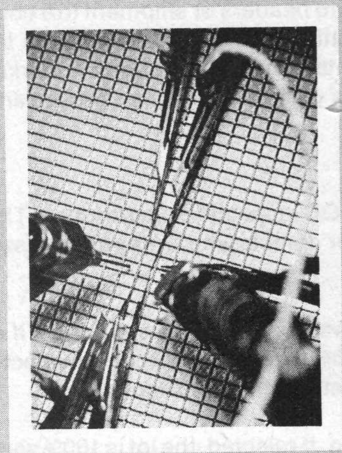
Device Testing
Before shipment, all devices are 100% production tested to the following minimum inspection levels.

Functional dc	0.25% AQL
25° C dc	0.65% AQL
25° C ac	1.5% AQL
Temperature dc	1.5% AQL
Mechanical/Visual	0.65% AQL
Marking Performance	15/0 LTPD
Fine Leak	1.0% AQL
Gross Leak	0.4% AQL

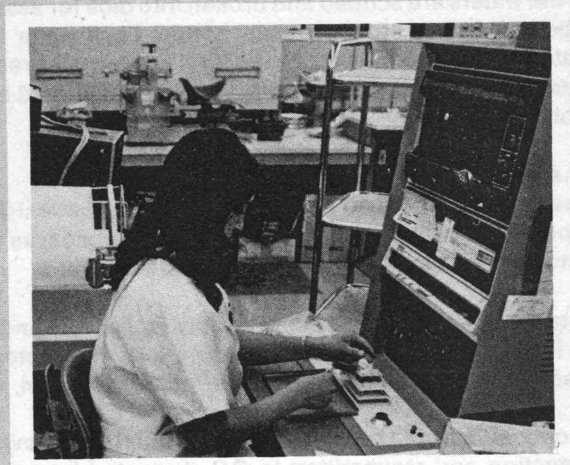
Customers with special testing requirements are accommodated through an internal specification system. All internal test specifications formatted from customer documents are signed off by QA before they can be issued to the test area.

Device Application
The total reliability effort is completed full-cycle with the customer. Operation in the customer application is the final consideration in device reliability. How each device is handled during system assembly by the customer, heat-sunk (mounted) and cooled during operation, and the amount of overload stresses (due to the system malfunction or misuse) greatly impacts the device reliability. Thus, the customer's specification requirements, the manufacturer's device design, manufacture, test, the actual circuit into which the device is inserted and the equipment containing that circuit in the field all affect the device and reliability.

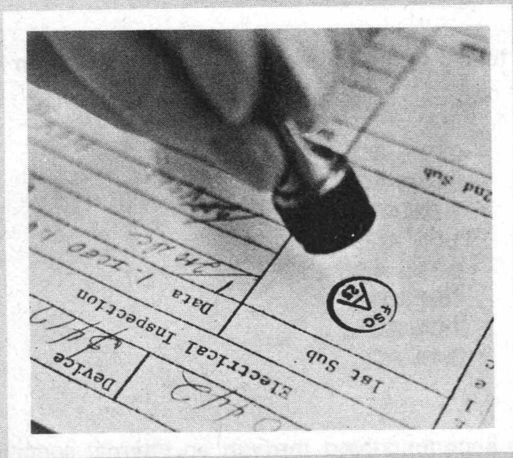
Failure Analysis
Failure analysis results performed by customers and by Fairchild on returned devices provide one of the most important inputs for consideration in Fairchild's total linear reliability concept. Failures generated by line monitors, life tests and field applications are analyzed to provide corrective action in terms of product design, assembly and testing methods. A scanning electron microscope (SEM) and an Auger electron microscope for chemical analysis are available for inspection of materials.



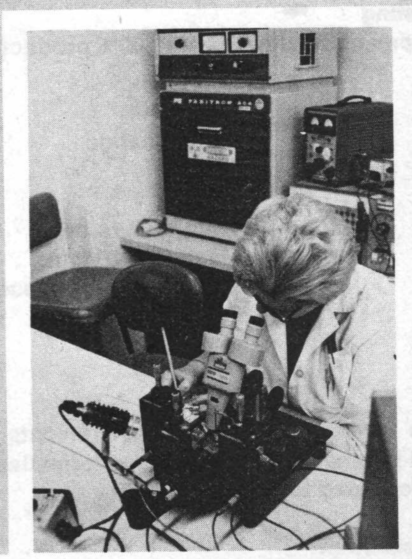
Die Probing

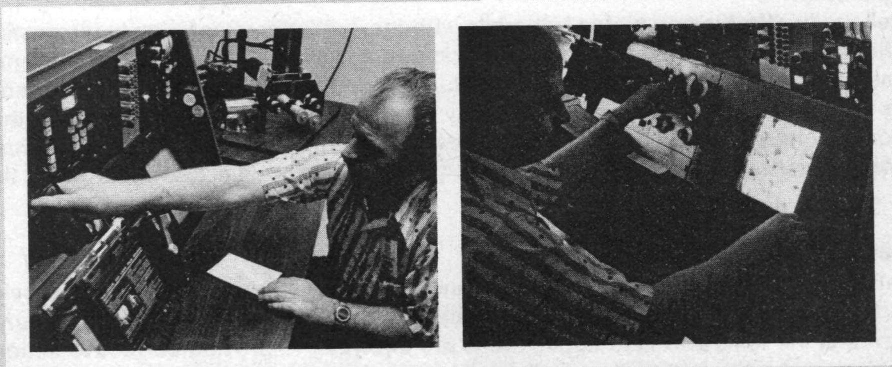


Device Testing



IQC Sign-off





Failure Analysis

Reliability Monitor and Control

Line Monitors

Line monitors are used to monitor the production line on a weekly basis. These monitors are designed to provide a constant feedback on product reliability. The following assembly/test monitors are conducted on a routine basis.

Assembly	Test
Package integrity	High-temperature reverse bias
Lead integrity	Intermittent operating life (power cycling)
Die integrity	High-temperature storage
Die-attach integrity	Temperature cycling
Bond integrity	Thermal shock
	Autoclave*
	85% R.H./85° C biased*

*Applied to plastic devices only.

2

Extended Reliability Tests

In conjunction with the weekly line-monitor program, Fairchild employs an extended reliability test program which is designed to reflect the long-term stability of Fairchild's regulator products. A summary of these reliability tests is shown in *Table 2-1*.

Quality and Reliability Data

Supplemental brochures are published on an annual basis which provide detailed failure rate data. Please contact Fairchild Sales Offices for additional reliability and quality information.

HI REL PROCESSING — MIL-M-38510/MIL STD-883

A unique "company", within Fairchild Linear, is totally dedicated to the processing of high reliability products and to serving the special needs of the HI REL community. It consists of marketing, engineering, production control, manufacturing and quality assurance. Fairchild's HI REL processing facilities are among the most modern and sophisticated in the semiconductor industry. Screening procedures are set up to conform to the most recent version of MIL-STD-883, in conjunction with MIL-M-38510, which establishes standardized requirements for design, material, performance, control and documentation needed to achieve prescribed levels of device quality and reliability.

HI REL Unique II Program

Fairchild's Unique II program fills a longstanding need for a definite and comprehensive program covering HI REL semiconductor products...a program offering users a selection among multi-level screening flows and reliability requirements...a program providing clear and precise definitions on all areas of contractual performance...a program designed to reduce the high costs and delivery delays normally associated with HI REL. The objectives and benefits of the Unique II program for integrated circuits are these:

- Offers a full spectrum of processing options, including full compliance JAN and 883 Classes S, B, and C.
- Offers full compliance with JAN MIL-M-38510 and emphasizes the importance of this program.
- Accommodates the special needs of users' source control and specification control drawings.
- Offers models to aid users in development of source control drawings.

EXTENDED RELIABILITY TESTS	METAL CAN	PLASTIC
High Temperature Operating Life $T_A = 150°C$ Readouts at 0, 168, 500, 1000 Hours	X	X
Temperature Cycling -65°C to +150°C (MIL-STD-883, Method 1010.1, Cond. C) Readouts at 0, 10, 100 Cycles Hermeticity (1×10^{-7} - TO-5, 1×10^{-6} - TO-3)	X	
Constant Acceleration F = 20K g 1 Min. Ea. 6 Axis (MIL-STD-883, Method 2001.1)	X	
Impact Shock 1500 g x 5 Blows (MIL-STD-883, Method 2002.1)	X	
Vibration, Variable Frequency 10 g (MIL-STD-883, Method 2007)	X	
Biased Humidity $T_A = 85°C$, RH = 85% Readouts at 0, 168, 500, 1000 Hours		X
Thermal Shock -55°C to +125°C Readouts at 0, 10, 100 Cycles MIL-STD-883, Method 1011.1, Condition C	X	X
Autoclave $T_A = 125°C \pm 2°C$ 15 PSI, 24 Hours		X

Table 2-1 Reliability Test Summary

- Takes the mystery out of in-house processing to MIL-STD-883 and to MIL-M-38510 detail specifications. The Unique II program is definitive as to the similarities and differences in these requirements.
- Provides users with alternatives that may be used when JAN slash sheets or QPLs are unavailable, or for programs that demand the highest level of quality and reliability.

Fairchild offers a complete processing capability to fulfill requirements ranging from the least demanding to the most complex, including the following:

- Scanning Electron Microscope (SEM) Inspection
- Level A Visual
- Bond Pull and Die Shear Testing
- Read and Record and Δ Drift Parameters
- Particle Impact Noise Detection (Pin-D) Testing
- Group A, B, C and D Qualification Testing.

Standard Unique II processing flows are given on the following pages; special flows will be quoted on an individual basis.

2

MATRIX VI — COMMERCIAL AND INDUSTRIAL RELIABILITY PROGRAM

Commercial and industrial users increasingly demand optimized quality and reliability for the semiconductor integrated circuits purchased for their systems. Specific factors — increased integrated circuit usage per board, high costs for receiving inspection, pc board and systems repair, and the frequently immeasurable cost associated with field failures — require the user to attain high quality and reliability coupled with total cost. Matrix VI is designed to meet these user requirements.

Fairchild's Matrix VI Program offers a broad spectrum of screens and high technology/high volume integrated circuit products to meet the user's quality and reliability requirements typically associated with the commercial and industrial marketplace. There are two screening options for each package type, each with a separate degree of reliability and cost level. To simplify a cost-effective analysis, reliability factors have been assigned to each screening level. (See following pages.)

It is the goal of Matrix VI to achieve the highest possible reliability consistent with the user's needs and to avoid "over-buying". Cost-effective reliability is the essence of Matrix VI, the most comprehensive program of its kind now offered to the industrial/commercial marketplace.

JAN PART NUMBERING SYSTEM

J M 38510/ 101 01 B G C

JAN DESIGNATOR (J)

Cannot be marked with "J" unless qualified on Part I or Part II of QLP-38510

General Procurement Spec. (M 38510/)

REFERS TO DETAIL SPEC (101)

- 101 Op Amps
- 102 Voltage Regulators
- 103 Comparators
- 104 Interface
- 105 733
- 106 Voltage Followers
- 107 3-Terminal Voltage Regulators
- 108 Transistor Arrays
- 109 Timers
- 110 Quad Op Amps

Defines Device Type (01)

PROCESSING LEVEL (B)

- A
- B
- C

PACKAGE TYPE (G)

- A 14-lead 1/4 x 1/4 Flatpak
- B 14-lead 1/4 x 1/8 Flatpak
- C 14-lead 1/4 x 3/4 DIP
- D 14-lead 1/4 x 3/8 Flatpak
- E 16-lead 1/4 x 3/4 DIP
- F 16-lead 1/4 x 3/8 Flatpak
- G 8-lead Can
- H 10-lead 1/4 x 1/4 Flatpak
- I 10-lead Can
- J 24-lead 1/2 x 1 1/4 DIP
- K 24-lead 3/8 x 1/2 Flatpak
- L 24-lead 3/8 x 1/2 Flatpak
- X 3-lead TO-5 Can
- Y 2-lead TO-3 Can
- Z 24-lead 1/4 x 3/8 Flatpak

LEAD FINISH (C)

- A Hot Solder DIP
- B Tin Plate
- C Gold Plate
- X Any of the above

LINEAR JAN GENERIC PART NUMBERS – EXAMPLES

JM38510/	01	02	03	04	05	06	07	08	09	10
101	741	747	101A	108A	2101	2108	118			
102	723									
103	710	711	106	111	2111					
104	55107	55108	9614	9615	55113	7831	7832	7820	7830	
105	733									
106	102	110	2110							
107	109	78M05	78M12	78M15	78M24	7805	7812	7815	7824	
108	3018	3045								
109	555	556								
110	148	149	4741	4136	124					

Note: Dated material. Please contact Fairchild for latest revisions.

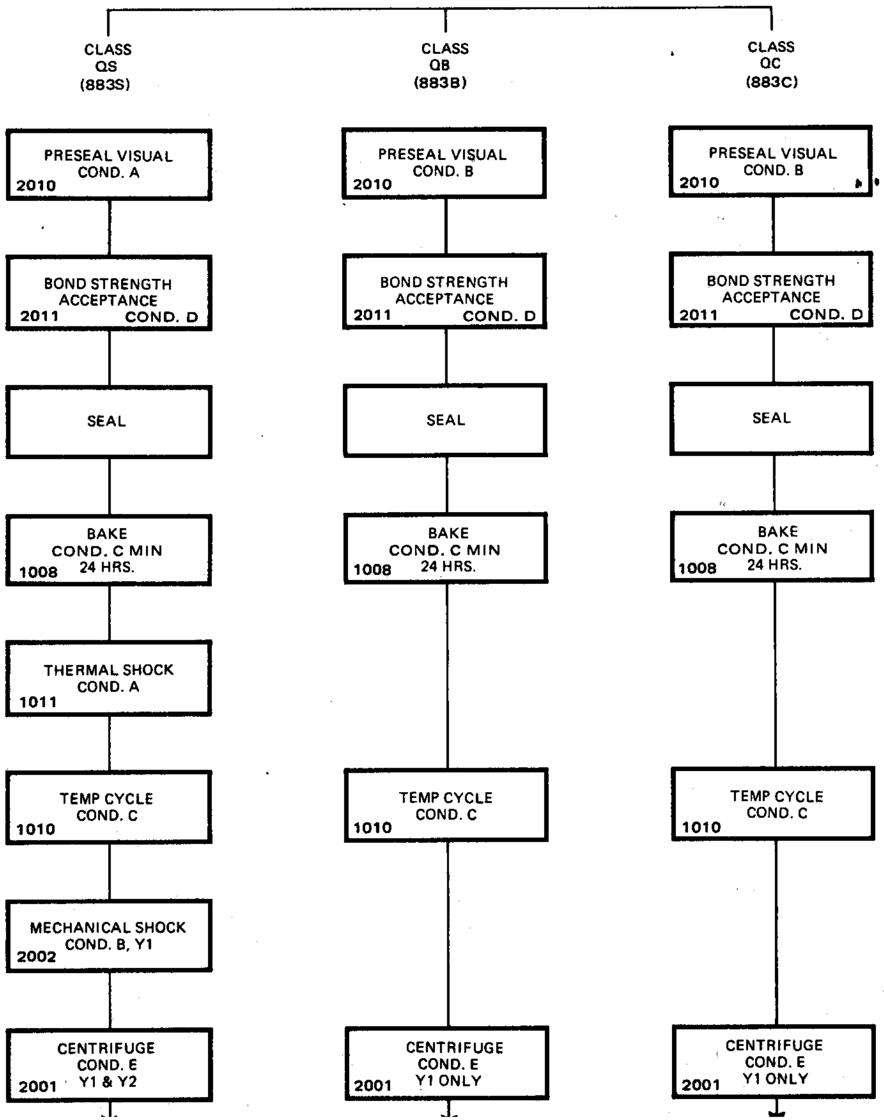
HI REL PROCESS SCREENING REQUIREMENTS

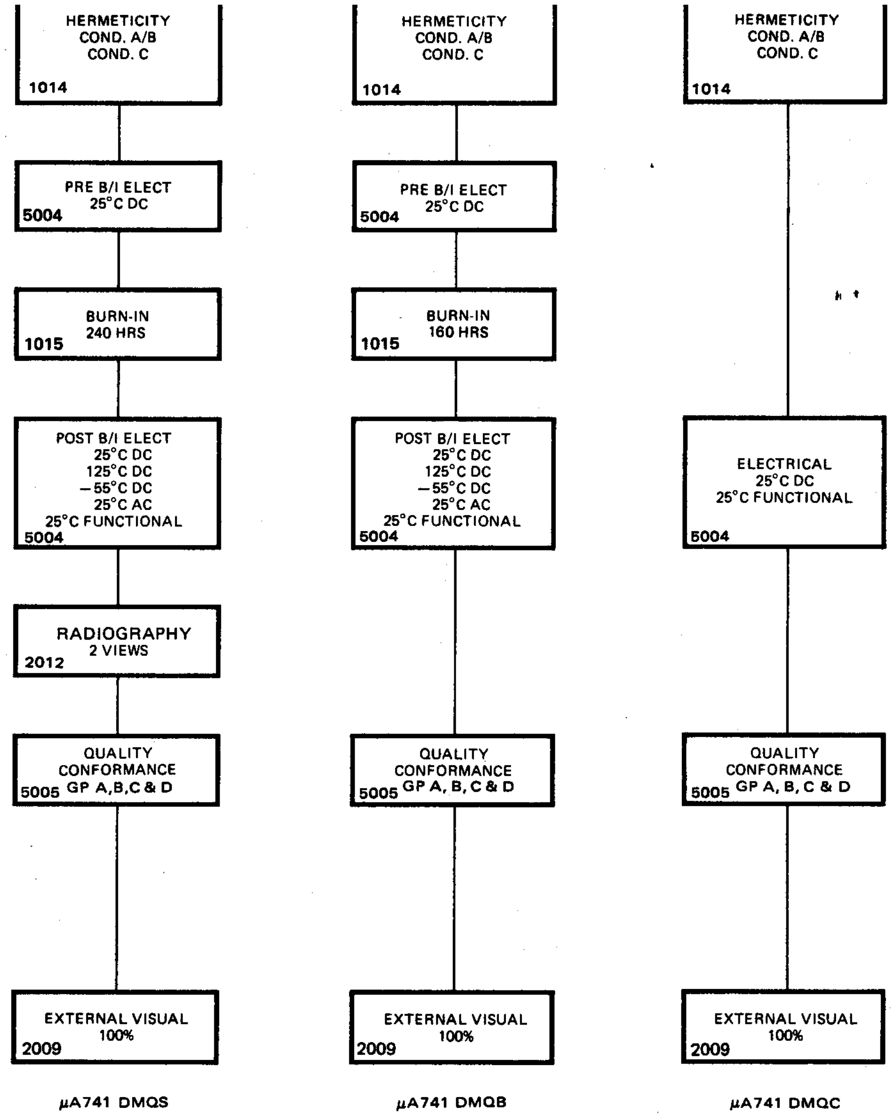
MIL-STD-883A TEST METHODS	DESCRIPTION	JAN M38510 CLASS B	JAN M38510 CLASS C
Preseal Visual MTD. 2010	Cond. A Maximum Visual Criteria Cond. B. Optimum Visual Criteria	PRESEAL VISUAL COND. B	PRESEAL VISUAL COND. B
Bond Strength MTD 2011	Bond strength is monitored on a sample basis three times per shift per machine	BOND STRENGTH COND. D	BOND STRENGTH COND. D
Seal	Devices are hermetically sealed for compliance to MIL-STD-883 requirements	SEAL	SEAL
High Temp Storage MTD 1008	Cond. C Tstg = 150°C	BAKE COND. C MIN 24 HRS.	BAKE COND. C MIN 24 HRS.
Temperature Cycle MTD 1010	Cond. C −65°/150°C 10 cycles	TEMP CYCLE COND. C	TEMP CYCLE COND. C
Constant Acceleration MTD 2001	Cond. E 30000 G's X_1, X_2, Y_1, Y_2	CENTRIFUGE COND. E Y_1 ONLY	CENTRIFUGE COND. E Y_1 ONLY
Hermetic Seal MTD 1014	Cond. A Fine-Helium 5×10^{-8} cc/sec Cond. B Fine-Radiflo 5×10^{-8} cc/sec Cond. C Gross-FC43/Hot 10^{-3} cc/sec or Gross-FC78/Vacuum 10^{-5} cc/sec	HERMETICITY COND. A/B COND. C	HERMETICITY COND. A/B COND. C
Pre Burn-in Electrical MTD 5004	25°C dc electrical testing to remove rejects prior to submission to burn-in screen	PRE B/I ELECT 25°C dc	
Burn-in Screen MTD 1015	Cond. A, Cond. B, Cond. C Cond. D, Cond. E, Cond. F	BURN IN* 160 HRS 125°C	
Post Burn-in Electrical MTD 5004	Post Burn-in electrical screening to cull out devices which failed as a result of burn-in. Test Parameters may include: 25°C dc, 125°C dc, −55°C dc, 25°C dc, 25°C ac and 25°C Functional tests.	PST B/I ELECT 25°C dc +125°C dc −55°C dc 25°C ac 10% PDA	ELECTRICAL 25°C dc 25°C FUNCTIONAL
Quality Conformance Inspection MTD 5005	Group A: Electrical Characteristics Group B: Package oriented Tests Group C: Life Tests Group D: Environmental Tests	QUALITY CONFORMANCE Gp A, B, C and D	QUALITY CONFORMANCE Gp A, B, C and D
External Visual MTD 2009	3X, 10X magnification: Verify dimensions, configuration, lead structure, marking and workmanship	EXTERNAL VISUAL 100%	EXTERNAL VISUAL 100%
RELIABILITY	Figure of Merit	15	2
ORDERING	Part Number	JM38510/10101BCB	JM38510/10101CCB
	Part Marking	JM38510/10101BCB	JM38510/10101CCB

NOTE: RELIABILITY Figure of Merit is the Reliability Improvement Factor from RADC Reliability Notebook, Vol. II, RADC-TR-67-108, Table XII-6, page 419.

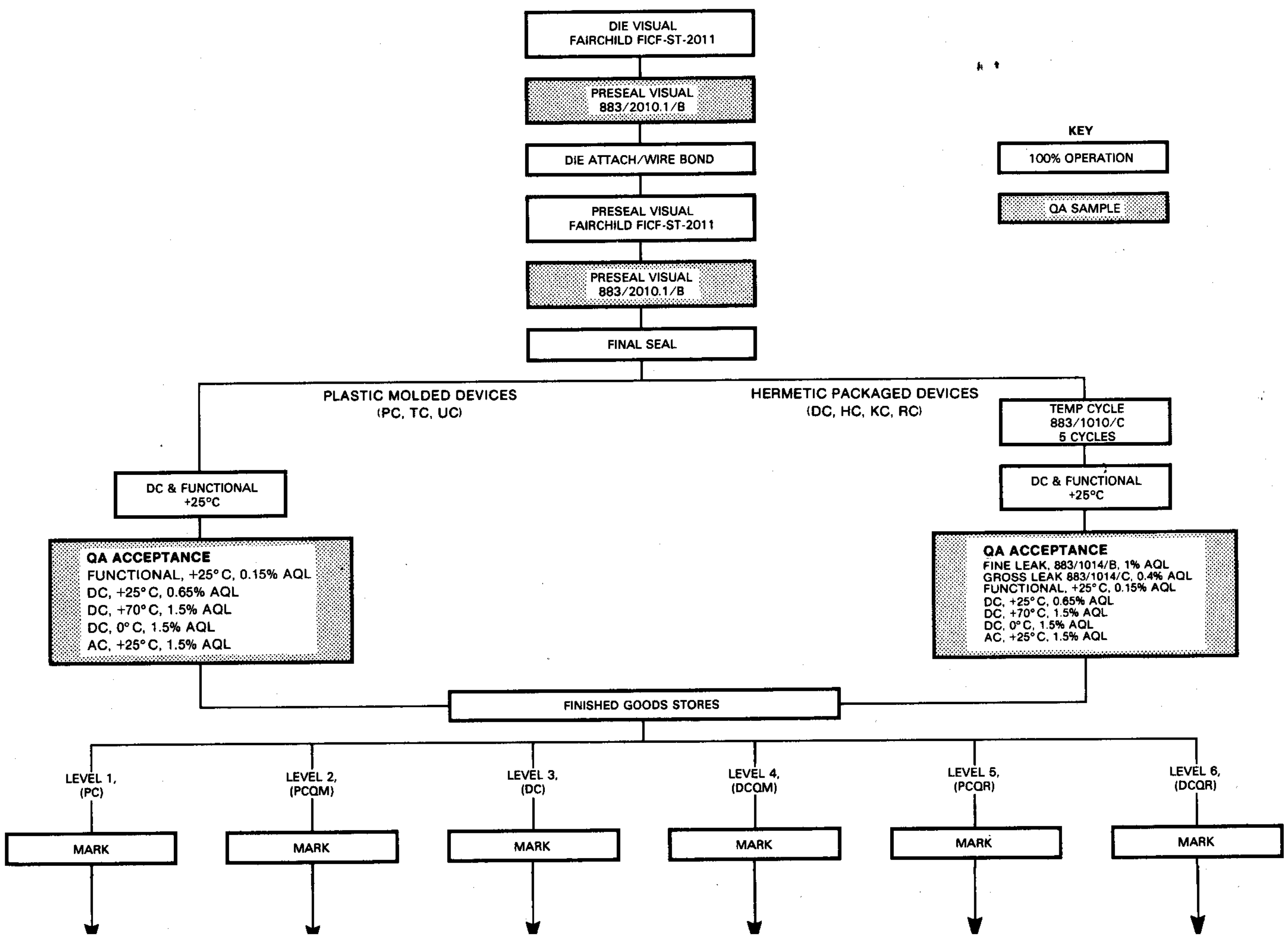
*Time Temperature Curve (method 1015) may be used.

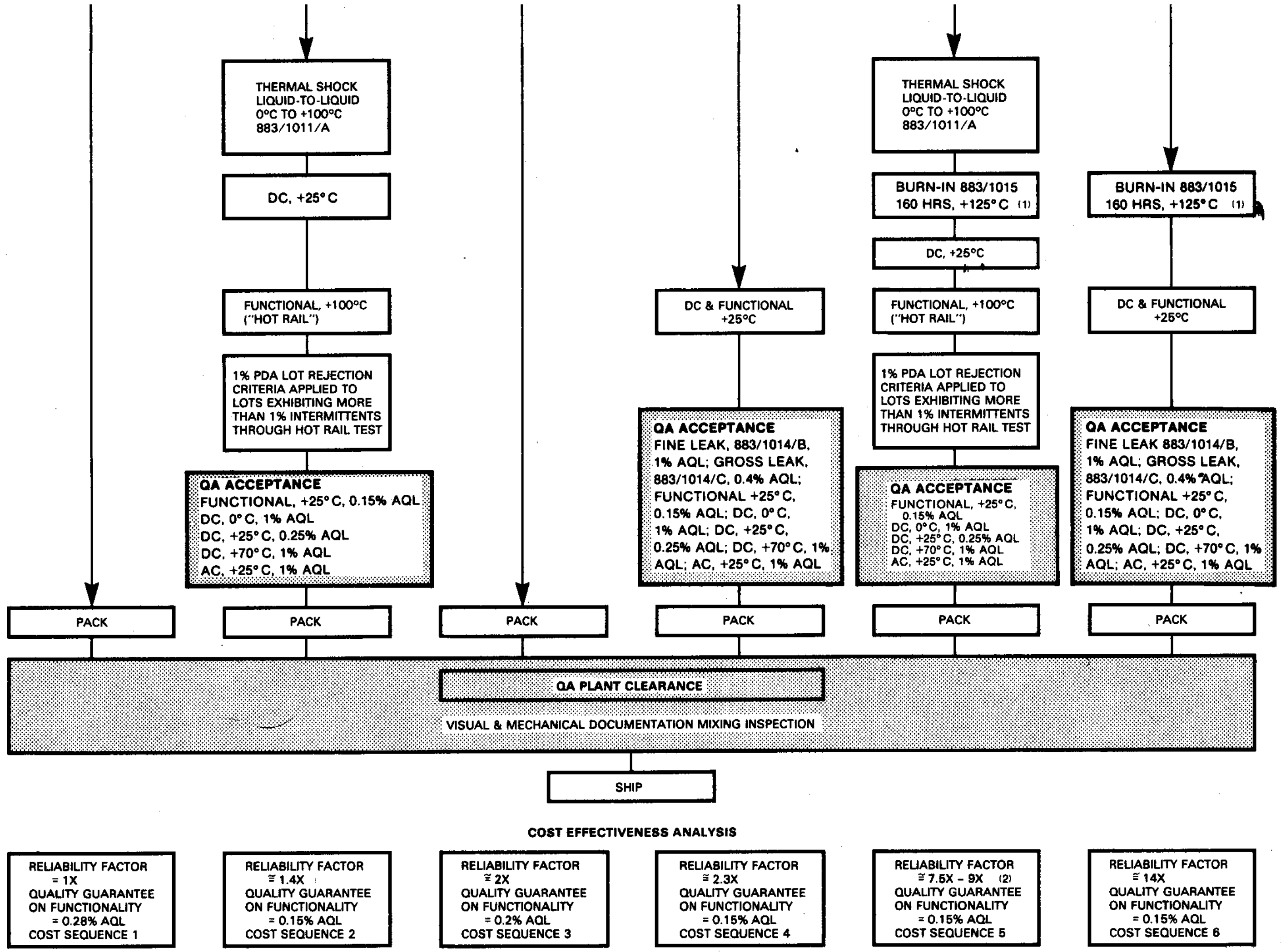
UNIQUE II


CLASS QS (883S)
PRESEAL VISUAL COND. A 2010
BOND STRENGTH ACCEPTANCE 2011 COND. D
SEAL
BAKE COND. C MIN 24 HRS. 1008
THERMAL SHOCK COND. A 1011
TEMP CYCLE COND. C 1010
MECHANICAL SHOCK COND. B, Y1 2002
CENTRIFUGE COND. E Y1 & Y2 2001
CLASS QB (883B)
PRESEAL VISUAL COND. B 2010
BOND STRENGTH ACCEPTANCE 2011 COND. D
SEAL
BAKE COND. C MIN 24 HRS. 1008
TEMP CYCLE COND. C 1010
CENTRIFUGE COND. E Y1 ONLY 2001
CLASS QC (883C)
PRESEAL VISUAL COND. B 2010
BOND STRENGTH ACCEPTANCE 2011 COND. D
SEAL
BAKE COND. C MIN 24 HRS. 1008
TEMP CYCLE COND. C 1010
CENTRIFUGE COND. E Y1 ONLY 2001


HERMETICITY COND. A/B COND. C 1014
PRE B/I ELECT 25°C DC 5004
BURN-IN 240 HRS 1015
POST B/I ELECT 25°C DC 125°C DC −55°C DC 25°C AC 25°C FUNCTIONAL 5004
RADIOGRAPHY 2 VIEWS 2012
QUALITY CONFORMANCE 5005 GP A,B,C & D
EXTERNAL VISUAL 100% 2009
µA741 DMQS
HERMETICITY COND. A/B COND. C 1014
PRE B/I ELECT 25°C DC 5004
BURN-IN 160 HRS 1015
POST B/I ELECT 25°C DC 125°C DC −55°C DC 25°C AC 25°C FUNCTIONAL 5004
QUALITY CONFORMANCE 5005 GP A, B, C & D
EXTERNAL VISUAL 100% 2009
µA741 DMQB
HERMETICITY COND. A/B COND. C 1014
ELECTRICAL 25°C DC 25°C FUNCTIONAL 5004
QUALITY CONFORMANCE 5005 GP A, B, C & D
EXTERNAL VISUAL 100% 2009
µA741 DMQC

MATRIX VI PROCESS FLOW OPTIONS & COST EFFECTIVENESS

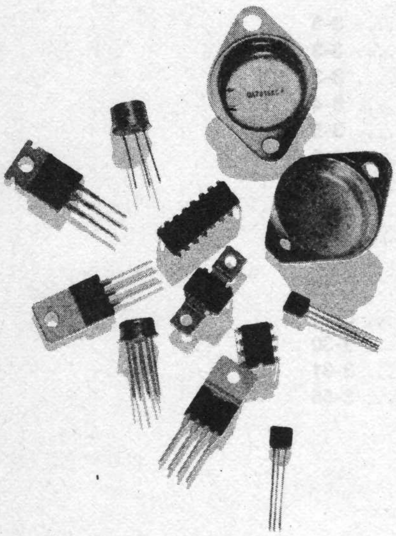




NOTE:

(1) Temperature Accelerated Testing may be used for MIL-STD-883 method 1015 Test Condition F.

(2) Burn-In has the same relative effectiveness for plastic molded devices as for ceramic/hermetic packaged devices. Assuming a controlled (air conditioned and constant power) field application/environment, the reliability factor would be approximately 9x. But should the field application be in a less controlled and power on/off application, the reliability would be approximately 7.5X.



IC VOLTAGE REGULATOR APPLICATIONS

Chapter 3
IC VOLTAGE REGULATOR APPLICATIONS

A few of the most popular and widely used series as well as switching regulator applications are discussed in this chapter. There is also a compendium of regulator applications for each Fairchild regulator at the end of this chapter. Similarities and differences in regulator types are described in Chapter 1.

SELECTING THE CORRECT SERIES TYPE REGULATOR

The regulator selection guides provide concise tables of key regulator specifications by device number, or by ascending I_{OUT}. Select the device that provides the desired output voltage and current, then proceed as follows.

Determine the required input voltage (V_{IN}).

$$V_{IN(max)} > V_{IN} > V_{O(max)} + V_{DO(max)} + \Delta V_L + V_{R(pk)}$$

where

$V_{IN(max)}$ = Maximum allowable input voltage

V_{IN} = Regulator input voltage under load

$V_{O(max)}$ = Maximum output voltage of regulator

$V_{DO(max)}$ = Maximum dropout voltage

ΔV_L = Maximum line voltage change

$V_{R(pk)}$ = Peak ripple voltage

Also determine $T_{A(max)}$ = Maximum ambient temperature and select $T_J < T_{J(max)}$ from the data sheet and see Chapter 6 for thermal and heat-sink requirements.

DESIGN PRECAUTIONS

When designing and laying out a regulator circuit, follow these guidelines to save time, money and simplify design.

- Keep all ground leads as short as possible. Use ground conductors sufficiently large enough to handle rated currents to reduce unwanted voltage drops across leads, and to minimize heating effects and lead inductance.
- Use single-point grounding at the regulator common terminal whenever possible to prevent circulating currents or ground loops.
- When using the adjustable multi-terminal regulators, especially at high output current levels, derive the feedback sense voltage from across the load rather than from across the regulator to improve circuit performance.
- Note that some devices are offered with the case or tab connected to either ground (positive regulators) or to the input (negative regulators). For example, the μA78G 4-terminal positive adjustable regulator is offered in an aluminum (TO-3) type or plastic Power Watt (similar to TO-202) package with the case or tab connected to common. In the complementary or negative version, the μA79G, the case or tab is connected to the negative input. Precautions should be taken to avoid accidentally grounding the case or tab of negative regulators. Negative regulators should be electrically insulated from the mounting surface, or the mounting surface should be insulated from ground or chassis.

BYPASSING

Monolithic 3 and 4-terminal regulators are particularly attractive for providing local on card regulation because of the small number of required external components. Positive regulators, in general, use npn emitter-follower output stages whereas negative regulators use npn common-emitter stages with the load connected to the collector. The emitter-follower output-stage configuration is not used in negative regulators because monolithic pnp series-pass transistors are difficult to make. Because of their output-stage configurations, positive regulators are more stable than negative regulators; therefore, bypassing of positive regulators can be omitted in certain applications. It is a good practice, however, to use bypass capacitors at all times. Input bypass capacitors (0.33 μF) for positive 3 and 4-terminal regulators are required if the regulator is located an appreciable distance from the power supply filter. Output bypass capacitors (0.1 μF) are not normally needed but they do improve the transient response of the regulator.

On the other hand, bypass capacitors *are a must* for stable operation of the 3 and 4-terminal negative regulators over the input voltage and output current ranges. The bypass capacitors (2 μF on the input, 1 μF on the output) should be mylar, ceramic or tantalum with good high frequency characteristics. If more than one bypass capacitor source or more than one type is used, stability should be checked on each source or type. Stable operation with one capacitor from one vendor may not necessarily result in stable operation with a capacitor of the same type from a second vendor, since the characteristics of the capacitors may vary.

Regulator output impedance is in the order of 100 mΩ or less and increases as a function of frequency above 10 kHz due to the gain rolloff of the error amplifier. A tantalum electrolytic bypass capacitor connected to the regulator output will maintain low impedance for frequencies up to 1 MHz. A ceramic capacitor should be placed in parallel with the tantalum capacitor for driving fast switching loads to compensate for the rising impedance of the electrolytic capacitor above 1 MHz. If switching loads are distributed over a large area, additional ceramic bypass capacitors should be located at the loads. Very large-value output bypass capacitors should not be used unless adequate measures are taken to prevent the output from rising above the input, or to avoid discharging the bypass capacitor through the series-pass transistor of the regulator if the input is accidentally grounded. A reverse-biased diode connected from input to output is normally sufficient to achieve this protection.

To assure stable operation of a regulator using the μA723, dc and ac performance of the internal gain stage and external components must be determined. Then, the required compensation may be applied using standard operational amplifier techniques. Compensation of μA723 circuits is explained in detail on pages 3-26 and 3-27.

PROTECTION CIRCUITS

Internal protection circuits are provided in all 3 and 4-terminal voltage regulators to improve reliability and make these regulators immune to certain types of overloads. These on-chip components protect the regulators against short-circuit conditions (current limit), excessive input-output voltage differential conditions (safe-area limit) and excessive junction temperatures (thermal limit). The protection circuits protect the device against abuse and fault conditions that may be encountered *occasionally*. Continuous operation of the device under fault conditions such as a short or in a thermal shutdown mode is *not* a recommended procedure.

Proper attention must be paid to the safe-area protection network when 3 and 4-terminal regulators are operating with excessive input voltage or excessive input-output differential-voltage conditions. In addition to reducing the available output current with high input-output differential conditions, the safe-area protection network may, under certain conditions, cause the device to latch-up if the output is shorted to ground. This situation is aggravated as the input voltage, load current or the operating junction temperature is increased. This mode of operation does not damage the device but power (input voltage or load current) must be interrupted momentarily for the device to recover from the latched condition. The details of the protection circuits are discussed in Chapter 1.

Precautions must also be taken to avoid regulator operation beyond its maximum ratings. Switching transients exceeding the maximum input voltage rating of a regulator, for instance, can destroy a regulator. These transients, which occur especially if the regulator input voltage is switched instantaneously rather than ramped by the natural smoothing provided by the ac line and the filter capacitors, are usually hard to track and normally caused by lead inductance and fast switching currents. Good quality bypass capacitors that have low series resistance cause the inrush current to increase further, thereby causing a higher magnitude transient at the input of the regulator. In such cases, a lower quality and cheaper bypass capacitor may be the answer.

Because of their output stage configurations, positive regulators source current and negative regulators sink current. These restrictions should be kept in mind and, under no circumstance, should a regulator output terminal be allowed to go more than a few volts higher than the regulated output of the regulator. The power should be turned off before removing or inserting a regulator into a test socket. However, if it is necessary to insert a regulator into a "live" socket, care must be taken to ensure that the common terminal connection is made prior to, or simultaneously with, the input terminal connection. In the absence of the common terminal connection, the output voltage of the regulator is 1 or 2 V below the input voltage. This type of fault condition can cause an excessive output voltage which may adversely affect the circuits supplied by the regulator. If the common terminal is quickly connected, the regulator can be destroyed. Also, damage to the regulator may result from the discharging of the bypass capacitor through the output and common terminals.

THERMAL CONSIDERATIONS

The thermal properties and limitations of voltage regulators are extremely important in circuit design. Whether or not a heat sink is required should be determined before the circuit is laid out. See Chapter 6 for a detailed discussion of thermal considerations and how to choose the proper heat sink.

APPLICATIONS

The capabilities of regulators can be increased beyond their basic capacities by the addition of external components. Two or more regulators can be connected to increase output current, or widen the input and output voltage ranges. The applications discussed are divided into the following seven groups:

- Fixed Positive – 3-Terminal Regulators
- Fixed Negative – 3-Terminal Regulators
- Adjustable Positive – 3 and 4-Terminal Regulators
- Adjustable Negative – 3 and 4-Terminal Regulators
- Dual Regulators – Tracking and Non-tracking Regulators
- Precision Multi-terminal Regulators – μA723
- Switching Regulators

Note that apart from power and current considerations, the μA7800, μA78M00, μA78C00 and μA78L00 are interchangeable in most positive 3-terminal regulator applications, and the μA7900 and μA79M00 in 3-terminal negative regulator applications. The same applies for their 4-terminal counterparts. Appropriate changes may be necessary, however, in the external components when changing from one regulator to another. Line and load regulation data provided for the applications pertain to the circuit using the specific device indicated. This data would naturally vary somewhat with the use of different devices and is not meant to be a worst-case representation.

Fixed Positive 3-Terminal Regulators

Basic Regulator Configuration

The basic configuration of the 3-terminal positive regulator with a bypass capacitor and single-point grounding is shown in *Figure 3-1*. Currents in excess of the output capability of the basic 3-terminal regulators can be obtained with the circuit shown in *Figure 3-2*. Resistor R1 determines the point at which the external series-pass transistor Q1 begins to conduct; its value is determined by the following formula.

$$R1 = \frac{V_{BE1}}{I_{REG(max)} - \frac{I_{OUT(max)}}{\beta_{Q1(min)}}}$$

where $\beta_{Q1} > 10$

Maximum available current with this circuit is expressed as follows.

$$I_{OUT(max)} = \beta_{Q1}\left[I_{REG(max)} - \frac{V_{BE1}}{R1}\right]$$

It should be noted that Q1 is not short-circuit protected but protection can be achieved by adding a short-circuit sense resistor R_{SC} and a pnp transistor Q2 as shown in *Figure 3-3*. In this circuit, Q2 must be able to handle the short-circuit current of the regulator since, when Q1 is bypassed, the regulator goes into the short-circuit mode. The short-circuit current is determined by the base-emitter voltage of Q2 and the short-circuit resistor R_{SC}.

$$R_{SC} = \frac{V_{BE2}}{I_{SC}}$$

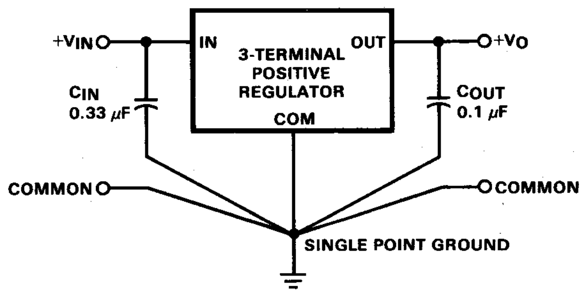
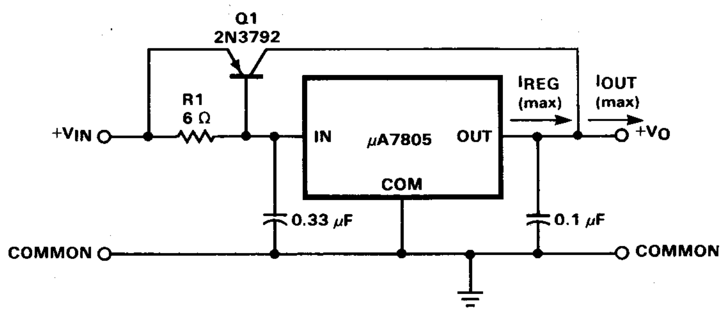


Fig. 3-1. Basic 3-Terminal Positive Regulator with Bypass Capacitors



NOTES:
Line Regulation: I_{OUT} = 100 mA, ΔV_{IN} = 5 V, ΔV_O = 1 mV
Load Regulation: V_{IN} = 10 V, ΔI_{OUT} = 5 A, ΔV_O = 10 mV

Fig. 3-2. High Current Voltage Regulator

Another method of achieving short-circuit protection with an external series-pass element is to use a diode as shown in *Figure 3-4*. Resistors R1 and R2 are used to set the ratio of the current handled by the regulator and the series-pass transistor, so that, assuming the diode drop $V_{D1} = V_{BE1}$

$$\frac{R1}{R2} = \frac{I_1}{I_{REG}}$$

Maximum current achievable with this circuit is expressed as follows.

$$I_{OUT(max)} = \frac{(R1 + R2)}{R1} I_{REG(max)}$$

By proper selection of the regulator and transistor heat sinks, the thermal protection of the regulator can be extended to the series-pass transistor. This circuit has one drawback – the dropout voltage is considerably higher than that in the circuit of *Figure 3-3*. This is due to the voltage drop across the current sharing resistors R1 and R2.

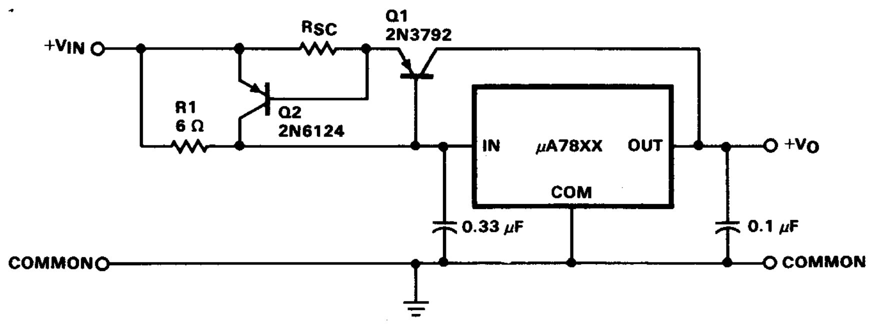
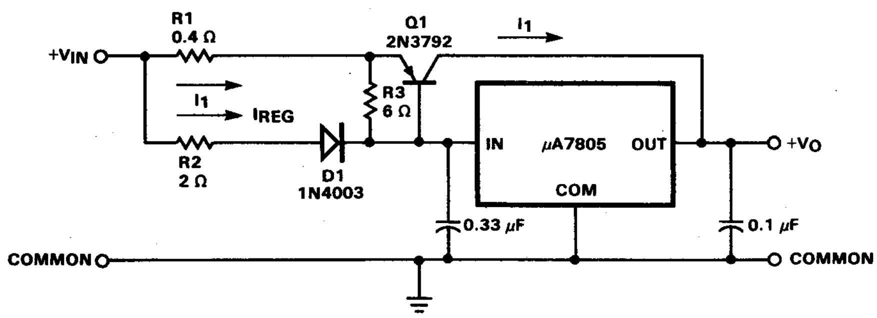


Fig. 3-3. High Output Current Voltage Regulator (Short Circuit Protected)



NOTES:
Line Regulation: $\Delta V_{IN} = 10$ V, $I_{OUT} = 3$ A, $\Delta V_O = 1$ mV
Load Regulation: $V_{IN} = 12$ V, $\Delta I_{OUT} = 5$ A, $\Delta V_O \doteq 30$ mV

Fig. 3-4. 5-Amp Regulator (with Short Circuit Protection)

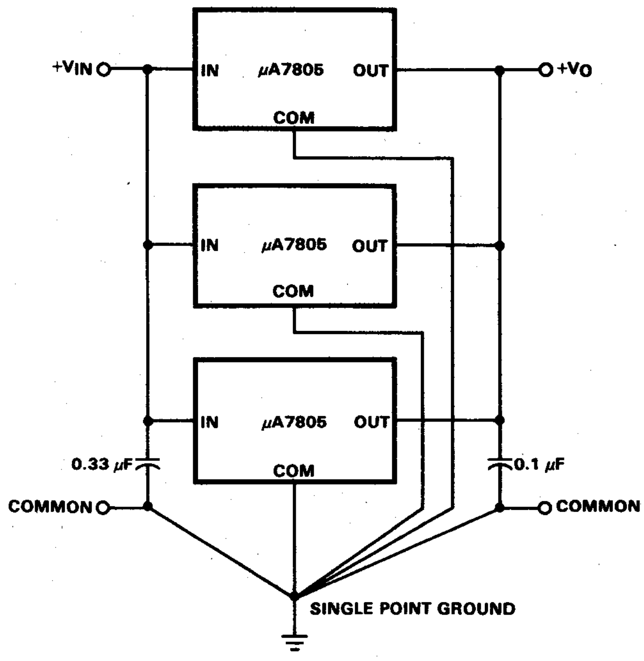
Parallel Regulators

To obtain higher output current without using a power transistor as a booster, several regulators in parallel may be used. Regulation of the overall system can be improved if the individual devices are matched for output voltages as shown in *Figure 3-5*. If the outputs are not matched, it is likely that the output current will not be shared between the regulators and, as a result, some of the regulators will operate at or near the current limit while others are at their quiescent no-load levels.

Excessive Input/Output Differential

When a regulator is operating with a large input-output differential, the addition of a series resistor with the input extends the operating range of the device by sharing the power dissipation, see *Figure 3-6*. The value of the series resistor R1 must be low enough so that, under worst-case conditions, (lowest supply voltage, highest output voltage, and highest load) the device remains in regulation. R1 can be calculated as follows.

$$R1 = \frac{V_{S(min)} - V_{O(max)} - V_{DO(max)}}{I_{OUT(max)} + I_{Q(max)}}$$



NOTES:
Line Regulation: I_{OUT} = 1 A, ΔV_{IN} = 10 V, ΔV_{OUT} = 3 mV
Load Regulation: V_{IN} = 10 V, ΔI_{OUT} = 1.5 A, ΔV_O = 30 mV, ΔI_{OUT} = 2.5 A, ΔV_O = 65 mV

Fig. 3-5. Parallel Operation of Regulators (High Output Current without a Power Transistor) – Output Voltages Matched to ±50 mV

where
$V_{S(min)}$ is the minimum supply voltage
$V_{DO(max)}$ is the maximum dropout voltage
$I_{Q(max)}$ is the maximum quiescent current

Maximum regulator dissipation, however, occurs with highest supply voltage and highest load current.

$$P_{D(max)} = \left[V_{IN(max)} - V_{O(min)}\right] I_{OUT(max)}$$

where

$$V_{IN(max)} = V_{S(max)} - \left[I_{OUT(max)} + I_{Q(max)}\right] R1$$

For a constant load, the regulator input voltage varies by the same amount as the supply voltage and consequently the line regulation of the device remains essentially the same.

For load regulation, assuming constant supply voltage, the combined effects of the change at the input due to the voltage change across R1 must be taken into consideration. In this configuration, as the load is increased, the regulator input voltage decreases and the net result, in most cases, is a slight degradation in the performance of the regulator since these two effects are additive.

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The load regulation can therefore be calculated as follows.

Load regulation at constant V_S = load regulation at constant V_{IN} + line regulation

Example: Assume a supply range of 25 to 35 V used with a μA78M12 regulator delivering an output current of 100 to 300 mA.

From the data sheet: $V_{O(min)} = 11.4$ V
$V_{O(max)} = 12.6$ V

Assume $V_{DO(max)} = 2.5$ V,
$I_{Q(max)} = 6$ mA

$$R1 = \frac{25 - 12.6 - 2.5}{.300 + .006} = 33\ \Omega$$

With this value of R1 and a load varying from 100 to 300 mA, the input voltage to the regulator varies,

$$\Delta V_{IN} = \Delta I_{OUT}\ R1 = 6.6\ V$$

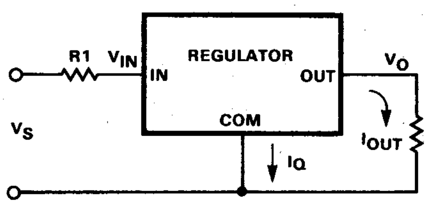


Fig. 3-6. Reducing Power Dissipation in a Regulator with Dropping Resistor R1

The effect of the 6.6 V change at the regulator input under the worst case condition is 50/14 x 6.6 = 24 mV additional change at the output terminal. The inclusion of the 33 Ω reduces the maximum power dissipation of the regulator as shown below.

From $P_{D(max)} = (35 - 11.4) \times 0.306 = 7.22$ W (without R1),
To $P_{D(max)} = (35 - 33 \times 0.306 - 11.4) \times .306 = 4.13$ W (with R1)

Note that the power dissipation is shared between the regulator and R1.

Input Voltage > $V_{IN(max)}$

When a regulator is used with supply voltages greater than the rated regulator maximum input voltage, the circuit shown in *Figure 3-7* can be used. This circuit essentially provides a constant voltage to the regulator with supply voltage variations. The choice of Zener diode voltage is dictated by $V_{IN(min)}$ of the regulator and $V_{BE(max)}$ of Q1.

High Output Voltages

Figure 3-8 shows a simple circuit that can be used to obtain an output voltage greater than the standard fixed voltages available. The quiescent current biases Zener diode D1 and the regulator common terminal rides on the pedestal established by D1. If the Zener must be operated at currents greater than the quiescent current level of the regulator, then R1 can be used to increase the Zener current. If, on the other hand, lower Zener current is satisfactory, R1 can be placed in parallel with D1 to shunt some of the current. *Caution:* this circuit configuration cannot utilize the thermal shutdown or short-circuit protection features of the regulator if the input voltage exceeds the maximum input voltage rating of the regulator.

Figure 3-9 can be used to take advantage of the protective features of the regulator. Here too, the regulator common terminal operates on the pedestal established by Zener diode D1. Zener diode D2 and the Darlington configuration of Q1, Q2 reduces the regulator input voltage to a safe value. The Darlington configuration prevents loading of Zener diode D2, and thus maintains a high level of regulation. Diode D3 protects the regulator against accidental shorts by clamping the common terminal of the regulator to a diode drop above the shorted output.

Remote Shutdown

Electronic shutdown is used in some applicatons where, under certain conditions, the removal of power from the load is desired. This function can easily be achieved with multi-terminal regulators, such as the μA723, μA105, μA104, since these regulators are either equipped with shutdown capability or the non-inverting input of the error amplifier is accessible (*See Figure 3-67*). With the 4-terminal regulators, the control terminal is the inverting input and therefore some external parts are necessary to turn off these devices. The same applies for the 3-terminal devices. The 3-terminal regulator circuit of *Figure 3-10* has a remote shutdown feature. Under normal conditions, Q2 is on and provides the base current of Q1.

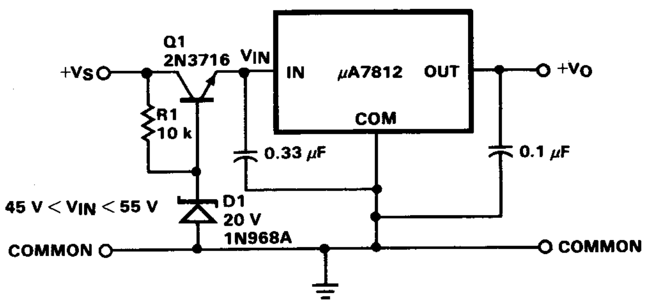
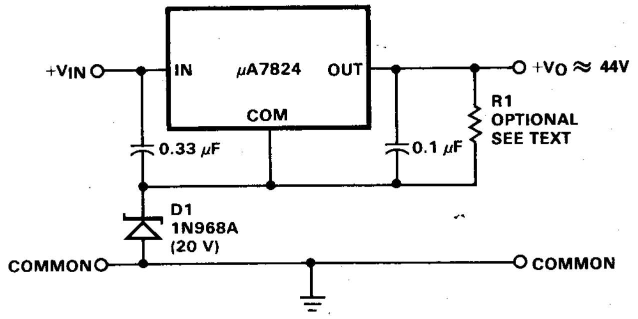
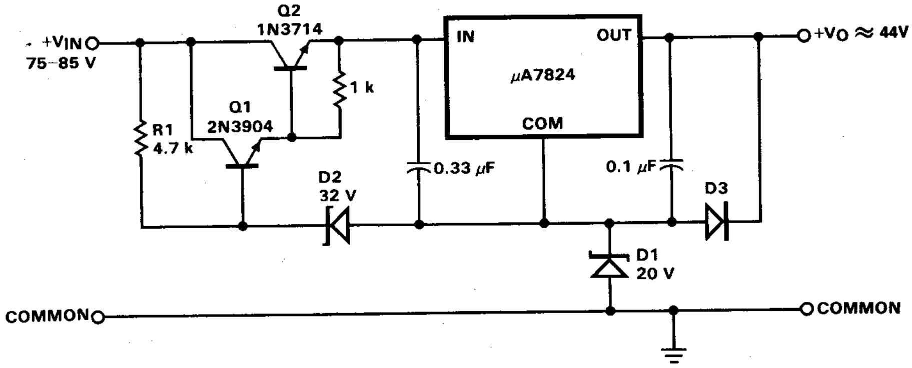


Fig. 3-7. Regulator Input Circuit for Input Voltage Source Greater than $V_{IN(max)}$



NOTES:
Line Regulation: ΔV_{IN} = 10 V, I_{OUT} = 0.5 A, ΔV_O = 60 mV
Load Regulation: V_{IN} = 50 V, ΔI_{OUT} = 1 A, ΔV_O = 70 mV

Fig. 3-8. High Output Voltage Regulator, No Short-Circuit Protection



NOTES:
Line Regulation: I_{OUT} = 1 A, ΔV_{IN} = 10 V, ΔV_O = 230 mV
Load Regulation: V_{IN} = 75 V, ΔI_{OUT} = 1 A, ΔV_O = 18 mV

Fig. 3-9. High Output Voltage Regulator with Short-Circuit Protection

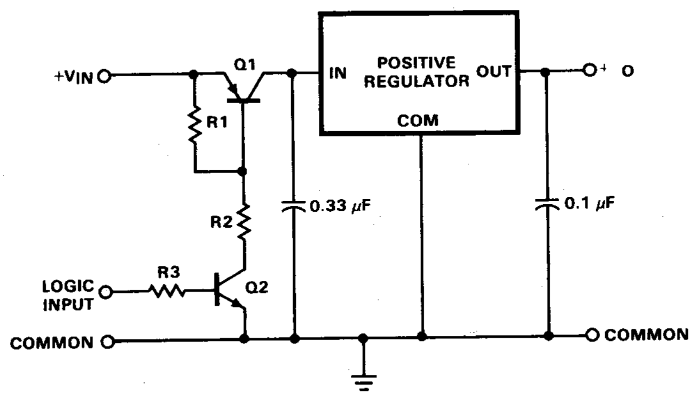


Fig. 3-10. Remote Shutdown

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Q1 acts as a switch and is either in saturation, when the signal to the base of Q2 is high, or is off when the signal to the base of Q2 is low. It must have a current rating equal to the load current. Turn-off time is dependent on C2 and the load current; the higher the load current, the faster the turn-off time.

Constant Current Regulator

Any 3-terminal regulator can be used as a constant-current regulator as shown in *Figure 3-11*. The current I_{OUT} which dictates the regulator type to be used is determined by this equation.

$$I_{OUT} = \frac{V_O}{R1} + I_Q$$

where V_O is the regulator output voltage and I_Q is the quiescent current.

The input voltage V_{IN} must be high enough to accommodate the dropout voltage at the low end, but must not exceed the maximum input voltage rating at the high end.

Fixed Negative 3-Terminal Voltage Regulators

Since negative voltage regulators are complements of the positive voltage regulator, almost all the positive-regulator applications can be converted into negative versions by appropriate changes in the polarity of the input voltages. If external active components such as series-pass transistors are used, they should be the complements of those used in the positive-regulator application, *i.e.,* npn transistors replaced by pnp and vice versa. The basic configuration of the 3-terminal negative voltage regulator is shown in *Figure 3-12*, below.

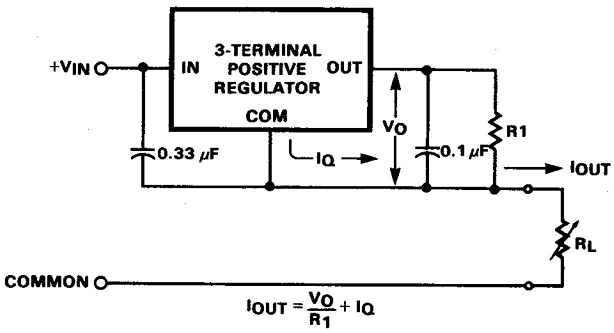


Fig. 3-11. Constant Current Regulator (Positive Output)

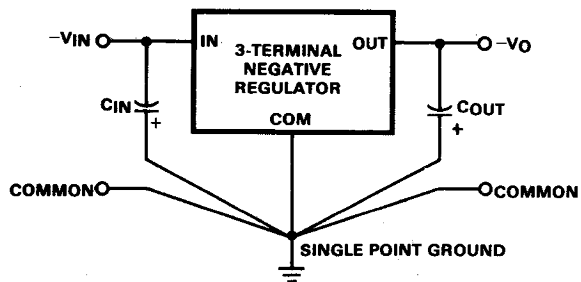


Fig. 3-12. Basic 3-Terminal Negative Regulator with Bypass Capacitors

Figures 3-13 and *3-14* show the negative complements of the positive voltage-regulator circuits in *Figures 3-2, 3-3* to obtain higher output currents, while *Figure 3-15* shows a negative current regulator with an output current expressed as follows.

$$I_{OUT} = \frac{V_O}{R1} + I_Q$$

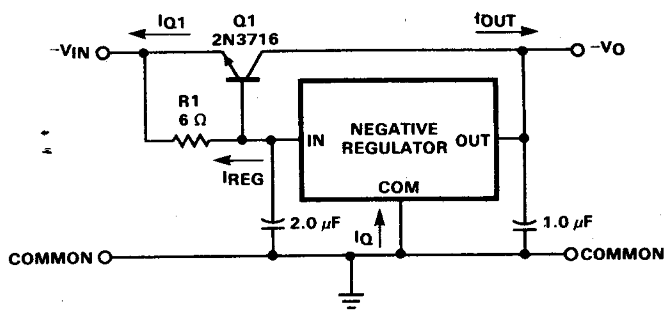


Fig. 3-13. High Output Negative Current, Short-Circuit Protected Regulator

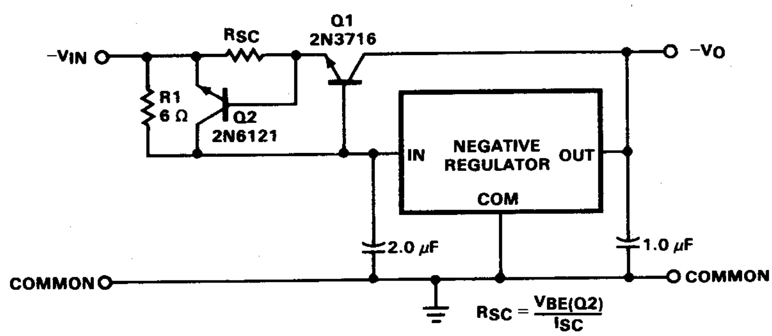


Fig. 3-14. High Negative Current Voltage Regulator

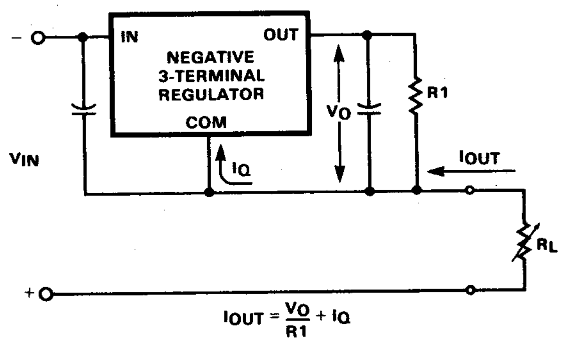


Fig. 3-15. Negative Current Regulator

Adjustable Positive 3 and 4-Terminal Voltage Regulators

The circuits covered so far are restricted to the fixed voltages of the 3-terminal regulators. With some external components, the normal output voltage of a 3-terminal regulator can be changed to meet other voltage requirements. This often results in a slight degradation of the regulator parameters; therefore, before selecting a 3-terminal regulator for these applications, an adjustable 4-terminal regulator should be considered. Usually, the same function can be attained by an adjustable regulator with fewer components and no sacrifice in performance.

Non-Standard Fixed Positive Output Voltage Regulator

Non-standard regulated output voltages greater than the regulator voltage can be obtained from a fixed 3-terminal regulator as shown in *Figure 3-16*. The voltage pedestal developed across R2 is added to the normal regulated output voltage, V_{REG}.

$$V_{OUT} = V_{REG}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

The current through R1 is set much higher than I_Q to minimize the effects of the change in I_Q that occurs with a change in the load current or the input voltage. The values of R1 and R2 can be calculated as follows.

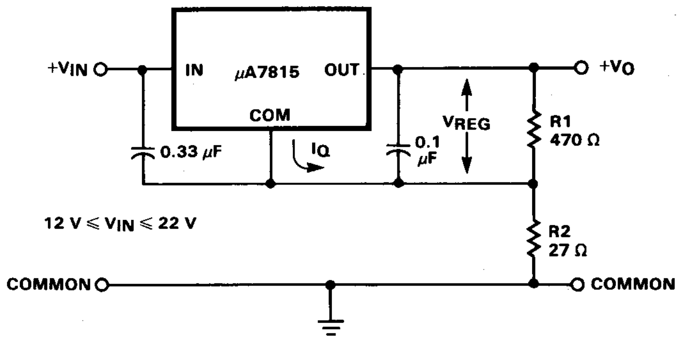
$$R1 = \frac{V_{REG}}{I_{R1}}$$

and

$$R2 = \frac{V_O - V_{REG}}{I_{R1} + I_Q}$$

if $I_{R1} = 5I_Q$, then

$$R1 = \frac{V_{REG}}{5I_Q}$$



NOTES:
With R2 = 0 Ω, V_O = 14.85 V
Line Regulation: ΔV_{IN} = 10 V, I_{OUT} = 0.5 A, ΔV_O = 5 mV
Load Regulation: ΔI_{OUT} = 1 A, V_{IN} = 25 V, ΔV_O = 28 mV
With R2 = 27 Ω, V_O = 16 V
Line Regulation: ΔV_{IN} = 10 V, I_{OUT} = 0.5 A, ΔV_O = 8 mV
Load Regulation: ΔI_{OUT} = 1 A, V_{IN} = 25 V, ΔV_O = 32 mV

Fig. 16. Non-Standard Fixed Positive Output Voltage Regulator

and

$$R2 = \frac{V_O - V_{REG}}{6I_Q}$$

Example: Assuming 16 V output from a μA7815 and $I_Q = 5.1$ mA, with R1 = 470 Ω

$$I_{R1} = \frac{15}{\cancel{510}\ 470} = 31.9 \text{ mA}$$

$$R2 = \frac{16-15}{37} = 27\ \Omega$$

To compensate for fluctuations in quiescent current, output voltage tolerance and resistor tolerance, R2 may have to be an adjustable resistor if a tight tolerance V_O is desired.

Another method of obtaining non-standard output voltages or adjustable outputs from a fixed 3-terminal regulator is to use an operational amplifier as shown in *Figure 3-17*. The voltage pedestal developed across R2 is added to the normal regulated output V_{REG} so that, for the component values shown,

$$V_O = \frac{V_{REG}}{11} + \frac{R1 + R2}{R1}$$

The negative supply is required to allow adjustment to the lower output voltages. The maximum supply voltage is restricted by the maximum supply voltage rating of the μA741.

Basic 4-Terminal Positive Regulators

The 4-terminal adjustable regulators are ideal for applications that require non-standard output voltages. Fixed or adjustable output voltages are determined by the following equation.

$$V_O = V_{cont}\ \frac{(R1 + R2)}{R2}$$

where V_{cont} = control pin voltage which is nominally 5.0 V for the μA78G or μA78MG.

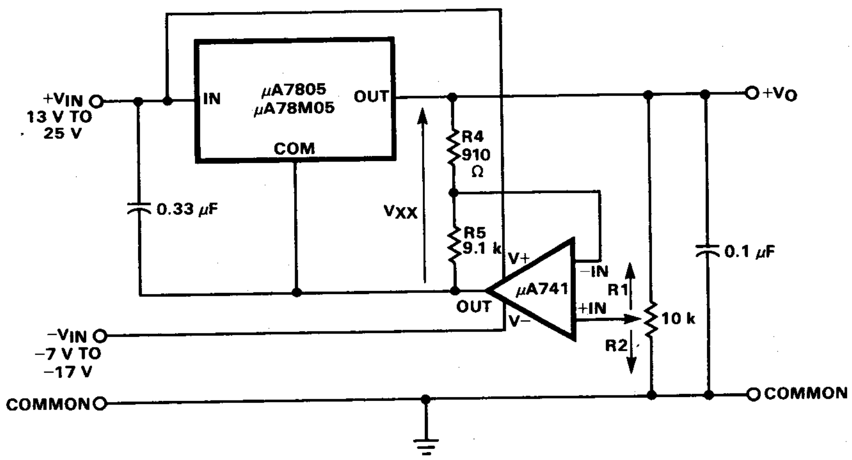
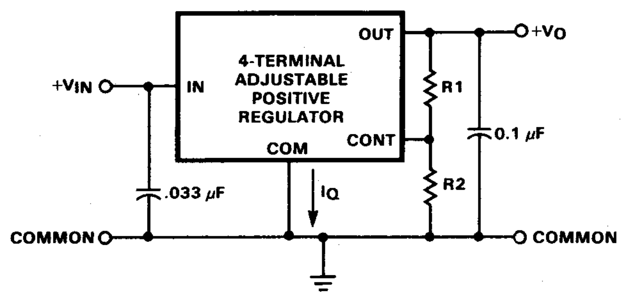


Fig. 17. Variable Output Voltage, 0.5 to 10 V

Output voltage ranges from the value of the control voltages to 30 V can be obtained using the circuit in *Figure 3-18*. Load regulation of the 4-terminal regulators can be improved if the feedback resistors R1 and R2 are connected to the load side of the output rather than directly across the regulator.

Adjustable Regulator with Increased Output Current

For applications that require higher output current, the bootstrapped emitter-follower output circuit shown in *Figure 3-19* provides current in excess of 20 A. Note that the base-emitter junction of the external series-pass transistor Q1 is in the feedback loop and consequently does not affect the temperature coefficient of the output voltage. Also note that Q1 is not protected against output shorts. Protection can be added as shown in *Figure 3-20a*. Here Q2 protects Q1 and Q2 must have a current rating equal to the short circuit current of the regulator. *Figure 3-20b* illustrates how short-circuit protection can be added when more than one device is used as a series-pass element. Another method of obtaining increased output currents is shown in *Figure 3-21* and *3-22*. These are basically the same circuits covered under fixed regulators (*Figures 3-2* and *3-3*).



NOTES:

$V_O = \frac{R1 + R2}{R2} V_{CONTROL}$

$V_{CONTROL}$ Nominal = 5 V

Recommended R2 current ≈ 1 mA

Fig. 3-18. Basic 4-Terminal Fixed or Adjustable Positive Regulator

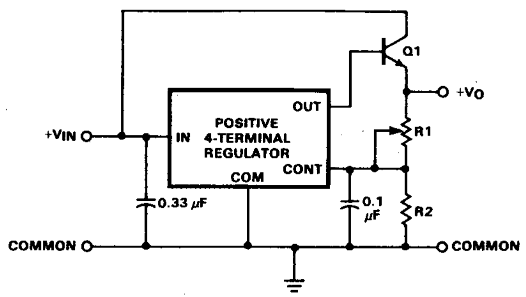


Fig. 3-19. Adjustable Positive Regulator with Increased Output Current

Low Output Voltage Regulator

For applications requiring output voltages below the capabilities of the 4-terminal regulator, another regulator of opposite polarity can be used to offset output voltage by the required amount. *Figure 3-23* shows a supply with an adjustable output from 0 to 25 V. The negative μA79M05 is used to offset the μA78MG common by 5 V to achieve an adjustable output range down to 0 V. The drawback of this circuit is that it requires a dual supply. The addition of the μA79M05 increases the circuit complexity, but the resulting increase in output range will compensate for the additional number of circuit components.

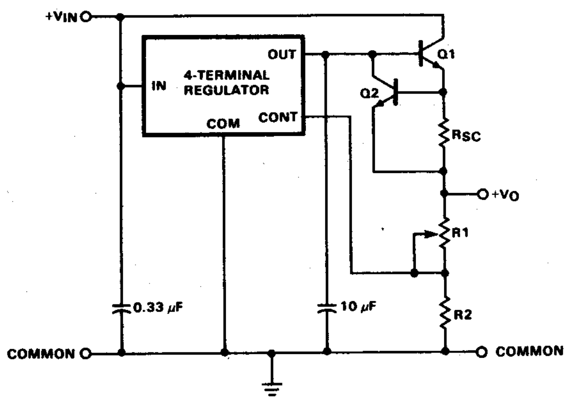
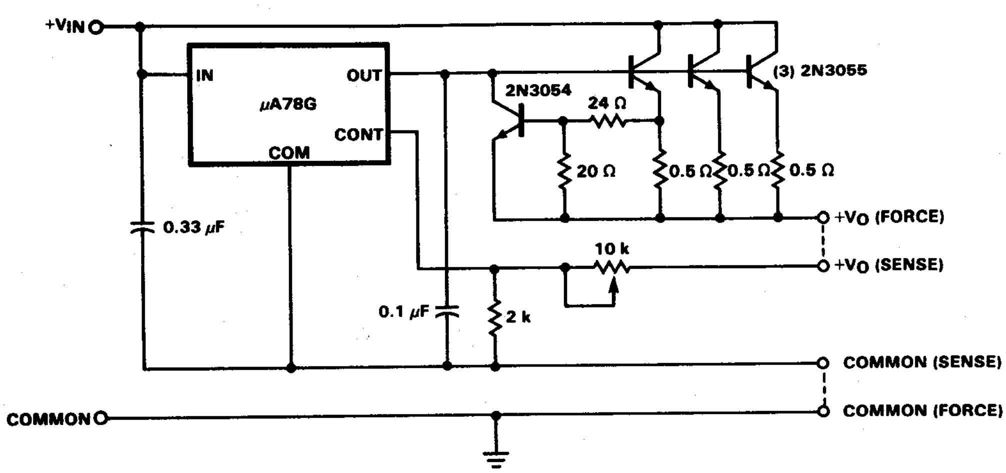


Fig. 3-20a. Positive High Current Short Circuit Protected Regulator



NOTES:
Typical Performance: $V_O = 10$ V
Line Regulation: $I_{OUT} = 5$ A, $\Delta V_{IN} = 10$ V, $\Delta V_O = 4$ mV
Load Regulation: $V_{IN} = 18$ V, $\Delta I_{OUT} = 10$ A, $\Delta V_O = 2$ mV
Short Circuit Current: $V_{IN} = 18$ V, $I_{OUT} = 13$ A

Fig. 3-20b. 10 A, 5 to 30 V Adjustable Regulator with Short Circuit Protection

Adjustable 3 and 4-Terminal Negative Regulators

The concepts used for the positive regulators can be expanded to include negative regulators. The fixed 3-terminal or adjustable 4-terminal negative regulators can be used to obtain the required outputs.

Non-Standard Fixed Negative Output Voltage

Figure 3-24 shows the method for obtaining a non-standard negative output voltage from a standard negative 3-terminal regulator. The design procedure is exactly the same as that used for the positive regulator. The voltage pedestal across R2 raises the output voltage to the required level. The output voltage can be calculated as follows.

$$V_O = V_{xx} \frac{(R1 + R2)}{R1} + I_Q R2$$

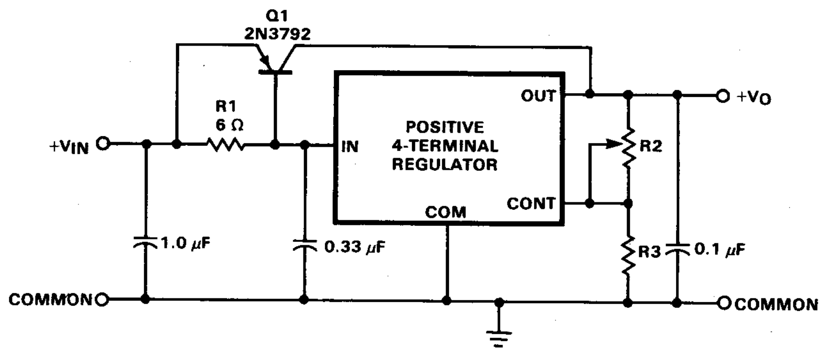


Fig. 3-21. Positive High Current Adjustable Regulator (No Short Circuit Protection)

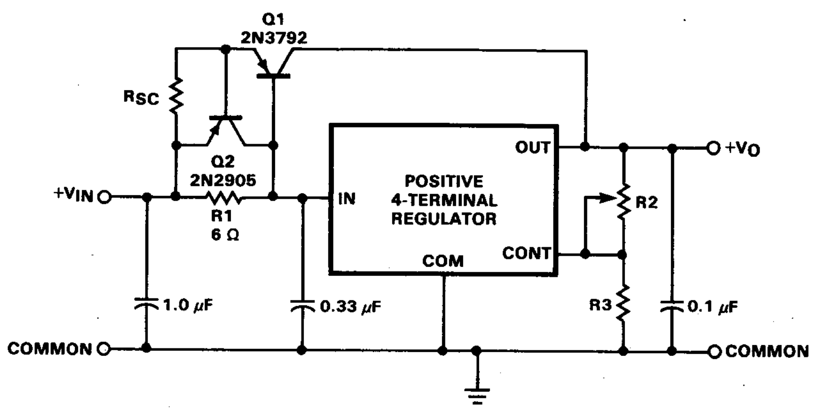
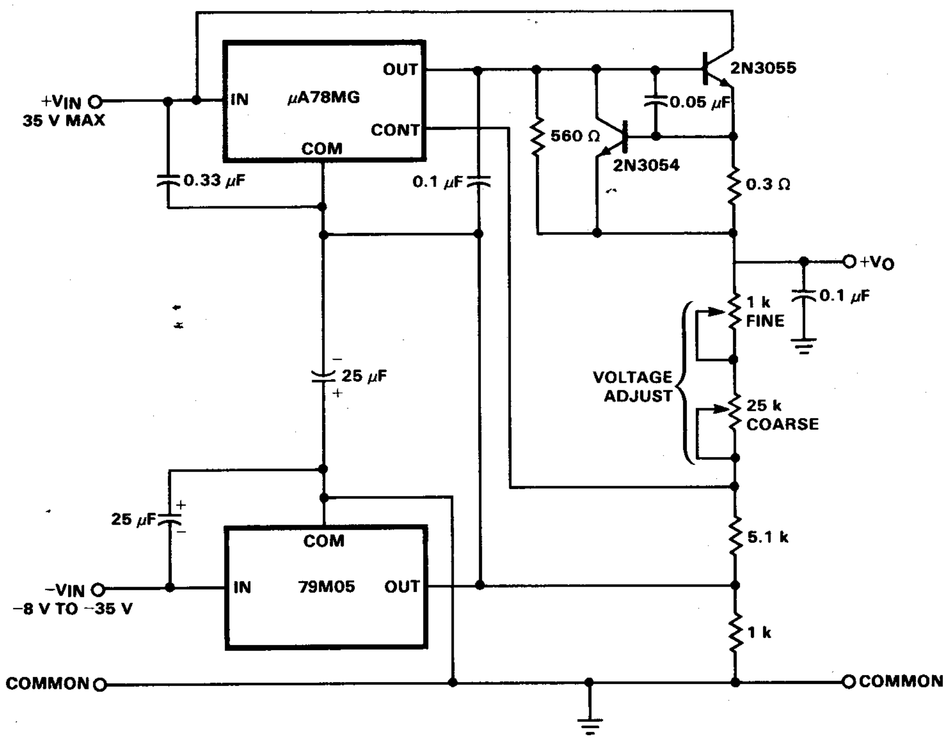


Fig. 3-22. Positive High Current Adjustable Regulator (With Short Circuit Protection)



NOTES:

Load Regulation: $V_{IN} = 30$ V

$V_O =$	2 V	6 V	26 V
$\Delta V_{OUT} = 1$ A	-26 mV	-28 mV	-12 mV
$\Delta I_{OUT} = 2$ A	-30 mV	-35 mV	-18 mV

$V_O = 0$ to 25 V

$I_{OUT} = 0$ to 2 A

Fig. 3-23. Adjustable Power Supply with Short Circuit Protection

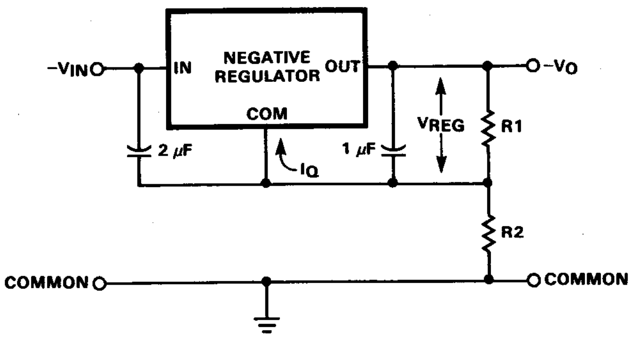


Fig. 3-24. Non-Standard Fixed Negative Output Voltage

Figure 3-25 **shows an adjustable output negative regulator circuit with an output voltage range from −0.5 to −10 V. It requires a dual polarity supply. If a 5 V regulator is used, the output voltage is determined by the following formula.**

$$V_O = V_{REG}\,\frac{R1 + R2}{11R1} \text{ or } 0.45\left(1 + \frac{R2}{R1}\right) V$$

Basic 4-Terminal Negative Regulators

The μA79G and μA79MG 4-terminal negative adjustable voltage regulators have a nominal reference of −2.23 V. The output voltage is determined as follows:

$$V_{OUT} = V_{cont}\,\frac{(R1 + R2)}{R2}$$

Output voltages from the control voltage to −30 V can be obtained using the circuit in *Figure 3-26*. The output-current capability of the 4-terminal negative adjustable regulators can also be increased by using

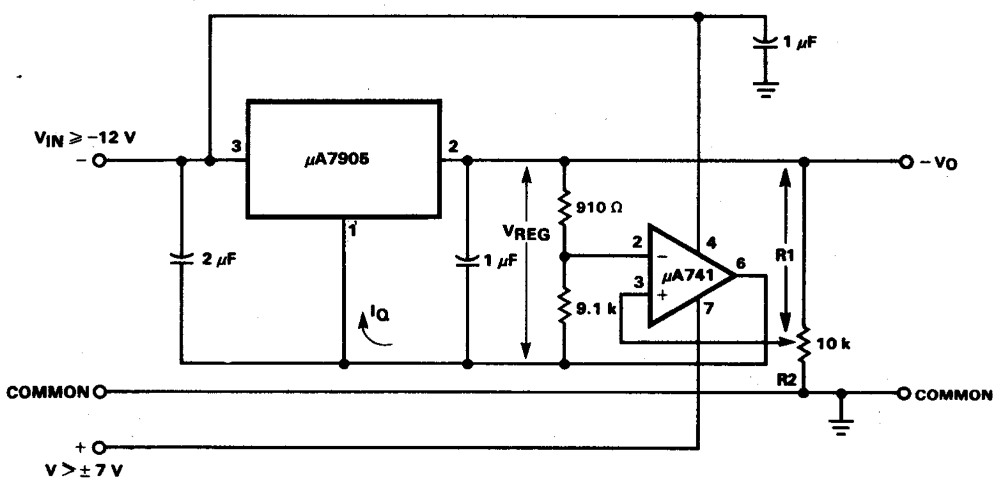
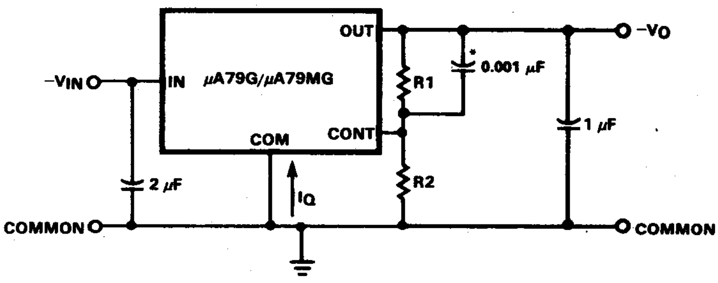


Fig. 3-25. Adjustable Output Negative Regulator (−0.5 V to −10 V)



*may be necessary with long leads

$$V_O = \left(\frac{R1 + R2}{R2}\right) V_{CONTROL}$$

$V_{CONTROL}$ Nominal = −2.23 V

Fig. 3-26. Basic 4-Terminal Fixed or Adjustable Negative Regulator

an external pnp or npn series-pass transistor as shown in *Figure 3-27* and *3-28*. These two circuits do not have short-circuit protection. *Figure 3-29* shows an adjustable high-current negative regulator with short-circuit protection. Transistor Q2, which protects the external series-pass transistor Q1 against shorts must have a current rating equal to the short-circuit current of the IC regulator.

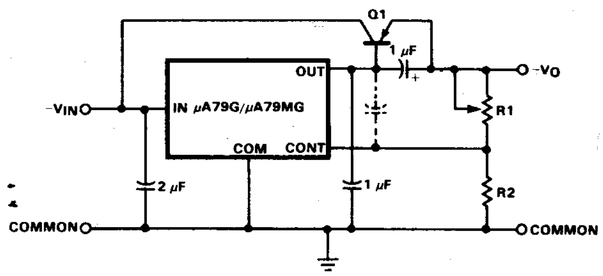
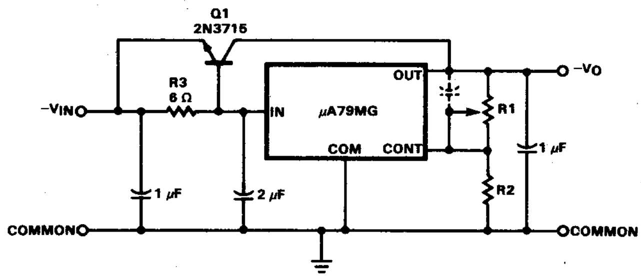


Fig. 3-27. Adjustable High Current Negative Regulator

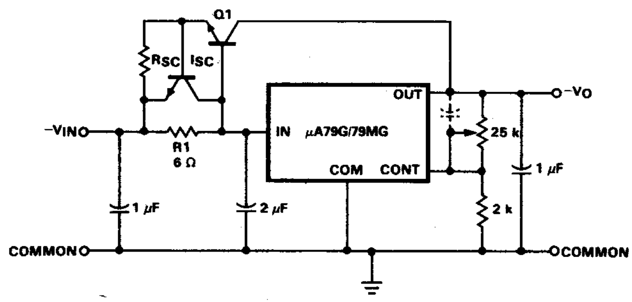


NOTES: $V_{IN} = -10$ V, $V_O = -5$ V

Line Regulation: $\Delta V_{IN} = 10$ V, $I_{OUT} = 2$ A, $\Delta V_O = 20$ mV

Load Regulation: $\Delta I_{OUT} = 4$ A, $\Delta V_O = 15$ mV

Fig. 3-28. Negative High Current Adjustable Regulator



NOTES: $V_O = -2.2$ V to -30 V

$$R_{SC} = \frac{V_{BE}\,(Q1)}{I_{SC}}$$

$$R1 = \frac{\beta \times V_{BE}\,(Q1)}{I_{REG(max)}\,\beta - I_{OUT(max)}}$$

Fig. 3-29. Negative High Current Regulator with Short Circuit Protection

Dual Regulators

Dual regulators, or dual power supplies, are normally used for applications requiring two output voltages of opposite polarities that do not necessarily have equal magnitudes, for example, +12 V, −5 V. However, the word dual can also imply two supplies of the same polarity but of different magnitudes, such as +5 V, +12 V. With dual tracking, not only are the output voltages of different polarities, but one output voltage always follows the other one, *i.e.,* an increase in the positive voltage results in a decrease in the negative output voltage.

Dual Supplies

The simplest dual-polarity supply can be obtained by using a positive and a negative 3-terminal regulator with a center-tapped transformer as shown in *Figure 3-30*. The same type of dual supply can be achieved with two positive (or two negative) regulators if a transformer with two isolated windings is used as shown in *Figure 3-31*.

The reverse-biased diodes connected across the outputs of the dual regulator circuits are not necessary if the loads are referenced to ground. If the loads are tied between the two outputs, however, a latch-up may occur at the instant power is turned on, especially if one regulator input voltage rises faster than the second one. The diodes, that ensure proper start-up of the regulators by preventing a parasitic action from taking place when power is turned on, should have a current rating equal to half the load current.

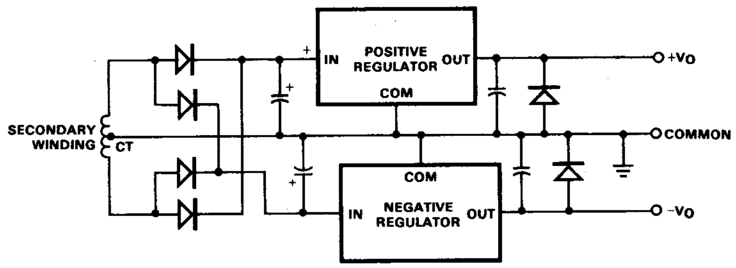


Fig. 3-30. Dual Supply using a Center Tapped Transformer with a Positive and a Negative 3-Terminal Regulator

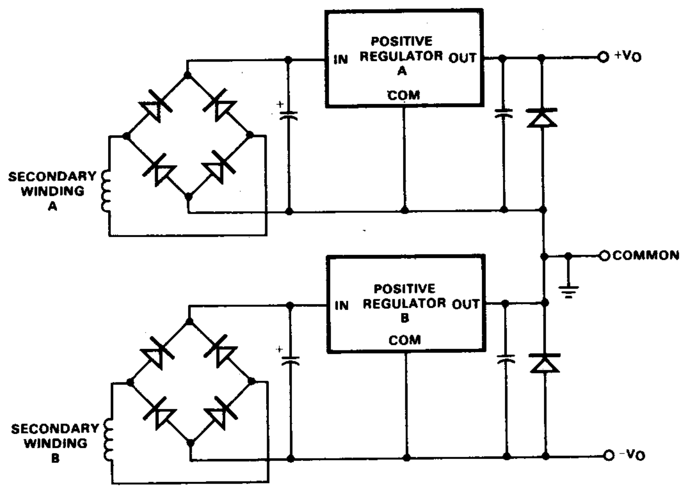


Fig. 3-31. Dual Supply using a Transformer with Two Windings and Two Positive 3-Terminal Regulators

Figure 3-32 shows a single positive-polarity dual supply with +5 and +10 V output. It uses two 5 V µA78M05 regulators operating from a single positive voltage source. The +10 V output is achieved by connecting the common terminal of the top regulator A to the output of the bottom regulator B. Diode D1 ensures proper start-up of the top regulator and prevents a latch-up that may occur under a heavy load condition on regulator A. Resistor R1 provides a path for the quiescent current of regulator A and can be eliminated if regulator B has a minimum load current greater than the quiescent current of regulator A.

The concept of *Figure 3-32* can be used to achieve a dual-polarity output from a floating single supply as shown in *Figure 3-33*. This circuit is restricted in that $R_L+ > R_L-$, since all of the current provided by the positive regulator A must flow through R_L-.

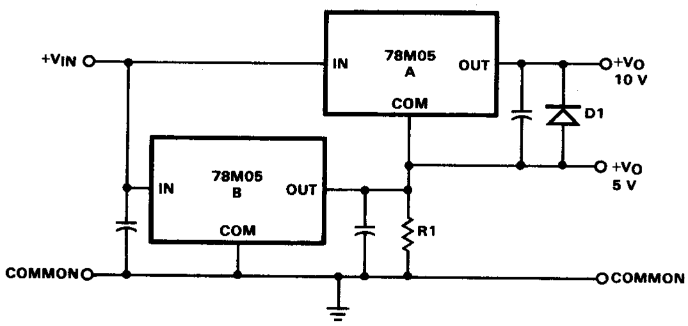
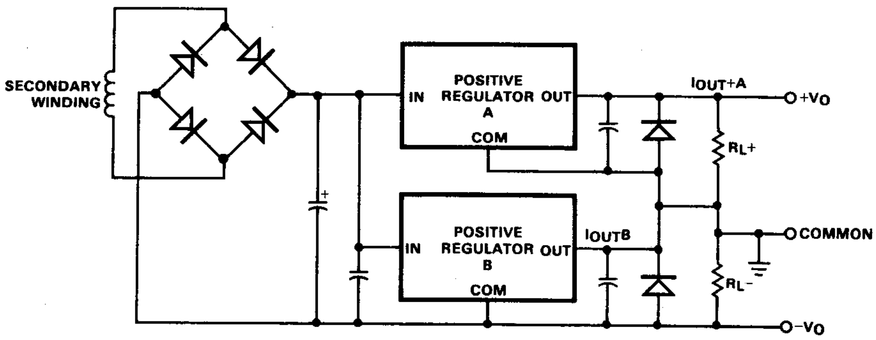


Fig. 3-32. A Dual Positive Supply with a +5 V and +10 V Output



NOTE: $R_L+ > R_L-$

Fig. 3-33. A Dual Polarity Supply from a Single Transformer Winding

3

Fixed Dual Tracking Regulators

Figure 3-34 **illustrates a power supply for applications that require tracking between dual supplies. This circuit has a positive and a negative regulator, an operational amplifier used as a comparator, and two matched resistors. Tracking is accomplished by connecting the two regulator common terminals to the output of the μA741 that provides a potential on which the common terminals of the regulators float. The summed regulator outputs, V_O+ and V_O-, are then compared to the power supply common.**

The positive and negative regulator outputs track as follows: any change in the positive regulator output causes an opposite change on the common terminals and also on the negative regulator output. For example, a decrease in the positive regulator output voltage causes a like change in the amplitude of the negative regulator output. Since each regulator has a reference, no slaving exists between the outputs and, as a result, tracking is true and independent of polarity.

The degree of tracking depends on the matching of R1 and R2 since $V_O+/V_O- \approx R1/R2$. This configuration is also valid for non-symmetrical voltages. Proper care must be taken to insure that the maximum supply voltage rating of the μA741 is not exceeded when the regulators are operating with high input voltage sources.

Adjustable Dual Tracking Regulators

For applications requiring independently adjustable tracking outputs, the circuit of *Figure 3-35* can be used. Tracking is accomplished by connecting a common resistor between the control terminals of the two 4-terminal adjustable regulators. Because of the internal feedback of the 4-terminal regulators, a constant voltage is developed across the resistor string R1, R2 and R3. Variations at one of the output nodes are reflected at the control nodes causing corresponding variations at the opposite output node. Note that tracking between the two outputs is not one to one but rather depends on the absolute value of the two references and the feedback resistors R1, R2, and R3. The output voltages are determined by

$$V_O^+ = V_{REF}^+ + \frac{R1}{R2}\left(V_{REF}^+ - V_{REF}^-\right)$$

$$V_O^- = V_{REF} - \frac{R3}{R2}\left(V_{REF}^+ - V_{REF}^-\right)$$

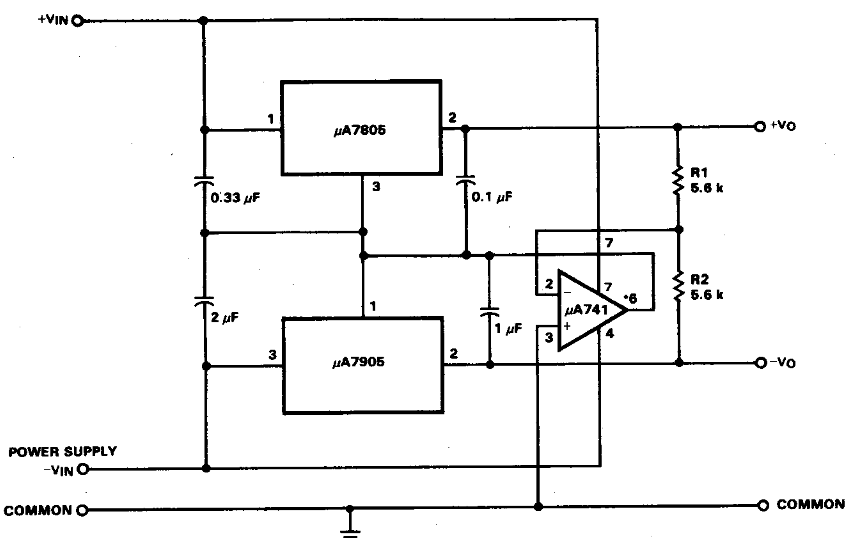


Fig. 3-34. 5 V Fixed Dual Tracking Power Supply Using μA7805 and μA7905 Regulators

Tracking between the outputs can be improved by adding a µA741 and modifying the circuit as shown in *Figure 3-36*. This circuit yields an adjustable true dual-tracking regulator with internal short-circuit protection, safe-area limiting, thermal overload protection, and is capable of a 500 mA maximum output current. The outputs of the regulators are independently adjustable by potentiometers P1 and P2. With the component values shown, the output voltage of the positive µA78MG can be varied from 5 to 30 V, and the negative µA79MG can be varied from −2.2 to 27.2 V. Operation of this circuit is the same as the circuit shown in *Figure 3-34*.

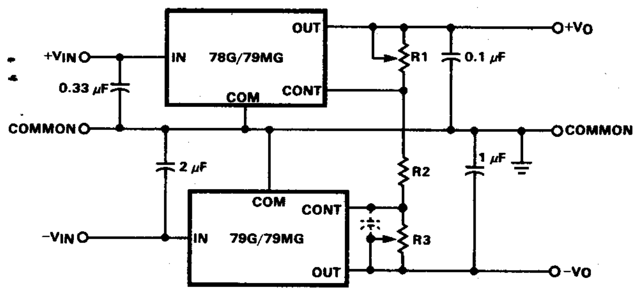


Fig. 3-35. Adjustable Dual Tracking Regulator

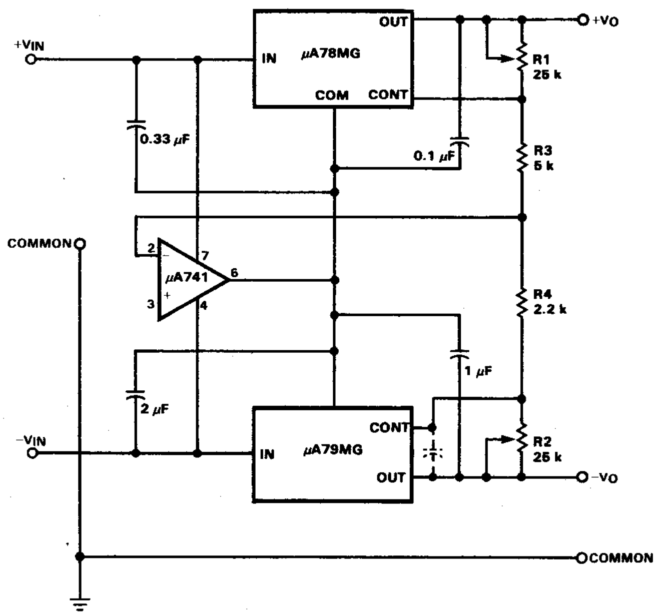
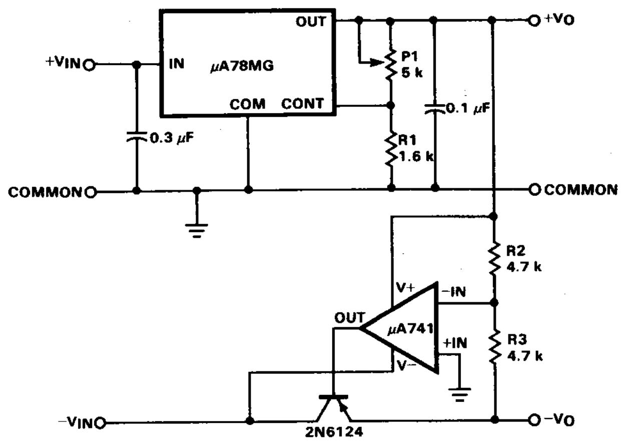


Fig. 3-36. Independently Adjustable True Dual Tracking Power Supply

Another method of obtaining dual tracking is to use a 4-terminal regulator with a μA741 and an external series-pass transistor as shown in *Figures 3-37* and *3-38*. Operation of the circuits is as follows.

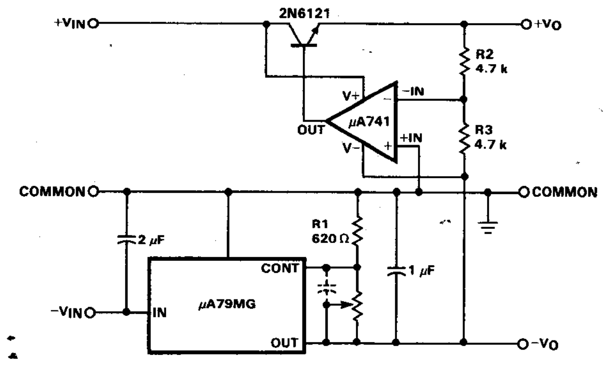
The 4-terminal regulator is used in its normal way as an adjustable regulator with the output adjusted by potentiometer P1. The μA741 functions as an inverting amplifier and drives an external transistor that serves as a series pass for the complementary output. By grounding the non-inverting input of the μA741 and connecting the inverting input to the junction of feedback resistors R2 and R3, the output of the external series pass transistor becomes a slave of the regulator output and, consequently, potentiometer P1 adjusts both outputs simultaneously. The output of the transistor side tracks the regulator output, because any change in the regulator output causes a proportionate change in the inverting input of the μA741 and results in a corresponding change in the complementary output. Since the regulator output functions independently of the complementary output obtained from the external series-pass transistor, any change in the output from the series-pass has no effect on the regulator output. The transistor output is a slave of the regulator output and is not protected against shorts. The outputs for both circuits can be adjusted to a maximum of ±30 V at the high end by the proper selection of R1 and P1. The low end can be adjusted to ±5 V for the circuit of *Figure 3-37*, and to ±2.23 V for *Figure 3-38*. For high input voltage conditions, proper care must be taken to insure that the maximum supply voltage rating of the μ741 is not exceeded.

The μA741 and the external series-pass transistor of *Figures 3-37* and *3-38* can be replaced by a power op amp such as the μA759 as shown in *Figures 3-39* and *3-40*. Operation of these circuits is identical to the previous two, but since the μA759 has internal short-circuit protection, thermal shutdown and safe-area protection, both outputs are therefore protected. Output currents in excess of +350/−200 mA and +200/−350 are achievable from the circuits of *Figures 3-37* and *3-38*, over the operating temperature ranges of the two parts. The output voltage range of *Figure 3-39* is limited by the 5 V reference of the μA78MG at the low end, and the maximum supply voltage of the μA759 at the high end. The output voltage of *Figure 3-40*, however, is adjustable over a wider range (±2.2 V to ±30 V) because of the lower reference voltage of the μA79MG and the common-mode range of the μA759.



NOTES:
Negative output is a slave of the positive output
Output voltage balance (V_O = 10 V): 10 mV
Load regulation (ΔI_{OUT} = 0.5 A): 6 mV
Line regulation (ΔV_{IN} = 10 V): 2 mV

Fig. 3-37. Dual Tracking Adjustable Regulator



NOTES:
Positive output is a slave of the negative output.
Performance is similar to the circuit of Fig. 3-37.

Fig. 3-38. Dual Tracking Adjustable Regulator

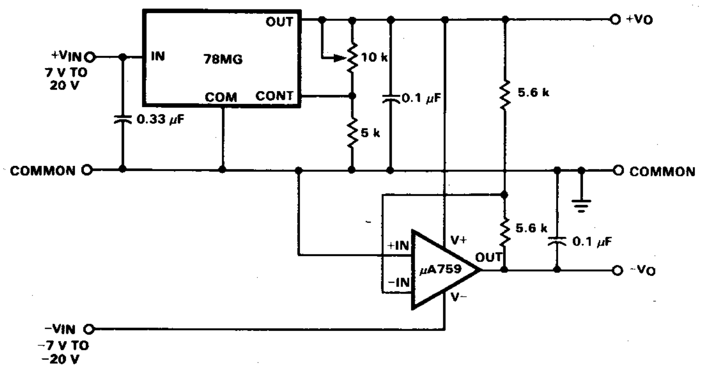


Fig. 3-39. ±5 to ±15 V Adjustable Dual Tracking Supply using a Positive Adjustable Regulator with a Power Op Amp

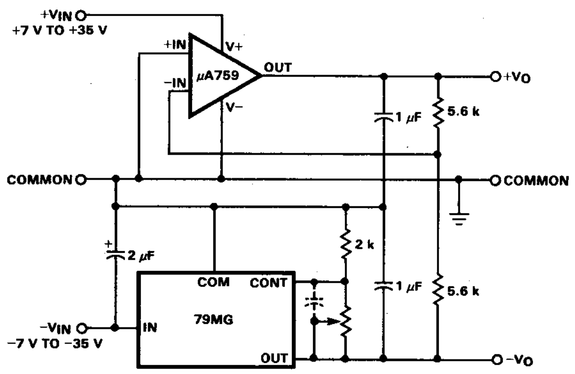


Fig. 3-40. ±2.2 to ±30 V Adjustable Dual Tracking Regulator using a Negative Adjustable Regulator and a Power Op Amp

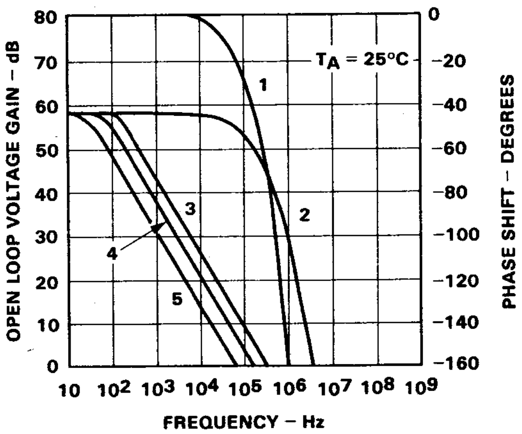
PRECISION VOLTAGE REGULATOR – μA723

The μA723 is an industry standard universal building block for power supply design. The device consists of a temperature compensated reference amplifier, error amplifier, power series pass transistor and current limit circuitry. Additional npn or pnp pass elements may be used when output currents exceeding 150 mA are required. Provisions are made for adjustable current limiting and remote shutdown. In addition, the device features low standby current drain, low temperature drift and high ripple rejection. The μA723 is intended for use with positive or negative supplies as a series, shunt, switching or floating regulator.

Figure 3-41 shows the open loop frequency response of the μA723 voltage gain stage. The increase in the rate of phase shift is due to the beta fall off of the output stage at higher frequencies. This increasing phase shift rate requires device compensation whether or not the μA723 is used with external components.

Recommended frequency compensation for the unity gain is either a 5000 pF capacitor from the compensation terminal to the V– terminal or a 20 pF Miller compensation capacitor connected from the frequency compensation terminal to the inverting input. To allow proper operation when using the Miller compensation, the inverting input must be isolated from the remaining circuitry by some impedance. This is illustrated in *Figure 3-48a.* For output voltages greater than V_{REF}, the closed loop gain is greater than unity. If higher closed loop gains are used, the compensation capacitor can be reduced in direct proportion to the increase in gain.

When using an external series pass device, the 3 dB bandwidth of this device must also be considered, particularly since the majority of these devices have a much lower bandwidth than the μA723. For instance, if a 2N3055 is selected as the series pass device to be used in a unity gain configuration power supply, this device has a minimum f_T of 800 kHz and a maximum beta of 70. This introduces a 3 dB point in the overall loop gain at approximately 11 kHz, which means that heavier frequency compensation of the regulator is required to assure stability. Since the first break point of 11 kHz is due to the external power device, the regulator should have less than unity gain at the second break point. The second break point is the first break point of the μA723 gain stage, which occurs at approximately 80 kHz as shown in *Figure 3-41.* Adequate compensation is provided by a 0.02 μF capacitor from the compensation terminal to common – or by a 40 pF Miller capacitor from the compensation terminal to the inverting input. As before, for any increase from unity gain, there can be a proportional reduction in the compensation capacitor.



NOTES:
1. OPEN LOOP PHASE SHIFT
2. OPEN LOOP VOLTAGE GAIN
3. GAIN WITH 5000 pF, COMP TO COMMON
4. GAIN WITH 0.01 μF, COMP TO COMMON
5. GAIN WITH 0.02 μF, COMP TO COMMON

Fig. 3-41. μA723 Open Loop Voltage Gain and Phase Shift as a Function of Frequency

However, the value of the Miller capacitor may not be reduced in direct proportion to the standard compensation reduction; this is to allow for gain variations in the μA723 and for parasitic capacitances. Extra capacitance may be required at both the input and the output of any power supply due to the inductive effects of long lines. Adding output capacitance provides the additional benefit of reducing the output impedance occurring at higher frequencies.

THERMAL CONSIDERATIONS

μA723 Load Current Capabilities

Figure 3-42 provides a quick reference to the allowable power dissipation of the μA723 in terms of the input/output differential voltage and load current. *Figure 3-42a* is for the μA723C in the TO-100 package (10-lead metal can), *Figure 3-42b* is for the μA723/μA723C in the TO-116 package (14-lead, hermetic dual in-line); and *Figure 3-42c* refers to the MIL temperature range μA723 in the metal can.

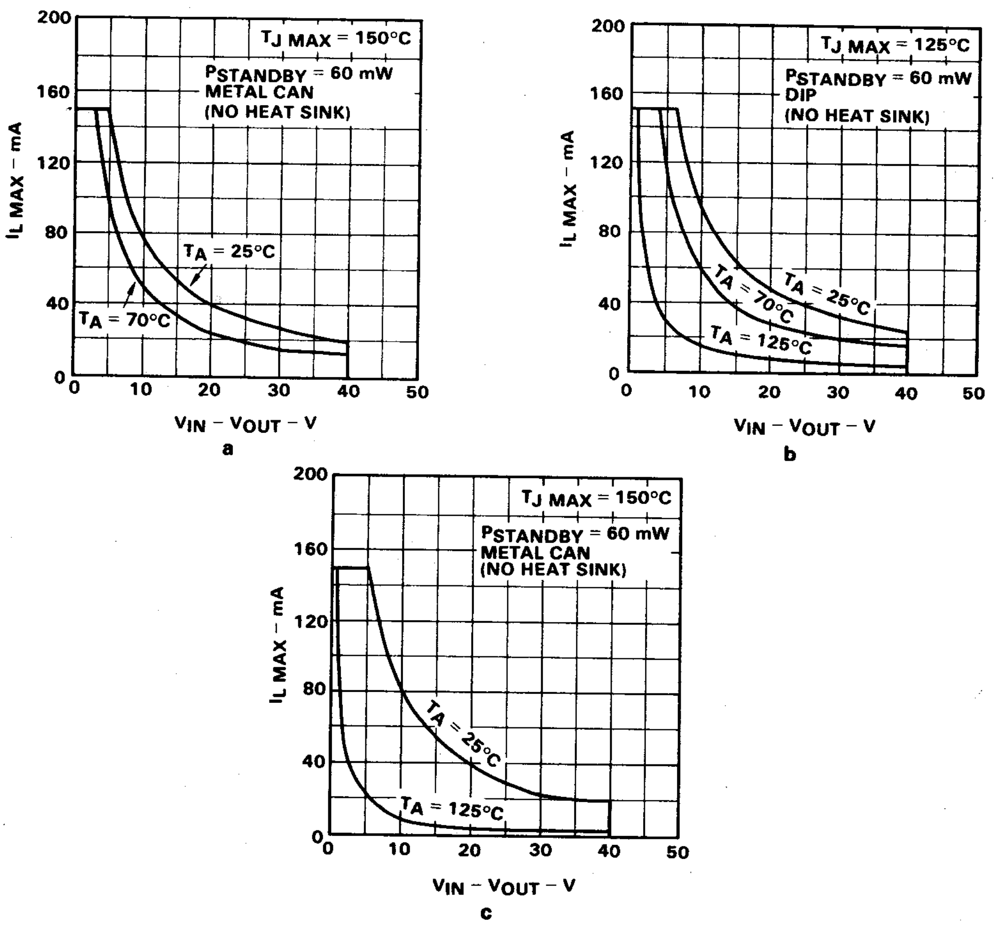


Fig. 3-42. μA723 Load Current Capabilities for Maximum Load Current as a Function of Input/Output Voltage Differential

μA723 Maximum Power Dissipation in Free Air

The previous curves are based on the free-air dissipation ratings shown in *Figure 3-43*. The thermal derating factor is 6.8 mW/°C for the TO-100 metal can and 8 mW/°C for the TO-116 hermetic DIP. When it is necessary to heat sink the TO-100 package, a thermal resistance 50°C/W junction-to-case may be used. The relationship between power dissipation P_D, maximum ambient temperature T_A, and thermal resistance from case to ambient θ_{CA}, is shown in the following equations. These equations may be used to calculate the maximum allowable power dissipation, P_D, or the maximum allowable heat sink resistance, θ_{CA}, from a given set of conditions.

$$P_D = \left(\frac{150^\circ C - T_A}{50^\circ C/W - \theta_{CA}}\right) W, \text{ or } \theta_{CA} = \left(\frac{150^\circ C - T_A}{P_D}\right) - 50^\circ C/W$$

FUNCTIONAL TEST CIRCUIT

Simplified Tester Schematic

A simplified functional test circuit for the μA723 is given in *Figure 3-44*. The output voltage is set for a nominal +5.0 V. The basic test steps are as follows.

1. Load Regulation at 50 mA, Close S1
   Measure output voltage change with S2 open and closed, (a load current change of 50 mA).
2. Line Regulation,
   Open S2
   Measure output voltage change resulting from a change in input voltage V_{IN}
3. Short Circuit Current, Open S1 and S1
   Measure output current when the output is shorted to ground

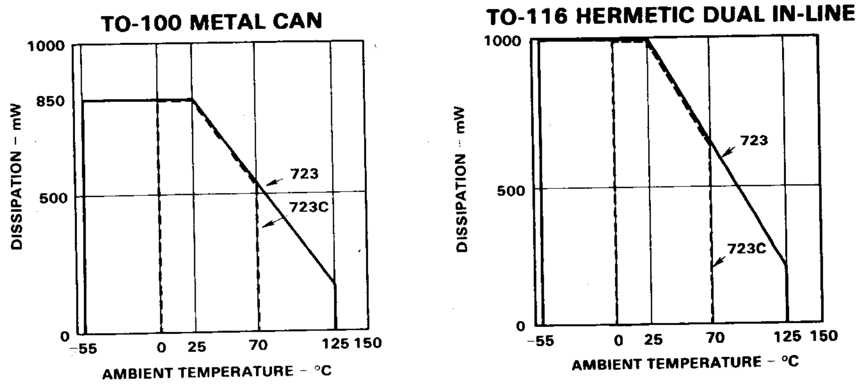


Fig. 3-43. μA723 Maximum Power Dissipation in Free Air

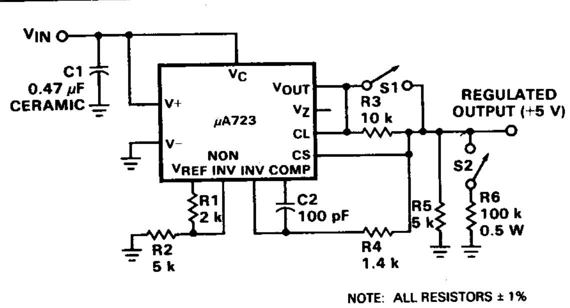


Fig. 3-44. Simplified Tester Schematic

TYPICAL APPLICATIONS

Introduction

The required output voltage for the following uA723 applications can be calculated from the equation accompanying each circuit. In all cases the resulting resistor values are assumed to include any potentiometer resistance used. In addition, *Table 3-1*, included at the end of the section, affords a quick reference for many standard output voltage requirements. The previous section on frequency compensation is a guide to the suitable values of compensating capacitors used in the various applications. Specific transistor types are not included in this section. However, Chapter 5 includes a discussion of the selection of power devices.

In the following applications, the μA723 is represented in a number of ways. In those circuits where the regulator operation is very basic, the symbol of *Figure 3-45* is used. In those applications where the circuit operation is clarified by the use of a functional schematic of the μA723, *Figure 3-46* is used. In some cases the individual components of this block may be rearranged to simplify a particular schematic. The reference voltage is represented by a single Zener diode, nominal voltage 7.15 V supplied from a constant current source. The output Zener diode, V_{OUT} to V_Z, is shown only in the required applications.

3

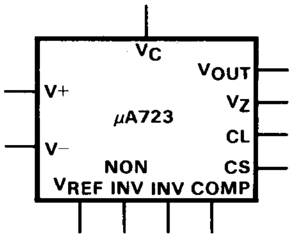


Fig. 3-45. μA723 Logic Symbol

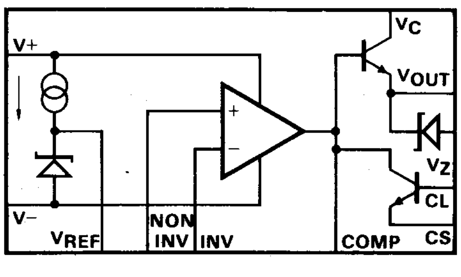


Fig. 3-46. μA723 Functional Symbol

Output Configurations

Many of the applications use internal Zener diodes for level shifting or for the generation of stabilized voltages. An explanation of where these diodes exist in the μA723 circuit may help to avoid any problems arising from improper biasing.

The μA723 output stage schematic is shown in *Figure 3-47a*. The V_Z terminal provides direct access to a 6.2 V Zener diode whose cathode is internally connected to V_{OUT}. Provided the internal current limit transistor is not required for output short circuit protection, its base-emitter junction provides another 6.2 V Zener diode (See *Figure 3-47b*). Note, however, that the anode of this diode, terminal CL, is connected internally by the collector-base junction diode to the base of the output drive transistor. When using the CL - CS Zener diode, the collector-base diode must always be reverse biased. Maximum permissible CL − CS Zener current is 5 mA. Correct biasing is assured in *Figure 3-47c* by interconnecting the V_{OUT} and CL terminals to provide both positive and negative 6.2 V Zener diodes referenced to the V_{OUT} terminal.

Positive Regulators, 150 mA Maximum

Figure 3-48a shows the basic low voltage configuration suitable for output voltages ranging from 2 to 7 V. The reference voltage, V_{REF} is first divided down by R1, R2, and, if desired, potentiometer P1. Then it is applied to the non-inverting input of the error amplifier. C_{REF} may be added if ripple rejection greater than that specified for the μA723 (74dB) is required. The presence of C_{REF} also reduces the regulated output noise voltage considerably.

Capacitor C1 provides frequency compensation. C1 is isolated from the low impedance output by R3 which also balances the error amplifier source impedances to give minimum temperature drift. To minimize component count at the expense of temperature drift, R3 may be omitted. In this case, C1 cannot be used for frequency compensation. Instead, C2 may be used from the compensation terminal to ground as shown in *Figure 3-48b*. To minimize power dissipation, the V+ and V_C terminals may be supplied separately, with V+ requiring a minimum of 9.5 V, while the V_C supply may be as low as 3 V above the regulated output voltage. The schematics shown in *Figure 3-48a* and *3-48b* have output voltages given by this equation.

$$V_O = \left(\frac{R2}{R1 + R2}\right) V_{REF} \text{ where } (R1 + R2) > 1.5\ k\Omega$$

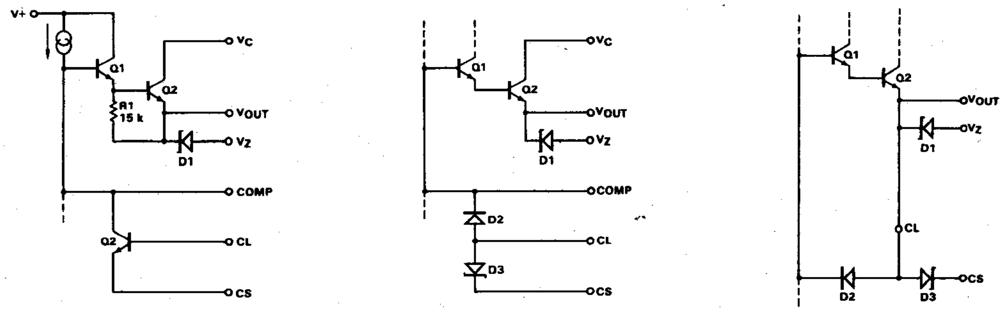
Output voltages from 7 to 37 V are obtainable with *Figure 3-48c*, with the equation below.

$$V_O = \left(\frac{R1 + R2}{R2}\right) V_{REF}$$

If the reference bypass capacitor is required in this circuit, it should be connected from the non-inverting input to ground using R3 to increase the reference source impedance and improve the effectiveness of the reference capacitance. A 150 mA output current is available with R_{SC} set to zero. When short circuit current limiting is desired, R_{SC} may be used to limit the maximum output current as follows

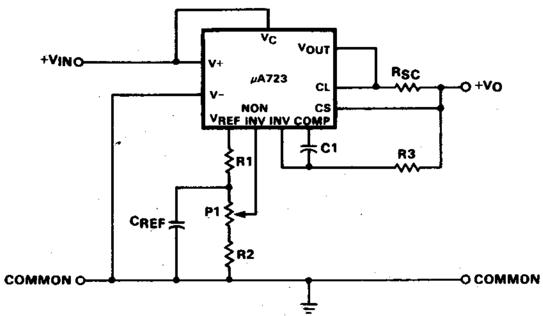
$$I_{LIMIT} = \frac{V_{SENSE}}{R_{SC}}$$

where V_{SENSE} (the sense voltage, or the voltage between terminals CL and CS) is given in *Figure 3-48d*. The resulting output current limit has a temperature coefficient of −0.3%/°C.



a b c

Fig. 3-47. Output Configurations

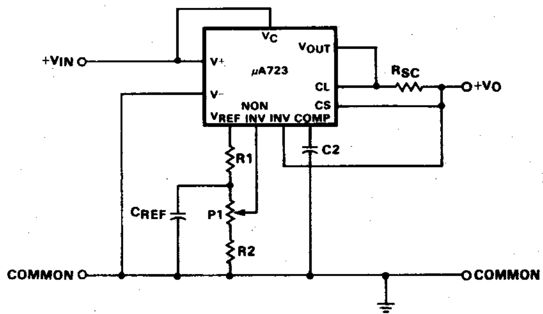


TYPICAL PERFORMANCE

Regulated Output Voltage	5 V
Line Regulation (ΔV_{IN} = 3 V)	0.5 mV
Load Regulation (ΔI_L = 50 mA)	1.5 mV

NOTE: $R3 = \dfrac{R1 \cdot R2}{R1 + R2}$ for minimum temperature drift

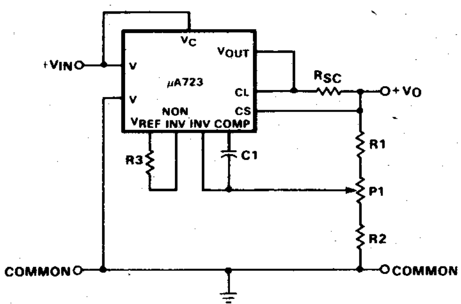
a



TYPICAL PERFORMANCE

Regulated Output Voltage	5 V
Line Regulation (ΔV_{IN} = 3 V)	0.5 mV
Load Regulation (ΔI_L = 50 mA)	1.5 mV

b



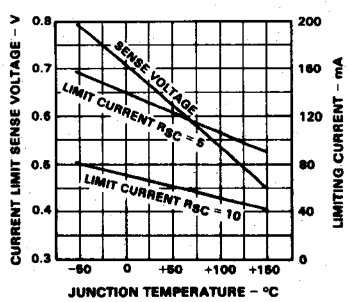
TYPICAL PERFORMANCE

Regulated Output Voltage	15 V
Line Regulation (ΔV_{IN} = 3 V)	1.5 mV
Load Regulation (ΔI_L = 50 mA)	4.5 mV

NOTE: $R3 = \dfrac{R1 \cdot R2}{R1 + R2}$ for minimum temperature drift

R3 may be elimitated for minimum component count

c



d

Fig. 3-48. Basic Regulator Configurations

Positive Regulators, High Output Current

In *Figure 3-49a* an npn transistor, Q1, boosts the available output current beyond the capability of the μA723. Q1 can consist of several transistors cascaded to satisfy very high current requirements. In this circuit, one V_{BE} voltage must be added to the 3 V minimum input/output differential requirement for each transistor added. Depending on the type of transistor used for Q1, R3 should be added giving I_{CBO} compensation, and alleviating the safe area limitation of the output device. With R_{SC} set to zero, the maximum output current capability is (Q1 beta) x (150 mA). R_{SC} may be used to limit the short circuit current to any desired value up to this maximum in the same manner as outlined previously in *Figure 3-48*.

An alternate circuit is shown in *Figure 3-49b*. Using an external pnp transistor, maximum output current is again (Q1 beta) x (150 mA). One V_{BE} should be added to the minimum input-output differential voltage requirement for each additional transistor. The circuits in *Figure 3-49* may support outputs in the range of 2 to 37 V by selecting the appropriate feedback network. *Figure 3-49a* is shown for output voltages from 7 to 37 V, whereas *Figure 3-49b* is shown for output voltages from 2 to 7 V.

If it is required to vary the output continuously over a 10 to 1 range, it is necessary first to attenuate V_O so that V_{INV} never exceeds V_{REF} even when V_O is at its maximum value, then provide a potentiometer adjustment from V_{REF} to the non-inverting input. This is illustrated in *Figure 3-49c*, where V_O is attenuated by a ratio of 5:2:1. Maximum permissible V_O is then 35 V (giving a V_{INV} of 6.8 V), which requires 38.6 V $\leq V_{IN} \leq$ 40 V. Minimum V_O is determined by the minimum value for V_{INV}. The specified minimum V_{INV} is 2 V; however, typically, V_{INV} may be reduced to approximately 0.72 V before the circuit no longer regulates. This corresponds to a V_O of 3.7 V. Other 10 to 1 voltage ranges may be obtained by varying the attenuation ratio, (R3 + R4)/R4, from 5.2 to, say, 1.4. Then V_O range will be 1 V to 10 V (13.6 V $\leq V_{IN} \leq$ 39 V).

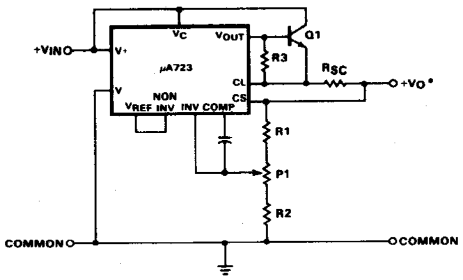
$$V_O = V_{REF}\left(\frac{R2}{R4}\right)\left(\frac{R3 + R4}{R1 + R2}\right)$$

or, with the values of R3 and R4 as shown,

$$V_O = 5.2\ V_{REF}\left(\frac{R2}{R1 + R2}\right)$$

Positive Shunt Regulator

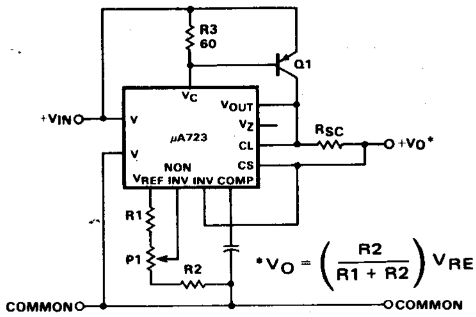
The μA723 may be used in a shunt regulating mode by adding an external transistor, Q1. Special attention should be paid to ensure that the series limiting resistor, R4, is capable of handling the high power dissipation inherent in this mode of operation. *Figure 3-50a* is used with the 14-lead DIP version of the μA723. When the 10-lead metal can is used, however, it is necessary to add a 6.2 V Zener diode externally, as in *Figure 3-50b*.



TYPICAL PERFORMANCE

Regulated Output Voltage	+15 V
Line Regulation (ΔV_{IN} = 3 V)	1.5 mV
Load Regulation (ΔI_L = 1 A)	15 mV

a

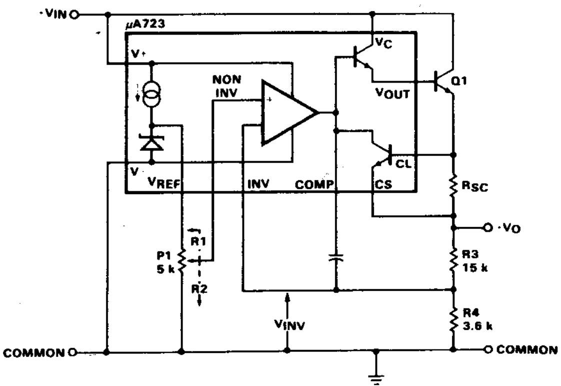


$$^{*}V_O = \left(\frac{R2}{R1 + R2}\right) V_{REF}$$

TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 3 V)	0.5 mV
Load Regulation (ΔI_L = 1 A)	5 mV

b

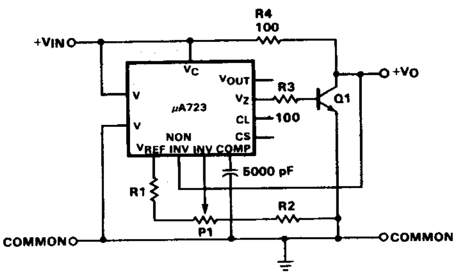


TYPICAL PERFORMANCE

Regulated Output Voltage	4-35 V
Line Regulation (ΔV_{IN} = 10 V)	1 mV
Load Regulation (ΔI_L = 100 mA)	1 mV

c

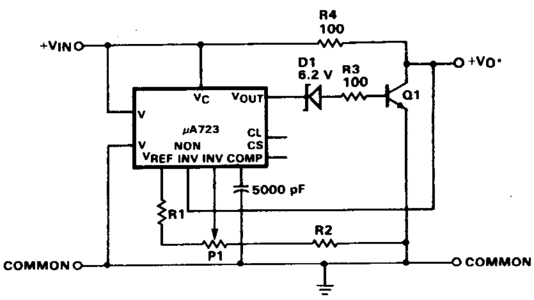
Fig. 3-49. High Current Regulators



TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 10 V)	0.5 mV
Load Regulation (ΔI_L = 100 mA)	1.5 mV

a



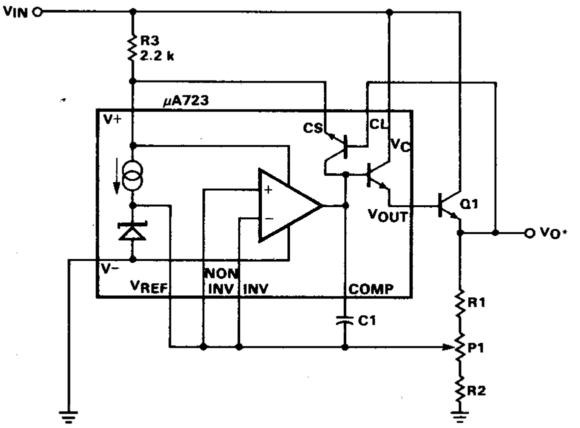
$$^{*}V_O = \left(\frac{R2}{R1 + R2}\right) V_{REF}$$

b

Fig. 3-50. Positive Shunt Regulators

Positive Regulators, High Line Rejection
As shown in *Figure 3-51a* and *b*, the circuits each use the internal current limit transistor to preregulate the V+ supply, thereby increasing the line rejection to more than 100 dB. The CS - CL terminals provide a 6.2 V Zener diode referenced to the output voltage, which is then used to supply V+. In these applications R3 must be chosen so that the current into the CS terminal is limited to 5 mA maximum.

Positive Regulators, High Input Voltage
Input voltages greater than 40 V may be applied when the μA723 is connected as shown in *Figure 3-52a*. The regulated output voltage must remain less than 38 V to protect the regulator. R3 may be replaced with a regulated current source in those cases where the variation of input voltage imposes excessive power dissipation in the internal series pass device. Q2 provides short circuit protection, if required (the internal current limit transistor cannot be used in this application). The maximum input voltage is determined by the breakdown characteristics of Q1. When using the μA723 DIP version, D1 may be omitted and the V_Z terminal grounded; in this case V_{REF} must be resistively divided by two before being applied to the inverting input.

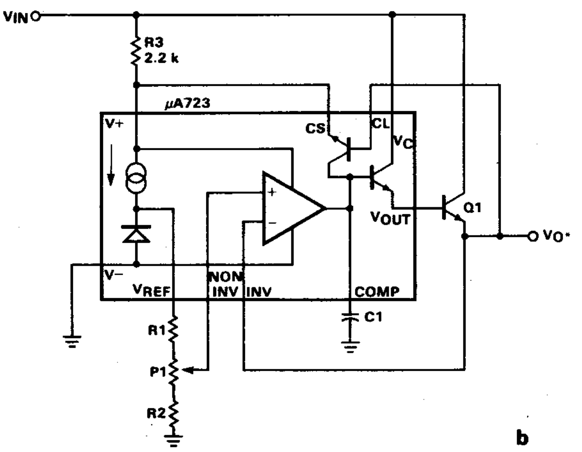


TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} =)	1 mV
Load Regulation(ΔI_L = 50 mA)	10 mV
I_L (min.) = 5 mA	

$$^{*}V_O = \left(\frac{R2}{R1 + R2}\right) V_{REF}$$

a



TYPICAL PERFORMANCE

Regulated Output Voltage	+15 V
Line Regulation (ΔV_{IN} = 15 V)	1 mV
Load Regulation (ΔI_L = 50 mA)	1 mV

$$(R1 + R2)\ \max = \frac{V_O}{5\ \text{mA}}$$

$$^{*}V_O = \left(\frac{R1 + R2}{R2}\right) V_{REF}$$

b

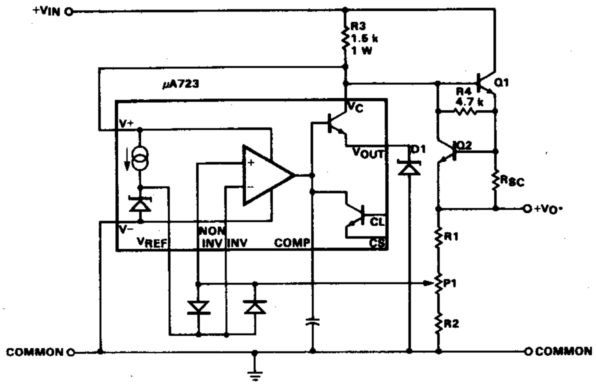
Fig. 3-51. High Line Rejection

Note that in this type of application where the μA723 output stage is used as an additional inverting amplifier rather than the usual emitter follower, V_{REF} must be connected to the inverting input of the error amplifier to maintain correct phase relationships around the regulating loop, i.e., negative feedback from the output.

When using a pnp series pass device, high input voltages may be tolerated by using a Zener diode to reduce the voltage appearing across the μA723, as in *Figure 3-52b*. For example, if D1 is a 20 V Zener diode, input voltages to 60 V are permissible. D1 must be selected such that no more than 40 V is applied to the μA723 V+ and V_C terminals under maximum input voltage conditions. Similarly, the regulated output voltage must not exceed 37 V to maintain the specified input-to-output differential.

Positive Regulator, Floating

The μA723 may be used to directly regulate hundreds of volts using the configuration shown in *Figure 3-53*, in which a floating power source is provided for the regulator by D1. The series pass transistor becomes the only limiting factor in determining the maximum voltage and current which may be controlled. The V_{REF} terminal supplies all the current drawn by the sensing resistors and the total current must not exceed 5 mA. R5 must be selected to provide sufficient current to bias D1 and to supply the μA723 standby current at the minimum input voltage condition. D2, D3 and D4 are for protection purposes; fast switching diodes should be used.

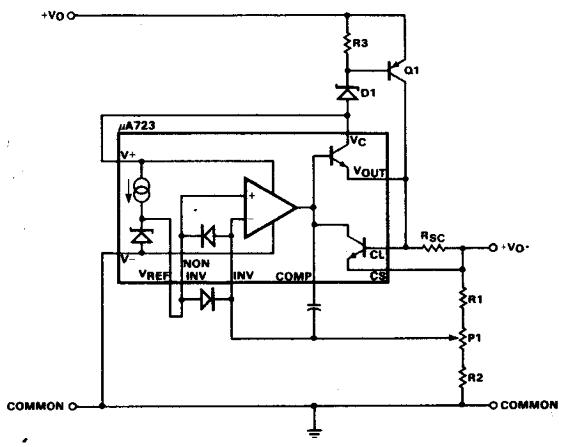


TYPICAL PERFORMANCE

Regulated Output Voltage	+30 V
Line Regulation (ΔV_{IN} = 20 V)	90 mV
Load Regulation (ΔI_L = 100 mA)	8 mV

$$*V_O = \left(\frac{R1 + R2}{R2}\right) V_{REF}$$

a



TYPICAL PERFORMANCE

Regulated Output Voltage	+15 V
Line Regulation (ΔV_{IN} = 20 V)	10 mV
Load Regulation (ΔI_O = 100 mA	30 mV

$$*V_O = \left(\frac{R1 + R2}{R2}\right) V_{REF}$$

b

Fig. 3-52. High Input Voltage

If Q1 is a high f_T device, it may be necessary to add C2 to reduce the output noise level. If V_{IN} is switched on and off, causing a very high dV_{IN}/dt to appear at the μA723 terminals, C3 may be added to ensure correct biasing throughout the circuit. In normal use, the on/off switch is in front of the rectifier/filter supply for V_{IN}, therefore C3 is not necessary. Note from *Figure 3-53* the following.

$$V_O = V_{REF}\left[\left(\frac{R2}{R1}\right) - \left(\frac{R3}{R1}\right)\left(\frac{R1+R2}{R3+R4}\right)\right]$$

If R3 and R4 are made equal,

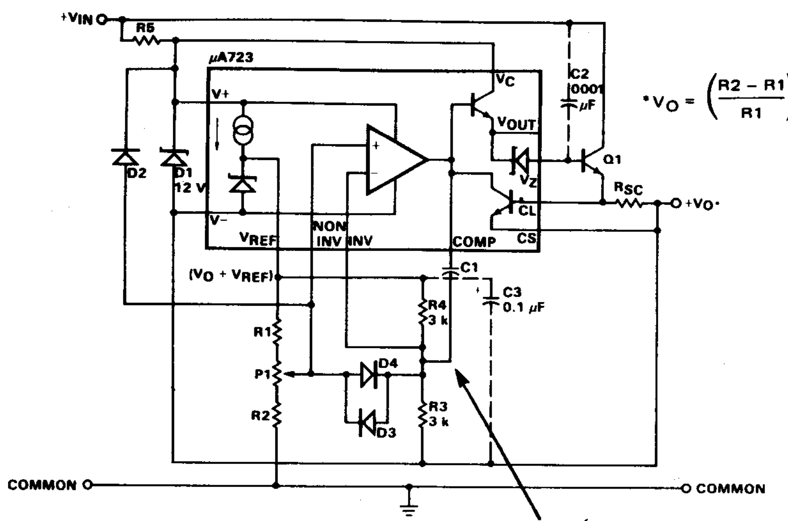
$$V_O = \frac{V_{REF}}{2}\left(\frac{R2-R1}{R1}\right)$$

The normal minimum regulated output voltage limitation of 2 V for the μA723 does not apply to this circuit, since output voltages down to zero volts are readily obtainable. Assuming the regulator is operating correctly, then the INV input equals the NON-INV input, i.e.,

$$(V_O+V_{REF})\left(\frac{R2}{R1+R2}\right) = (V_{REF})\left(\frac{R3}{R3+R4}\right) + V_O$$

$$V_O\left(\frac{R2}{R1+R2} - 1\right) = V_{REF}\left[\left(\frac{R3}{R3+R4}\right) - \left(\frac{R2}{R1+R2}\right)\right]$$

$$V_O = V_{REF}\left[\left(\frac{R2}{R1}\right) - \left(\frac{R3}{R1}\right)\left(\frac{R1+R2}{R3+R4}\right)\right]$$



$$^{*}V_O = \left(\frac{R2-R1}{R1}\right)\frac{V_{REF}}{2}$$

$$V_{REF}\left(\frac{R3}{R3+R4}\right) + V_O$$

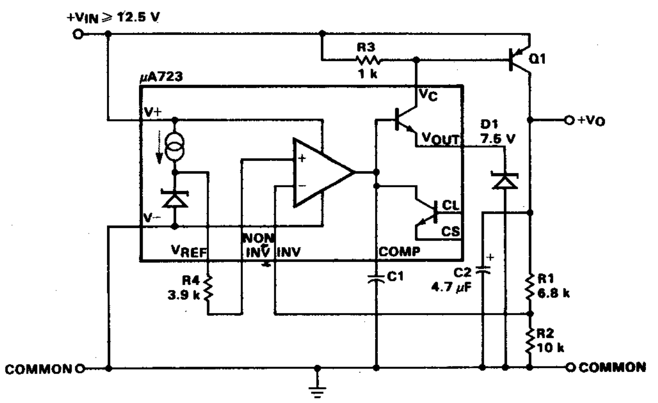
TYPICAL PERFORMANCE

Regulated Output Voltage	+50 V
Line Regulation (ΔV_{IN} = 20 V)	1.5 mV
Load Regulation (ΔI_L = 50 mA)	1.0 mV

$$I_{L\,(min)} = \left(I_{Standby\ max} + I_{D1} + \frac{I_{L\ max}}{Q1\beta_{min}}\right)$$

$$R5_{max} = \frac{(V_{IN\ min} - V_O - V_{D1\ max})}{I_{L\ min}}$$

Fig. 3-53. Floating Positive Regulator



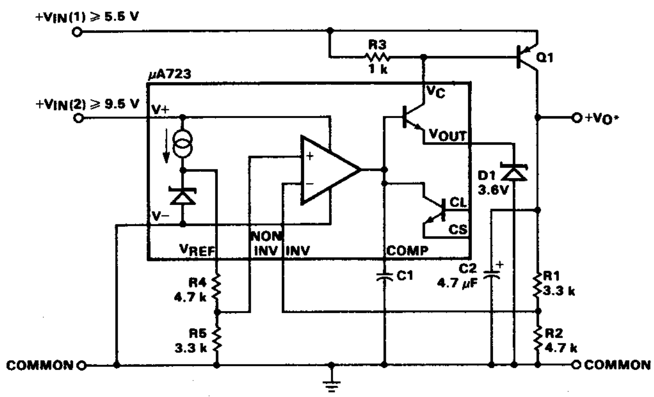
a

TYPICAL PERFORMANCE

Regulated Output Voltage	12 V
Line Regulation (12.5 V $\leq V_{IN} \leq$ 15 V)	3 mV
Load Regulation (ΔI_L = 1 A)	5 mV

$$^{*}V_O = \left(\frac{R1 + R2}{R2}\right) V_{REF} = 12\ V$$

3



b

TYPICAL PERFORMANCE

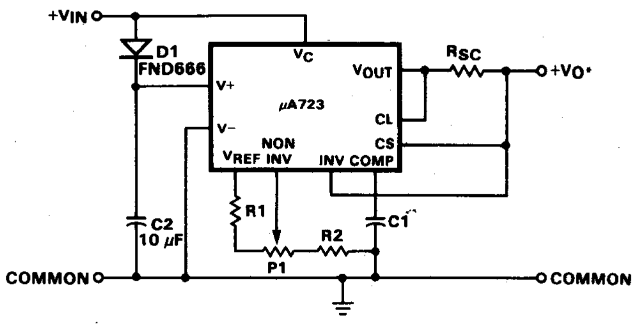
Regulated Output Voltage	5 V
Line Regulation (5.5 V $\leq V_{IN}$ (1) $\leq$ 10V)	1 mV
Load Regulation (ΔI_L = 1 A)	4 mV

$$^{*}V_O = \left(\frac{R1 + R2}{R2}\right) V_{REF} \left(\frac{3.3}{8}\right) = 5\ V$$

Fig. 3-54. Low Input/Output Differential

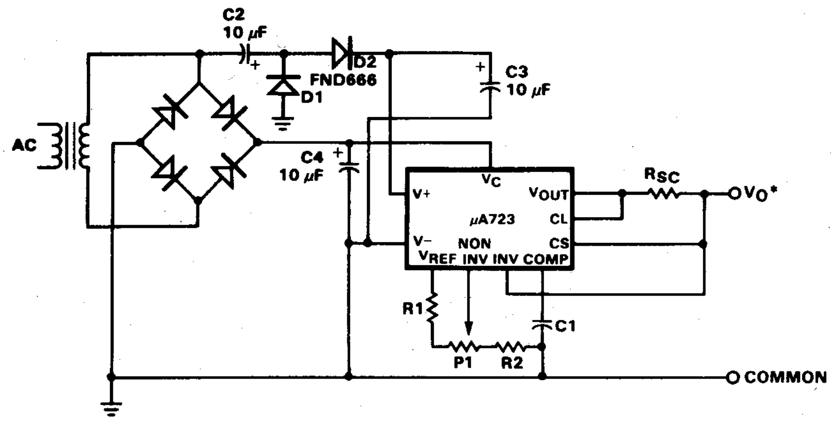
Positive Regulators, Low Input/Output Differential

Either of the two circuits shown in *Figure 3-54* allows an input-to-output voltage difference close to the saturation point of the series pass device. As in all applications, the $V_{IN(2)}$ of *Figure 3-54b* must be 9.5 V minimum. The 7.5 V Zener diode may be eliminated (see *Figure 3-54a*) when using the dual in-line package by grounding the V_Z terminal and reducing the V_{REF} to 3 V by a 4.7 kΩ/3.3 kΩ voltage divider to the non-inverting input of the μA723.



$$*V_O = \left(\frac{R2}{R1 + R2}\right) V_{REF}$$

a



$$*V_O = \left(\frac{R2}{R1 + R2}\right) V_{REF}$$

b

Fig. 3-55. Marginal Input Voltage

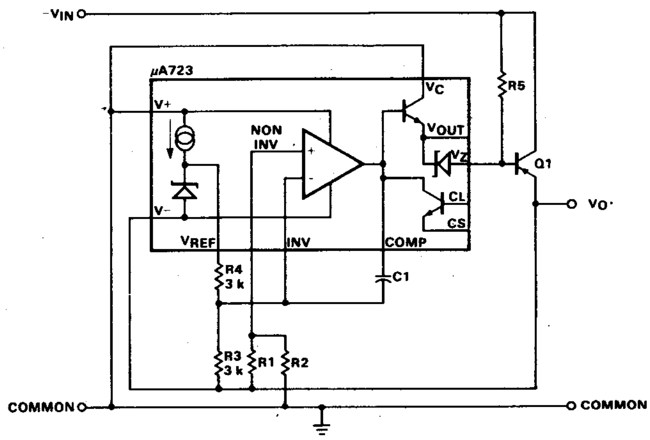
Positive Regulators, Marginal Input Voltage

The two circuits shown in *Figure 3-55* offer some relief from the 9.5 V minimum V+ voltage when regulating lower voltages. In those cases where the average voltage applied to the input is greater than the required minimum – but the negative ripple peaks are lower – a diode-capacitor peak detector provides the solution (*Figure 3-54a*). *Figure 3-55b* shows one method of using a voltage doubler to assure that, using a minimum of external components, the proper bias voltage is applied to the V+ terminal.

Negative Regulators, Medium/High Output Current

This configuraton (*Figure 3-56a*) regulates any negative voltage between −9.5 V and −40 V. Since the μA723 is operated between ground and the regulated output, the maximum unregulated input voltage is determined by the voltage breakdown and power dissipation capabilities of the pnp series pass device, Q1. Base current Q1 is supplied through resistor R5 such that the minimum input-to-output differential is controlled both by the base current required by Q1 and the value of R5. A Darlington connection may be used for Q1 to reduce the base current requirement (*Figure 3-56b*) and to increase the output current capability. Either the complementary Darlington as shown, or a standard pnp pair can be used.

For output voltages in the range −2 V to −9.5 V, the output voltage alone is insufficient to bias the μA723 in *Figure 3-56a*. This condition is satisified in *Figure 3-57* by an external, regulated or unregulated, positive voltage applied to the V+ and V_C terminals. The 40 V maximum limit between V+ and V− terminals must be observed. Maximum values for $-V_{IN(2)}$ and for the input-to-output differential are determined as for *Figure 3-56a*. In all cases, if the V_Z terminal is unavailable, then the V_{OUT} terminal may be used with a series 6.2 V Zener diode.



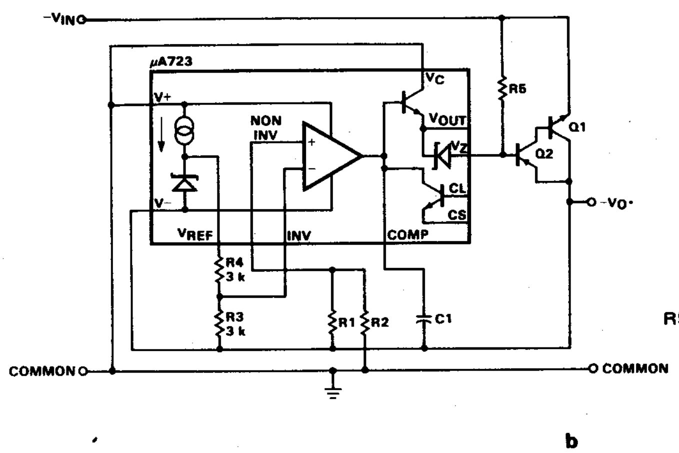
TYPICAL PERFORMANCE

Regulated Output Voltage	−15 V
Line Regulation (ΔV_{IN} = 3 V)	1 mV
Load Regulation (ΔI_L = 100 mA)	2 mV

$$R5 = (V_{IN}\,min - V_O - V_{BE})\left(\frac{Q1\beta_{min}}{I_{L\,max}}\right)$$

$$*-V_O = -\left(\frac{R1 + R2}{R1}\right)\frac{V_{REF}}{2}$$

a



TYPICAL PERFORMANCE

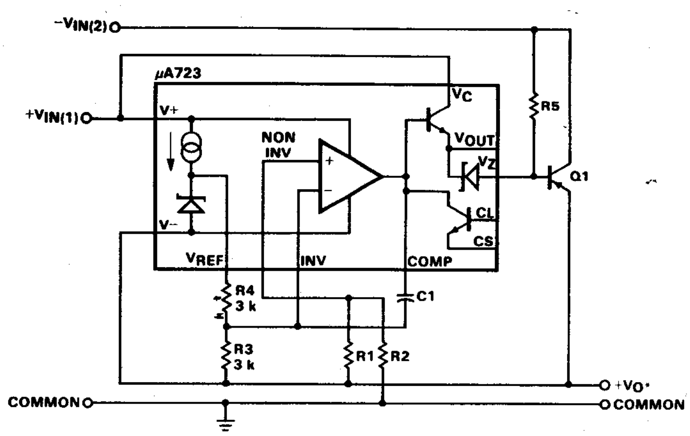
Regulated Output Voltage	−15 V
Line Regulation (ΔV_{IN} = 10 V)	4 mV
Load Regulation (ΔI_L = 50 mA)	2 mV

$$*-V_O = -\left(\frac{R1 + R2}{R1}\right)\frac{V_{REF}}{2}$$

$$R5 = \frac{(V_{IN}\,min - V_O - V_{BE})\,(Q1\beta_{min})\,(Q2\beta_{min})}{I_{L\,max}}$$

b

Fig. 3-56. Medium/High Output Current Negative Regulators



TYPICAL PERFORMANCE

Regulated Output Voltage	-6 V
Line Regulation (ΔV_{IN} = 10 V)	4 mV
Line Regulation ($\Delta V_{IN(2)}$ = 10 V)	10 mV

$$R5 = (V_{IN(2)min} - V_O - V_{BE}) \left(\frac{Q1\beta_{min}}{I_{L\,max}}\right)$$

$$40\text{ V} \geq (V_{IN(1)} - V_O) \geq 9.5\text{ V}$$

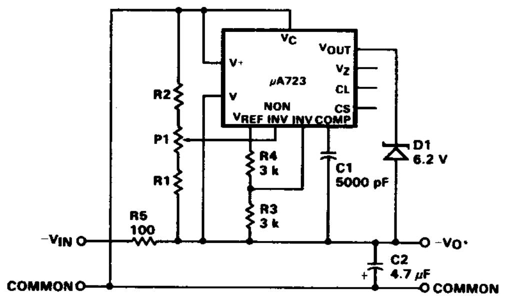
$$^*-V_O = -\left(\frac{R1 + R2}{R1}\right)\frac{V_{REF}}{2}$$

Fig. 3-57. High Output Current Negative Regulator

Negative Shunt Regulator

For low to medium output currents, the series pass transistor of the previous circuits can be omitted. However, special attention must be paid to the dissipation of D1 and R5, and the internal dissipation of the μA723. Maximum permissible current shunted to ground via the V_{OUT} terminal is 150 mA.

Figure 3-58 as shown is suitable for output voltages in the range −9.5 V to −40 V. By removing the V+ and V_C terminals from ground and supplying them with a low value positive voltage as in *Figure 3-57*, output voltages from −2 V to −9.5 V are obtainable. Total voltage from V− to V+ of 9.5 V minimum and 40 V maximum must be observed. If the maximum current from the V_{OUT} terminal is less than 20 mA in a particular application, then D1 may be omitted and the output connected to V_Z instead of V_{OUT}.



TYPICAL PERFORMANCE

Regulated Output Voltage	-15 V
Line Regulation (ΔV_{IN} = 3 V)	3 mV
Load Regulation (ΔI_L = 50 mA)	5 mV

$$^*-V_O = -\left(\frac{R1 + R2}{R1}\right)\frac{V_{REF}}{2}$$

Fig. 3-58. Negative Shunt Regulator

Negative Regulator, High Line Rejection

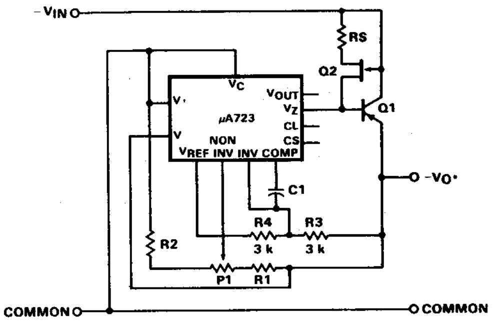
In the negative regulators with a series pass device, the only variation seen by the control circuitry under varying input conditions is the current variation caused by the fixed resistance across the collector-base junction of the series transistor.

By replacing the resistor with a FET current source in *Figure 3-59* the line rejection is greatly improved, typically exceeding 100 dB. Output voltage range is −9.5 V to −40 V, extendable down to −2 V by the addition of positive supply as in *Figure 3-57.* R5 and Q2 must be selected to provide sufficient base current for Q1 under worst case conditions. With R5 equal to zero, a good choice for Q2 would be a 2N5484 since its I_{DSS} (zero-gate voltage-drain current) of 1 to 5 mA provides sufficient current for Q1 in most applications.

Negative Regulator, Floating

When the desired output voltage exceeds the 40 V maximum which may be applied across the device, then a Zener diode should be used to limit the voltage, as shown (*Figure 3-60*). The actual Zener voltage selected may be between 9.5 V and 40 V with little change in performance. This circuit is the complement of *Figure 3-53.* R6 must be selected to provide sufficient current to bias D1 and to supply the μA723 standby current under minimum input voltage condition. Select R6 according to the requirements outlined in *Figure 3-56b.*

3

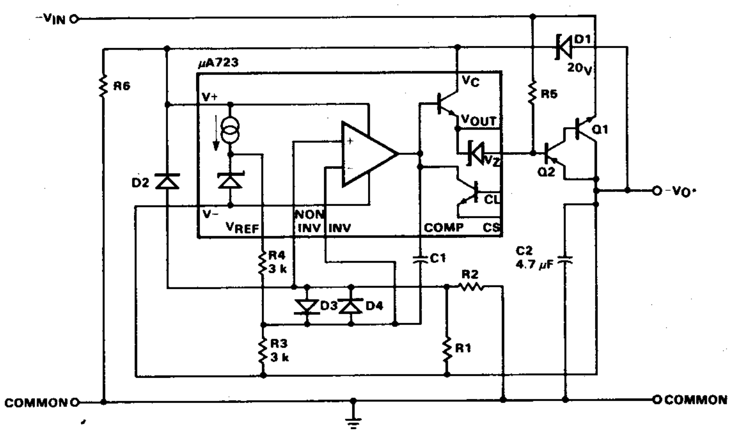


TYPICAL PERFORMANCE

Regulated Output Voltage	−15 V
Line Regulation (ΔV_{IN} = 3 V)	<1 mV
Load Regulation (ΔI_L = 50 mA)	2 mV

$$\bullet -V_O = -\left(\frac{R1 + R2}{R1}\right)\frac{V_{REF}}{2}$$

Fig. 3-59. Negative High Line Rejection Regulator



TYPICAL PERFORMANCE

Regulated Output Voltage	−100 V
Line Regulation (ΔV_{IN} = 3 V)	30 mV
Load Regulation (ΔI_L = 1 A)	20 mV

$$\bullet -V_O = -\left(\frac{R1 + R2}{R1}\right)\frac{V_{REF}}{2}$$

Fig. 3-60. Negative Floating

Current Regulators

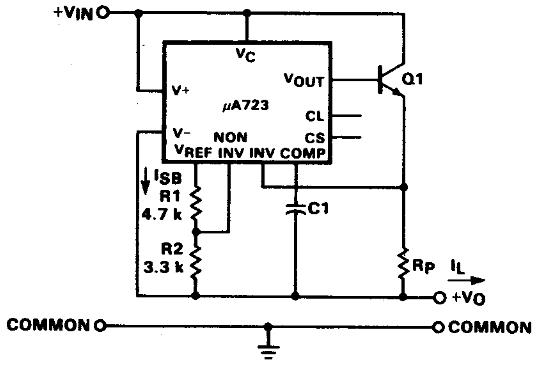
In *Figure 3-61*, the regulator forces a voltage to appear across R_P which is equal to the voltage existing across R2. The resulting current is summed with the regulator standby current, I_{SB}, and the current through R2, to provide a regulated current, I_L, into the load, R_L. Due to this summation, line regulation decreases for output currents below 10 mA.

The input voltage must be greater than $I_L\ R_{L(max)}$ +9.5 V to ensure sufficient voltage across the µA723. In *Figure 3-61*, the source current is from a positive voltage $+V_{IN}$. V_{IN} can, of course, be grounded while returning R_L to a negative voltage. Similarly, the output terminal may be grounded or taken to a negative voltage, at which time, the V_{IN} terminal provides a regulated current sink of magnitude I_L. In no case may the voltage from V− to V+ exceed 40 V.

$$I_L = \left(\frac{R2}{R1+R2}\right)\left(\frac{V_{REF}}{R_P}\right) + I_{SB} + I_{R2} = \left(\frac{V_{REF}}{R1+R2}\right)\left(1+\frac{R2}{R_P}\right) + I_{SB}$$

For output currents in excess of 10 mA, this approximates to the following with the values of R1 and R2 shown.

$$I_L = \left(\frac{R2}{R1+R2}\right)\left(\frac{V_{REF}}{R_P}\right) + I_{SB} \simeq \left(\frac{3000}{R_{P(\Omega)}}\right) + I_{SB}\ \text{mA}$$



TYPICAL PERFORMANCE

Output Current	3 mA
Line Regulation (ΔV_{IN} = 5 V)	0.3 mA
Load Regulation (ΔR_L = 200Ω)	0.2 mA

Fig. 3-61. Current Regulator

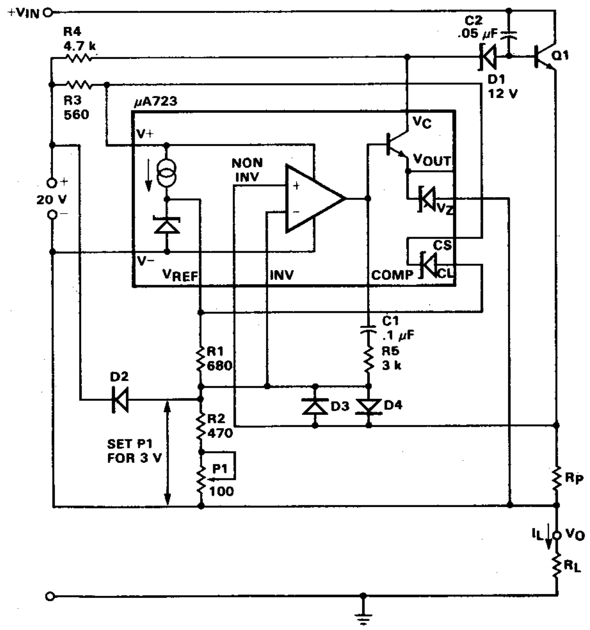
If a voltage compliance greater than 40 V is required, or if the regulation of *Figure 3-61* is insufficient, the configuration in *Figure 3-62* may be used. It is a precision floating current source capable of 0.05% regulation. In this circuit, a floating 20 V supply (typically a half-wave rectified output from a separate transformer winding of the main supply) is used to power the μA723, such that standby and reference currents do not add to the programmed output current.

$$I_L = \left(\frac{R2}{R1+R2}\right)\left(\frac{V_{REF}}{R_P}\right)$$

If P1 is adjusted so that $V_{R2} = 3.0$ V, as indicated in the schematic, then

$$I_L = \frac{3000}{R_P(\Omega)} \text{ mA.}$$

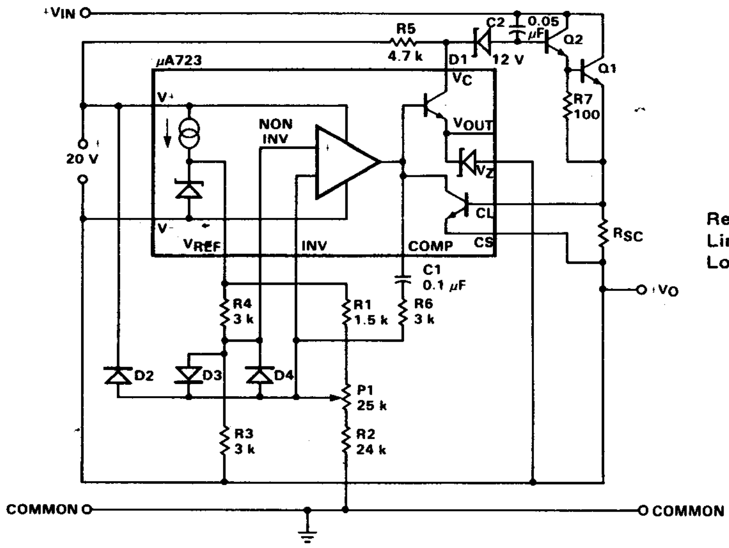
Both output current and voltage compliance are limited by the capabilities of the series pass device Q1. Diodes D2 through D4 are protection diodes which should be included whenever V_{IN} exceeds 40 V.



TYPICAL PERFORMANCE

Output Current	10 mA
Line Regulation (% of ΔV_{IN})	<.01%
Load Regulation (ΔV_O = 10 V)	<.05%

Fig. 3-62. Current Regulator



TYPICAL PERFORMANCE

Regulated Output Voltage	0-100 V
Line Regulation (% of ΔV_{IN})	<.01%
Load Regulation (% of V_O)	<.005%

$$^*V_O = \left(\frac{R2 - R1}{R1}\right)\frac{V_{REF}}{2}$$

Fig. 3-63. Precision Voltage Regulator

Precision Voltage Regulator

Figure 3-63 uses the same principle as the previous circuit to give a voltage output capable of 0.005% load regulation. Output voltage range is from zero volts up to the series pass device limit. Output current is also limited only by the series pass device; short circuit protection is available in this configuration by selecting R_{SC} as previously described. Protection diodes D1, D3 and D4 should be added whenever V_{IN} exceeds 40 V. With the component values shown, this gives an output voltage range of 0 to 100 V.

$$V_O = \left(\frac{R2-R1}{R1}\right)\frac{V_{REF}}{2}$$

Foldback Current Limiting

Foldback current limiting is a superior alternative to standard current limiting techniques particularly where intolerable output device power dissipation is a problem. Typically, this is a consequence of device/heat sink limitations under short circuit conditions.

In the following discussions, it is assumed that a regulated output voltage is available up to a maximum output current I_M. The output current then folds back with decreasing load resistance to a value of I_{SC} (with a short circuit load). The "knee" of the current limiting characteristic will be similar to that shown in the data sheet for normal current limiting. The regulation degrades considerably as I_M is approached and in a practical regulator the useful output current may be limited to approximately 80% of I_M.

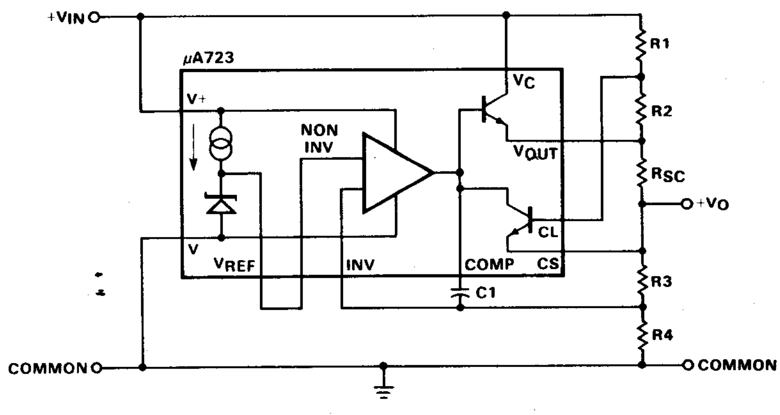


Fig. 3-64a. Foldback Current Limiting Positive Regulator

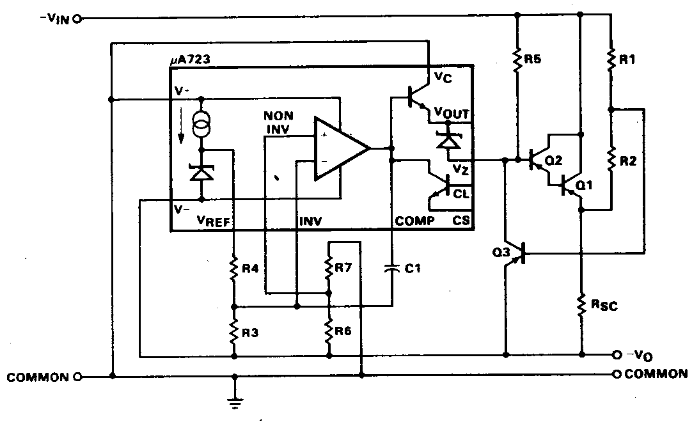


Fig. 3-64b. Foldback Current Limiting Negative Regulator

A minimum parts/cost method for providing the positive feedback required for foldback action is shown in *Figures 3-64a* and *b*. This technique introduces positive feedback by increased current flow through R1 and R2 under short circuit conditions. This forward biases the sensing-transistor base-emitter junction. The final percentage of foldback depends on the relative contributions of the voltage drop across R2 and R_{SC} to the base current of the sensing transistor. In the active region where the voltage buildup of R2 and R_{SC} provides base current to the sensing transistor, recovery of the full output capability takes place whenever a short circuit is removed from the output. As soon as there is no voltage buildup across R_{SC} providing a portion of the base current, 100% positive feedback is realized and a reset is required to restore normal operation once the short is removed.

In *Figures 3-64a* and *b*, input to the current limit transistor is ($V_{RSC} + V_{R2}$).

$$I_{SC} = \frac{V_{SENSE}}{R_{SC}}\left(\frac{R1 + R2}{R1}\right) - \frac{V_{IN}}{R_{SC}}\left(\frac{R2}{R1}\right) \text{ and } I_M = I_{SC} + \frac{V_O}{R_{SC}}\left(\frac{R2}{R1}\right)$$

Design equations to give a desired I_M with approximately zero I_{SC} are shown below.

$$R1\ (k\Omega) = V_{IN} - V_{SENSE}\ (V), \quad R2\ (k\Omega) = V_{SENSE}\ (V)\ (\text{i.e. } R2 = 620\ \Omega)$$

$$\text{and } R_{SC} = \frac{V_O}{I_M}\left(\frac{R2}{R1}\right), \text{ or } R_{SC} = \frac{V_O}{I_M}\left(\frac{V_{SENSE}}{V_{IN} - V_{SENSE}}\right)$$

In *Figure 3-64b*, a Darlington configuration is recommended for the bypass transistors, Q1 and Q2. This enables R5 to be a relatively high value, typically > 50 kΩ which requires Q3 to sink a low current under short circuit conditions. As R5 is reduced, the current through it increases drastically when $-V_O$ goes to zero volts, and Q3 base current increases to a point where the foldback circuit is no longer operative. From the start of base-emitter conduction of the sense transistor to the full shut off of the regulator series-pass devices requires a 2 μA base current. This represents a 10 mV increase in base-emitter voltage over the base-emitter zero-current threshold.

The latch condition, or 100% positive feedback, is generated by any change in the input voltage which increases the voltage drop across R2 past the 10 mV window with a short circuit applied. It can only be removed by breaking the positive feedback path by some manual reset to allow the series pass devices to once more be driven in a normal fashion. The addition of an external transistor Q1 in *Figure 3-64c* provides the same foldback limiting as *Figure 3-64a* but allows the extension of the active recovery region by several times that of the basic approach.

Latch problems are due to saturation of the current-sensing transistor. Because the additional circuitry shown operates as an antisaturation circuit, it bypasses base current above a value set by the voltage divider R3, R4 and the base-emitter threshold of Q1. This additional transistor acts as a V_{BE} voltage regulator and, assuming a good thermal link, temperature tracks the threshold changes of the current sensing transistor, tending to keep the foldback current drive at a constant level.

Foldback resistors R1 and R2 are calculated using the above equations. The 2N3641 used for Q1 was selected for both high base-emitter diode conductivity and reasonable beta at 2 μA collector current. Final adjustment under short circuit conditions occurs when R4 in *Figure 3-64c* is set just above the point of minimum output current under short circuit load and high ac line operation.

Another approach to low power dissipation under short circuit condition is shown in *Figure 3-64d*. This circuit does not follow the decreasing current, decreasing voltage load line which occurs with the standard foldback technique. Instead, under a short circuit, the output voltage decreases in a normal current limiting fashion, i.e., at a constant high output current until the output voltage is below that necessary to keep the FET pinched off. As soon as the output voltage reaches the pinch-off voltage, a low impedance path is established around the drivers and the output device, which turns off the compound followers. A voltage across the normal load resistor exceeding the pinch-off voltage of the FET whenever the short is removed provides recovery. Bypass resistor R1 supplies this voltage. The FET should be selected with a maximum pinch-off voltage approximately two-thirds the value of V_O. Its minimum pinch-off voltage should not be so low as to demand excessive safe area requirements in the μA723 output stage.

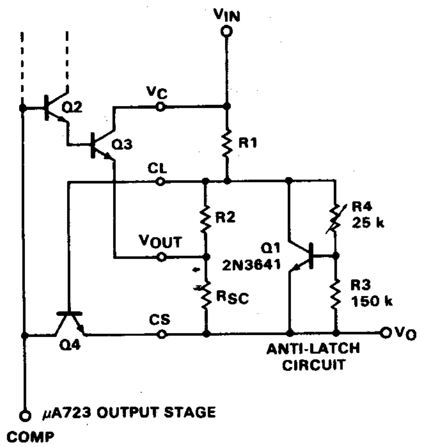
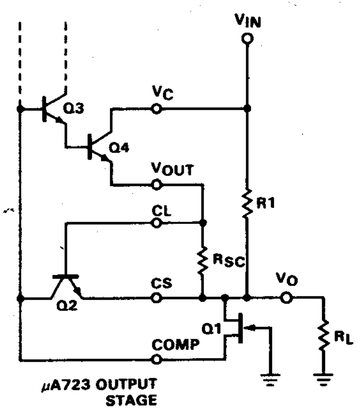


Fig. 3-64c. Foldback Current Limiting (Modified)



$$R_{SC} = \frac{V_{SENSE}}{1M}$$

$$R1 \leqslant \left(\frac{V_{IN\ min} - V_{GS(off)\ max}}{V_{GS(off)\ max}}\right) R_L\ (min)$$

Fig. 3-64d. Foldback Current Limiting (FET)

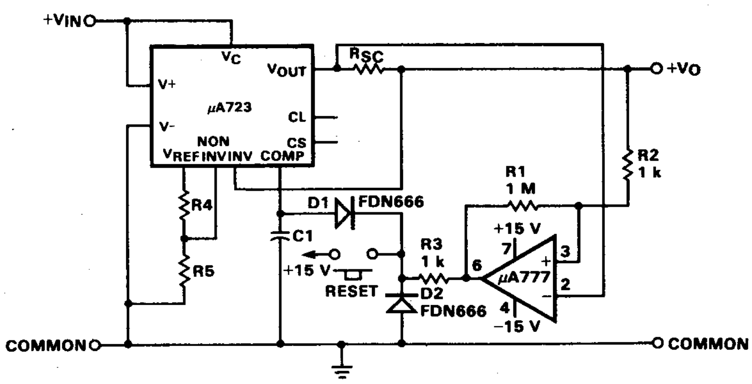


Fig. 3-65. Low Loss Short Circuit Sensing

3

Short Circuit Sensing, Temperature Stabilized

This circuit modification takes advantage of the internal temperature tracking which occurs in an integrated circuit. Since the current limit transistor and the internal series pass devices are at the same temperature and were fabricated at the same time, their base-emitter temperature coefficients are approximately the same. In *Figure 3-65* the current limit transistor is connected so that the temperature coefficients cancel. This is accomplished with a bridge circuit via resistors R4 and R5 which reduces the voltage drop (and therefore the temperature coefficient) to a 1 diode drop level. This voltage, appearing across R4, is balanced by an equal and opposite voltage developed across R3 by a FET current source. The current limit transistor is connected across these two voltages, plus the voltage across R_{SC} due to the output current. At room temperature, the current source is adjusted by P2 such that there is zero voltage between points A and B. Therefore, at room temperature, the current limit transistor is activated when the μA723 sense voltage is developed across R_{SC}, the voltages across R3 and R4 cancelling each other.

The threshold of the current limit transistor tends to track the voltage across R4 with temperature. Therefore, providing the current source remains constant with temperature, current limit set by R_{SC} also remains constant with temperature. *Figure 3-66* is shown for an output voltage of 15 V from a 25 V unregulated input. A higher breakdown FET is required for use with higher input voltages.

Remote Shutdown

A μA723 regulator may be turned off by pulling down the compensation terminal, thereby shunting the drive current for the output stage to ground. The simplest method of achieving this in a positive regulator is shown in *Figure 3-67a*. When the current limiting function is required, an external transistor may be substituted (Q1 in *Figure 3-67b*). The logic input may be from any positive voltage source, e.g., TTL or CMOS, capable of driving greater than 100 μA into the CL terminal or Q1 base. Typically, R3 may be 3 kΩ from a 5 V TTL systems, or 10 kΩ from a 10 V CMOS system. To protect the output stage from excessive reverse base-emitter voltage transients during the shutdown, D1 should be included when the output voltage V_O is greater than 10 V. R4 reduces the peak current that flows when Q1 saturates.

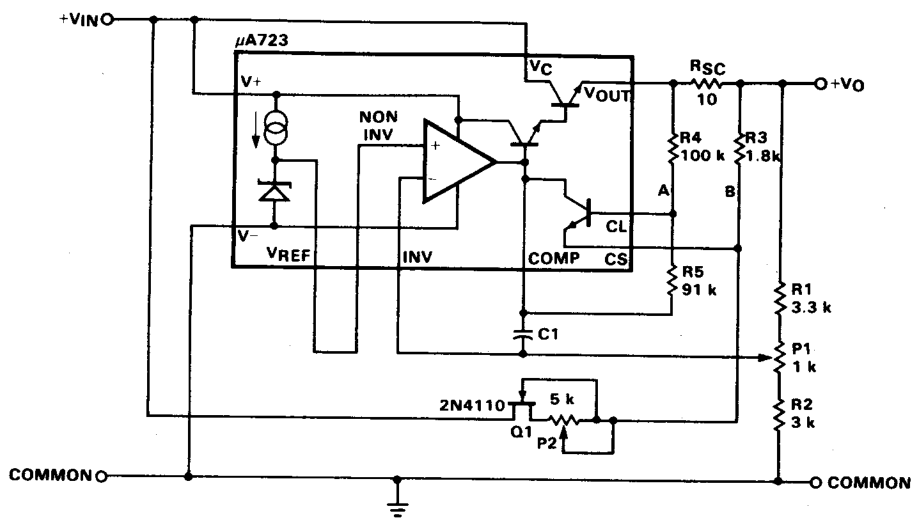


Fig. 3-66. Temperature Stabilized Short Circuit Sensing

Remote shutdown, when applied to a negative regulator, requires the additional circuitry to the right of the dashed line in *Figure 3-67c*. In operation, a logic LOW input, $V_{IL(max)}$, holds Q3 off, disabling the shutdown circuit. A logic HIGH input, $V_{IH(min)}$, from a TTL or CMOS gate turns Q3 on with the base drive limited by R8. Resistor R5 is calculated in the normal worst case manner for the series pass devices selected.

$$R5 = \frac{(V_{IN(min)} - V_O - 2\,V_{BE}{*})}{Q2I_{B(max)}}$$

*(This term becomes 3 V_{BE} if D2 is included.)

When Q3 is turned on, D1 is forward biased at a current limited by R7. The ratio of R5 and R7 is calculated such that the output of the supply is always at ground when the logic input is HIGH.

$$\frac{R7}{R5} = \frac{V_{IH(min)}}{V_{IN(max)}},$$

This formula guarantees that the junction of R5 and R7 is always positive during shutdown – R8 = 10 R7, to give a forced β of 10 for Q3, fully saturating that device. Diode D2 protects the output devices from reverse base-emitter transient voltages, and should be included when the output voltage is greater than the combined base-emitter breakdown voltages of the series pass devices.

3

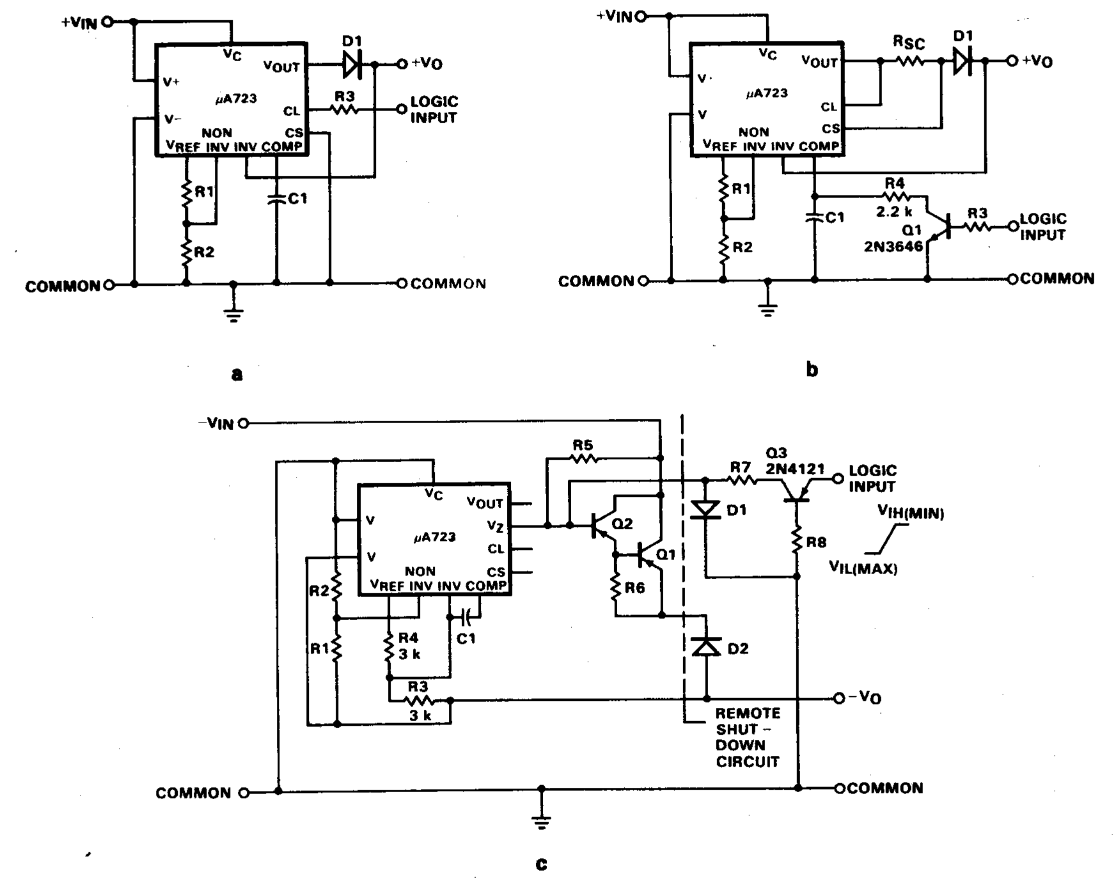


Fig. 3-67. Remote Shutdown

Overvoltage Crowbar Protection

Figure 3-38 shows a μA723 used as a latched comparator and SCR driver. It also provides the temperature compensated reference necessary for accurate overvoltage sensing. In normal operation, P1 is adjusted so that the voltage at point A is more negative than the reference voltage, V_{REF} (typically 7.15 V). Therefore, the voltage across R2 will bias the comparator (the μA723 error amplifier) such that its output, V_{OUT} is driven toward V−, and the internal 6.2 V Zener diode is cut off. Hence no gate current is able to flow into the SCR D2, which remains in an OFF state. Diode D1 blocks the positive feedback path in this condition, therefore, no current flows through R4.

By "crowbar" action, the comparator changes state as soon as the voltage across R2 reverses polarity, that is, as soon as the voltage at point A becomes more positive than V_{REF}. Potentiometer P1 is set so that this occurs at the desired over-voltage trip point, typically (V_O + 10%). When the comparator switches, V_{OUT} is pulled up toward V+, and the SCR is fired with gate current limited by R5. When V_{OUT} exceeds V_{REF}, the positive feedback loop R4/D1 latches the comparator into its switched state.

Firing the SCR places a low impedance across the unregulated supply to ground, and this blows fuse F1. From the initial overvoltage to the SCR clamping takes approximately 1 μs; if required the switching action can be slowed down by a capacitor from the μA723 COMP terminal to the inverting input.

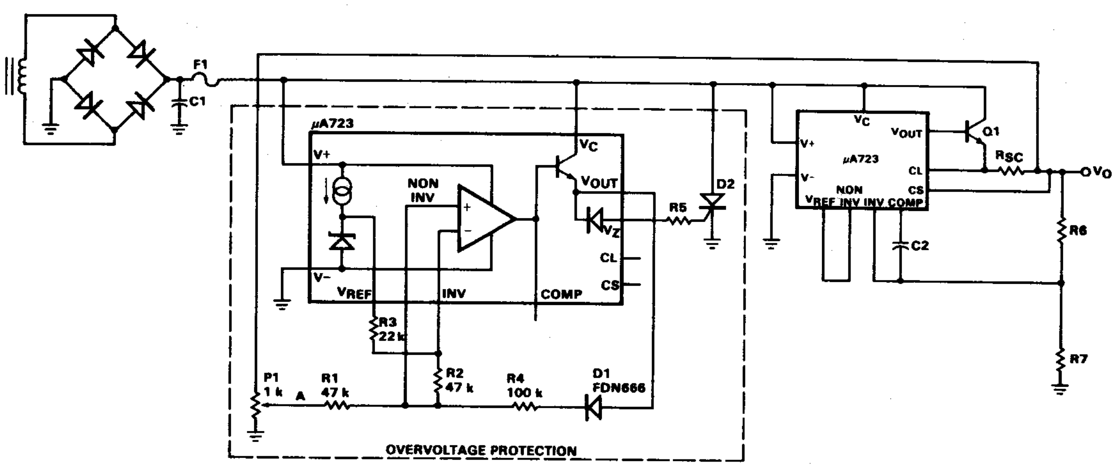


Fig. 3-68. Crowbar Protection

Over/Under Voltage Monitoring

There are many systems where it is important that, when the regulated supply lines deviate from their nominal values, an alarm is indicated and some action, such as system shutdown or system changeover, is initiated. Such a fault detection system requires overvoltage and undervoltage monitors for both positive and negative power supplies. The μA723 may be used very effectively in this application and provides a TTL-compatible output signal.

Figure 3-69 gives an indication of an undervoltage on a positive supply line. The internal reference voltage of the μA723, V_{REF}, is used to generate a threshold voltage of 2.0 V across R4. The voltage to be monitored, V_M, is divided down by R_M and R1. The voltage across R1 is compared to the threshold voltage across R4 by the μA723 error amplifier. When V_M is at its nominal value, the output of the μA723 is in its HIGH state, which is set at approximately 3.3 V by clamping the COMP terminal to the junction of R2 and R3 on the V_{REF} voltage divider. Current drain from V_{OUT} through R6 is nominally 15 mA.

If the monitored supply, V_M, should fall by a predetermined amount, the error amplifier changes state, and the output voltage V_O assumes its LOW state. R6 can drive one TTL load (1.6 mA at 0.4 V_{max} V_O). Positive switching action is assured by the hysteresis applied through R5. R_M is adjusted so that the voltage across R1 equals the threshold voltage (2.0 V) when V_M is at the desired undervoltage trip level. This circuit gives an overvoltage indication on a positive supply line when the amplifier inputs are interchanged as shown by the dashed lines.

3

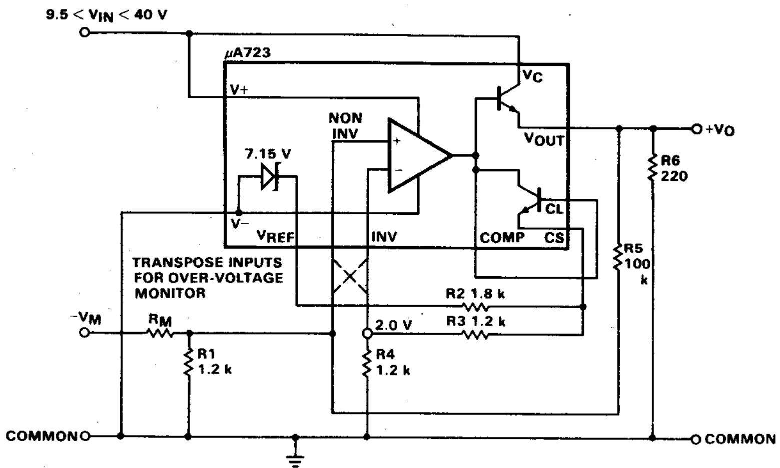


Fig. 3-69. Positive Supply Undervoltage Monitor

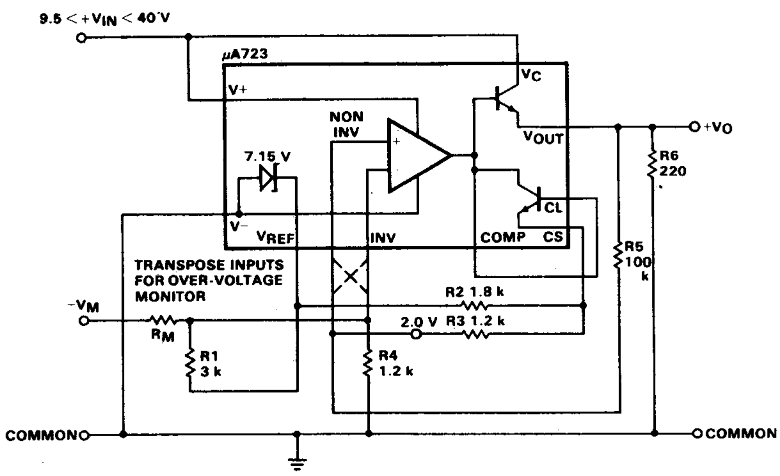
Figure 3-70 performs the same functions for a negative supply line. The monitored supply voltage, $-V_M$, is referenced to V_{REF} in this circuit, to provide the level shifting from any negative input to the +2.0 V threshold voltage. Response times for these monitor circuits are typically less than 1 μs.

The voltage necessary to turn on the current-limiting transistor is the sum of V_{SENSE} (the V_{BE} of the current-limiting transistor) and the voltage across R9. Then as shown in the formula below,

$$V_{RSC} = V_{SENSE} + (V_{IN} - V_O)\left(\frac{R9}{R8 + R9}\right) \quad \text{and} \quad I_{LIMIT} = \left(\frac{V_{SENSE}}{R_{SC}}\right) + \frac{(V_{IN} - V_O)}{R_{SC}}\left(\frac{R9}{R8 + R9}\right)$$

R8 and R9 are included to supply positive feedback and, hence, maintain switching action even under short circuit conditions. This prevents over-dissipation if the regulator were allowed to go into a linear mode. Typically, R8 may be 3 kΩ and R9 30Ω so that to a first approximation, current limit is derived as follows:

$$I_{LIMIT} = \left(\frac{V_{SENSE}}{R_{SC}}\right) + \frac{(V_{IN} - V_O)}{100\ R_{SC}}$$



b

Fig. 3-70. Negative Supply Undervoltage Monitor

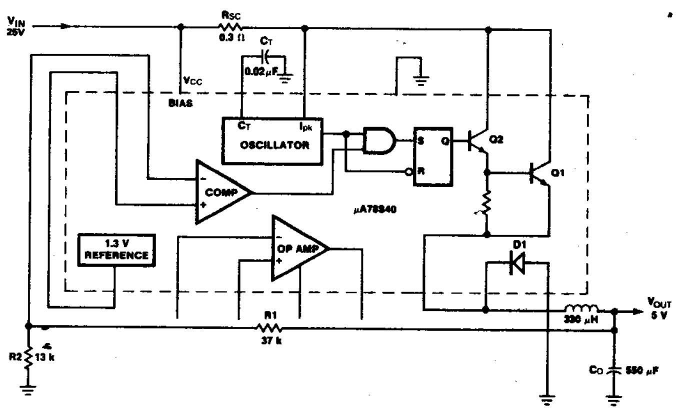


Fig. 3-71. Step-Down Voltage Regulator

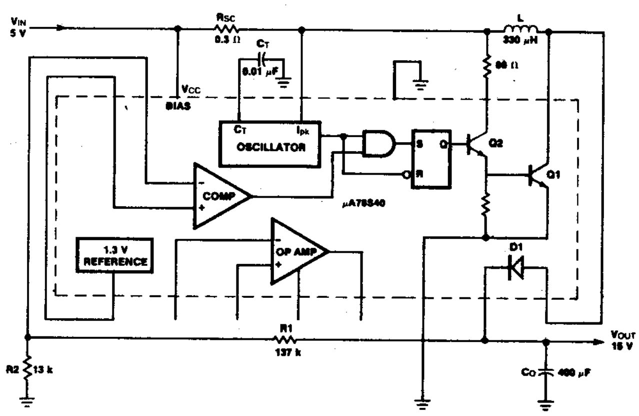


Fig. 3-72. Step-Up Voltage Regulator

USING THE μA78S40 UNIVERSAL SWITCHING REGULATOR

Typical applications of the universal regulator include the three switching regulator modes previously discussed; step-down, step-up, and inverting. *Figure 3-71* illustrates the necessary connections for using the μA78S40 in the step-down mode. This version satisfies a requirement for a 5 V output at 500 mA with output ripple less than 25 mV. In this application, the power switch (Q1 and Q2) is connected between the +25 V supply and the inductor. Switch voltage is determined by the emitter output limit of 1.6 V. For this value, off-time is approximately three times the on-time. Considering that the on-time should be greater than 10 μs, off-time is set by the user at 60 μs (C_T = 0.02 μF), and the inductor value is selected at 330 μH. The output voltage is set by resistors R1 and R2. Output capacitance is calculated to be 400 μF. The circuit standby power is less than 50 mW. Efficiency at full load is 79%; at 10% of full load it is 70%.

For operation as a step-up voltage regulator, the μA78S40 is connected as shown in *Figure 3-72*. In this case, the objective is to use a 5 V input and get a 15 V output at 150 mA, again with output ripple less than 25 mV. Using V_S = 0.5 V and V_D = 1 V, on-time is approximately 2 1/2 times the off-time. Timing capacitance is selected at 0.01 μF, setting the off-time at 30 μs. On-time is consequently approximately 73 μs. An 80 Ω resistor on the drive collector provides a 50 mA base drive to the switch. With a peak input current of 1.1 A, R_{SC} is selected at 0.3 Ω. At full load with an average input current of 555 mA, efficiency is 80%. At 10% of full load, regulator efficiency is 78%. Output capacitance is calculated to be 492 μF.

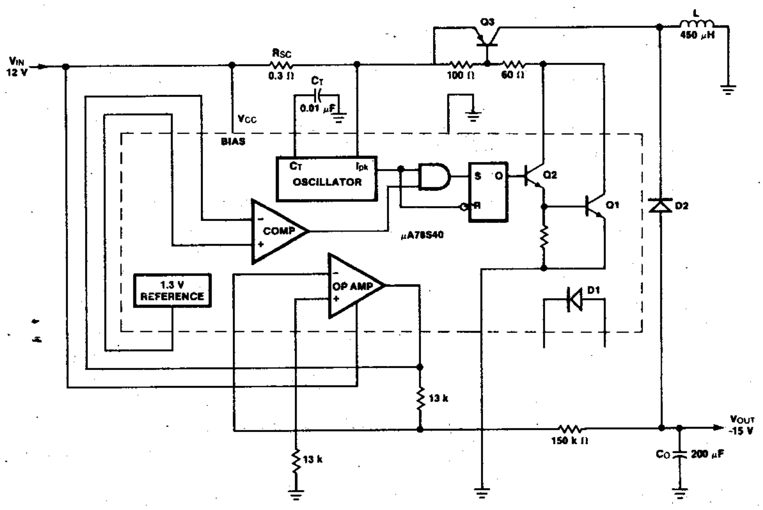


Fig. 3-73. Inverting Voltage Regulator

A voltage inverter configuration is shown in *Figure 3-73*. This mode requires an external pnp transistor (Q3) and a catch diode (D2). With a +12 V input, output voltage is −15 V at 200 mA, with output ripple less than 50 mV. With a timing capacitor value of 0.01 μF, off-time is 30 μF. Peak current can be calculated (0.96 A) as can the value of the inductor (500 μH). Average input current for this inverter mode is 2.75 mA with a regulator efficiency of 93% at full load and 90 % at 10% load. Output ripple is held to 50 mV by using an output capacitor with a value of 251 μF. In this inverter mode, the internal operational amplifier inverts the output voltage to compare it to the 1.3 V reference. This is only possible because the common mode range of the op amp includes ground. Circuit breakdown does not limit output voltage, because no portion of the control circuitry sees any negative voltage.

More Sophisticated Applications

With the addition of a few external parts, the μA78S40 can provide output power up to 100 W and output voltages up to and even exceeding 100 V. Two regulated outputs can be made available by using a switching output and a series-pass output.

One such interesting variation is the use of the universal regulator to provide a constant output for voltage inputs that are both higher and lower than the output, *Figure 3-74*. In this case, 12 V at 100 mA is provided at the output for input voltages over a 4 V to 24 V range. This is done by using a step-up mode similar to the version shown in *Figure 3-72* to provide a 15 V output and then using the internal op amp as a series-pass regulator to reduce the 15 V output to a 12 V output. When the input voltage exceeds 16 V, the step-up regulator circuit follows the input at approximately the input voltage minus 1 V, but the series-pass output remains constant at 12 V. The op amp exhibits excellent noise rejection, so output ripple is virtually non-existent at the 12 V output. Regulator efficiency is about 50% for the upper and lower limits of the input range (4 V and 24 V) and increases to a maximum of about 75% for intermediate voltages.

Another variation involves the addition of an external pnp transistor and an external catch diode to the step-down regulator, *Figure 3-75*. The transistor (Q3) increases output current capability by a factor of 10 and also improves switching efficiency because the switching voltage drops from 1.6 V to 1 V. The npn Darlington pair switch is connected to provide the base drive for Q3, with a 56 Ω resistor limiting the base drive to 500 mA. A peak input current of 10 A (plus the 0.5 A base drive) with an input voltage of 30 V provides a 5 V, 5 A output. The average input current is 1.1 A. Efficiency of the regulator is approximately 73%, with the control circuit dissipating the base drive

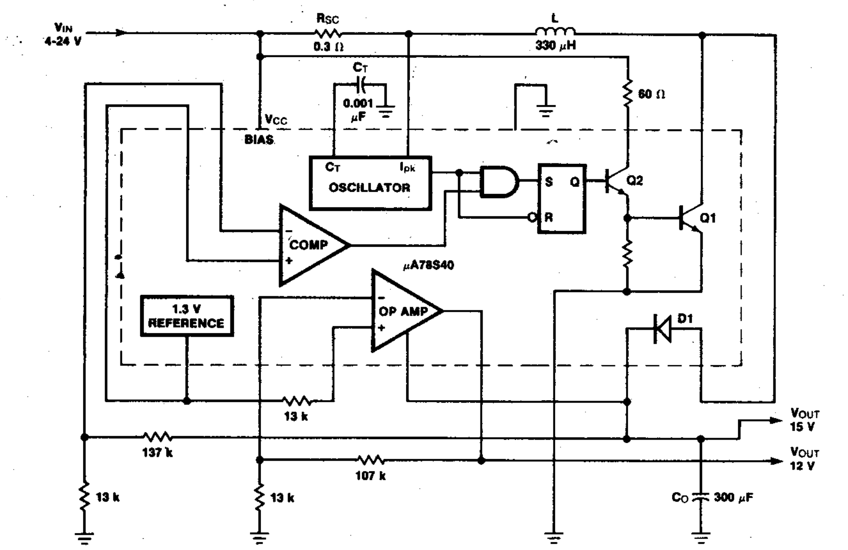


Fig. 3-74. Constant Output Voltage Regulator Over 4-24 V Input Range

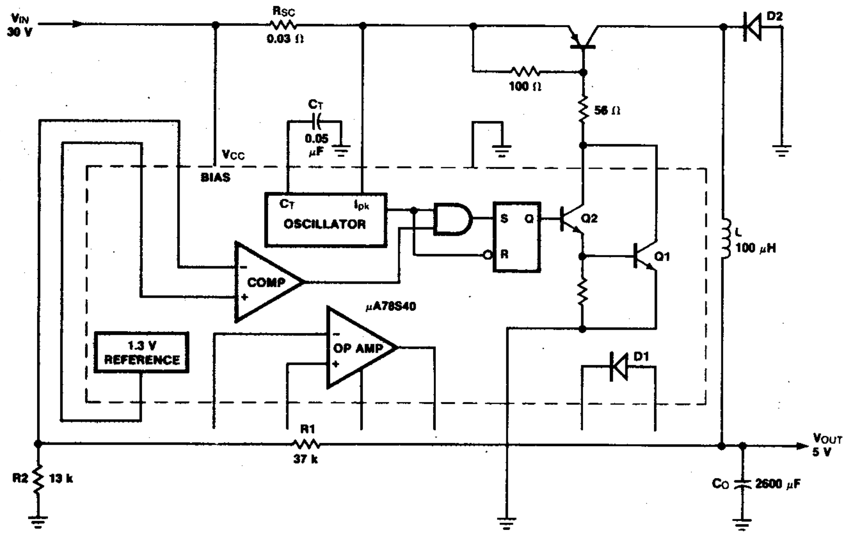


Fig 3-75. Modified Step-Down Regulator with 5 A, 5 V Output

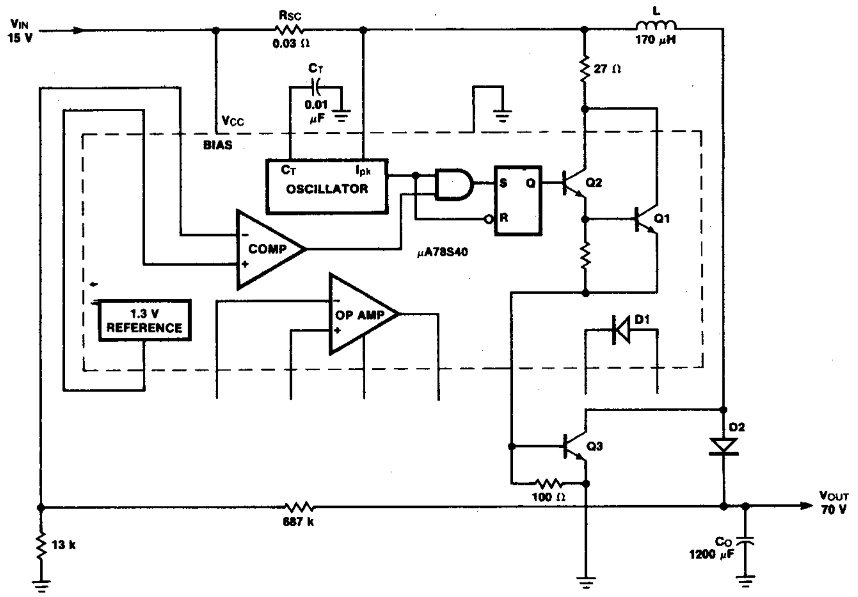


Fig. 3-76. Switching Regulator with 15 V Input, 70 V Output

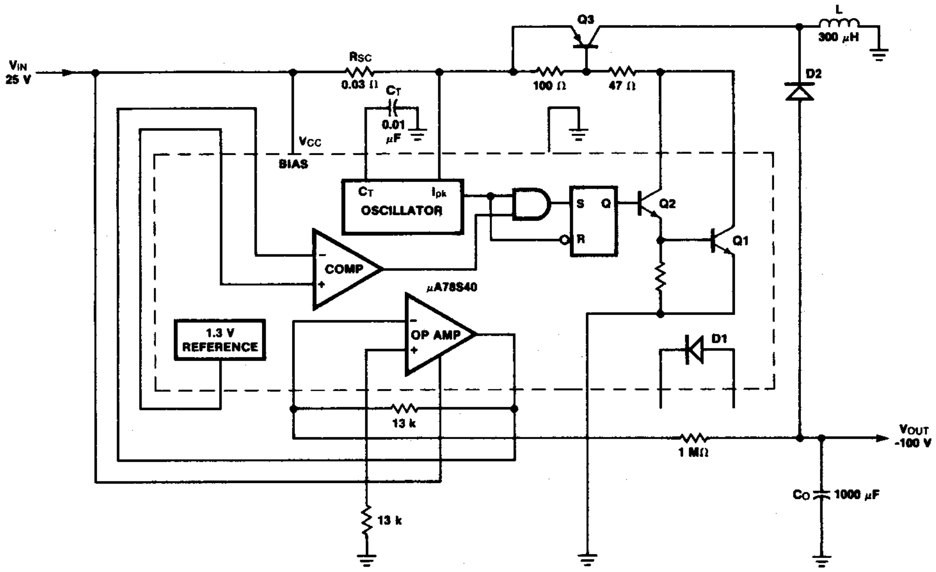


Fig. 3-77. Switching Regulator with 25 V Input, −100 V Output

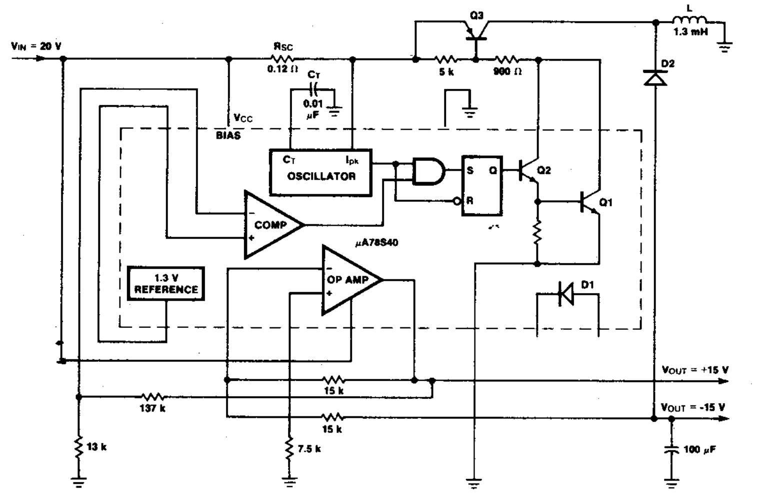


Fig. 3-78. Dual Tracking Supply

power (0.5 A x 30 V). In this case the off-time/on-time ratio is about 4:1, with the off-time at 150 µs and on-time at 38 µs. Output capacitance of 2500 µF keeps output ripple to 100 mV. The external diode (D2) is required to handle the 10 A switching current.

The addition of a boost transistor and a flyback diode to the step-up regulator configuration develops a regulated 70 V, 1 A output, *Figure 3-76*. The Darlington pair switch emitter output provides base drive to the external npn transistor Q3. Output voltage is limited by this transistor and diode breakdown voltages, not by the IC. The base drive to Q3 is limited to 0.5 A by a 27 Ω series resistor on the switch collector. For this situation (15 V in – 70 V, 1 A out) the on/off ratio is 4:1 with on-time at 120 µs and off-time at 30 µs (C_T = 0.01 µF). Average input current is 5.4 A, (1/2 the peak current plus the 0.5 A base drive). Regulator efficiency is 84%, and output ripple is limited to 100 mV by a 1200 µF output capacitor.

A voltage inverting regulator with an external pnp switch (Q3) and an external diode (D2) can generate almost any negative voltage, because the external transistor and diode limit the output voltage, *Figure 3-77*. This particular version provides –100 V at 1 A from a +25 V input. The peak current is 10.5 A, average current is 4.44 A, and the regulator efficiency is 83%. The on-time to off-time ratio is a little more than 4:1, resulting in an off-time of 30 µs and an on-time of 126 µs. A 1000 µF output capacitor limits output ripple to 120 mV.

Figure 3-78 illustrates a dual-tracking regulator that provides both +15 V and –15 V outputs from a single +20 V input. The negative output voltage is generated with an inverter circuit similar to the circuit of *Figure 5*, but the op amp is connected in a gain-of-1 configuration with its output divided down and compared to the 1.3 V reference voltage. As shown, this regulator provides ±15 V at 100 mA with 80% efficiency – 75% positive voltage, 85% negative voltage – with output ripple limited to 30 mV.

A high-output regulator with two outputs is illustrated in *Figure 3-79*. From a single 5 V input voltage, a 12 V and a 15 V output are provided. Two external npn transistors are used; Q3 boosts the step-up function, and Q4 increases the series-pass output to 1 A. A total of 1.5 A is available from the two outputs, with 80% efficiency on the 15 V output and 64% efficiency on the 12 V output.

The final switching regulator variation shown is a negative input/output regulator, *Figure 3-80*. This presents a slightly more difficult challenge, since the reference voltage is referred to a negative input rather than ground. A ground reference of –2.6 V can be generated by using the op amp as a differential amplifier. Then, using a typical step-down regulator configuration, a –48 V input produces a –12 V output at 300 mA with a regulator efficiency of 85%.

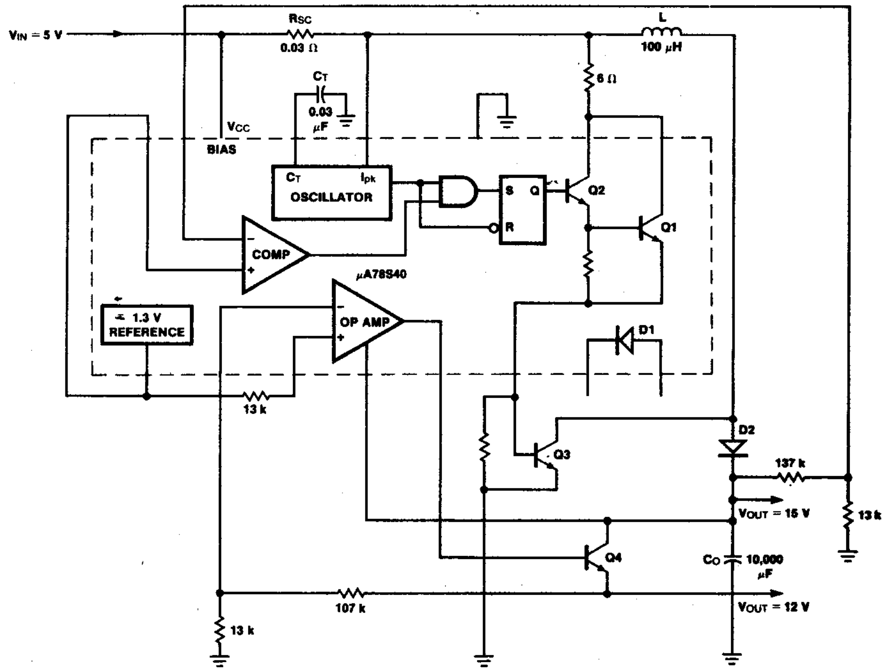


Fig. 3-79. Step-Up and Series-Pass Regulator

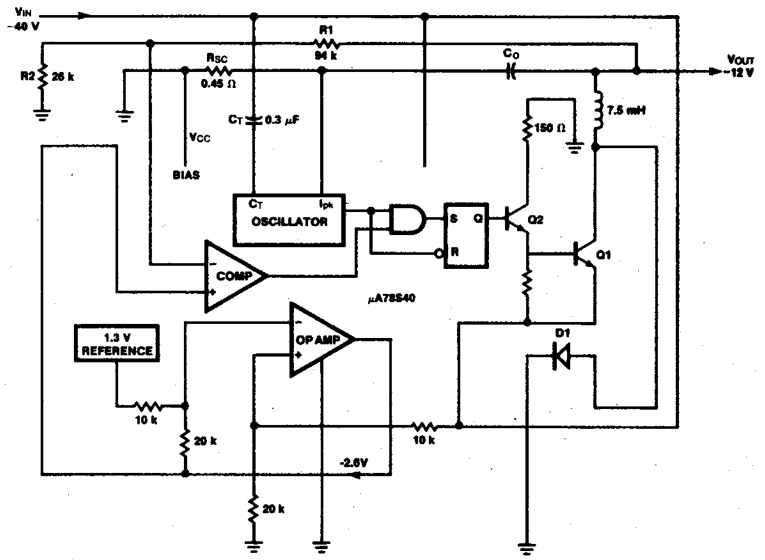


Fig. 3-80. Negative Input/Output Regulator

78S40 Design Formulae

CHARACTERISTIC	STEP DOWN	STEP UP	INVERTING
I_{pk}	$2\ I_{OUT(max)}$	$2\ I_{OUT(max)} \bullet \dfrac{V_{OUT} + V_D - V_S}{V_{IN} - V_S}$	$2\ I_{OUT(max)} \bullet \dfrac{V_{IN} + \lvert V_{OUT} \rvert + V_D - V_S}{V_{IN} - V_S}$
R_{SC} *	$0.33\ V/I_{pk}$	$0.33\ V/I_{pk}$	$0.33\ V/I_{pk}$
t_{on}	$\dfrac{i_{pk} \bullet L}{V_{IN} - V_S - V_{OUT}}$	$\dfrac{i_P \bullet L}{V_{IN} - V_S}$	$\dfrac{I_P \bullet L}{V_{IN} - V_S}$
t_{off}	$\dfrac{I_{pk} \bullet L}{V_{OUT} + V_D}$	$\dfrac{I_{pk} \bullet L}{V_{OUT} + V_D - V_{IN}}$	$\dfrac{I_{pk} \bullet L}{\lvert V_{OUT} \rvert + V_D}$
$\dfrac{t_{on}}{t_{off}}$	$\dfrac{V_{OUT} + V_D}{V_{IN} - V_S - V_{OUT}}$	$\dfrac{V_{OUT} + V_D - V_{IN}}{V_{IN} - V_S}$	$\dfrac{\lvert V_{OUT} \rvert + V_D}{V_{IN} - V_S}$
L *	$\dfrac{V_{OUT} + V_D}{I_{pk}} \bullet t_{off}$	$\dfrac{V_{OUT} + V_D - V_{IN}}{I_{pk}} \bullet t_{off}$	$\dfrac{\lvert V_{OUT} \rvert + V_D}{I_{pk}} \bullet t_{off}$
C_T*(μF)	$45 \times 10^{-5}\ t_{off}(\mu s)$	$45 \times 10^{-5}\ t_{off}(\mu s)$	$45 \times 10^{-5}\ t_{off}(\mu s)$
C_O *	$\dfrac{I_{pk} \bullet (t_{on} + t_{off})}{8\ V_{ripple}}$	$\dfrac{(I_{pk} - I_{OUT})^2 \bullet t_{off}}{2\ I_{pk} \bullet V_{ripple}}$	$\dfrac{(I_{pk} - I_{OUT})^2 \bullet t_{off}}{2\ I_{pk} \bullet V_{ripple}}$
Efficiency	$\dfrac{V_{IN} - V_S + V_D}{V_{IN}} \bullet \dfrac{V_{OUT}}{V_{OUT} + V_D}$	$\dfrac{V_{IN} - V_S}{V_{IN}} \bullet \dfrac{V_{OUT}}{V_{OUT} + V_D - V_S}$	$\dfrac{V_{IN} - V_S}{V_{IN}} \bullet \dfrac{\lvert V_{OUT} \rvert}{\lvert V_{OUT} \rvert + V_D}$
$I_{IN(avg)}$ (Max load condition)	$\dfrac{I_{pk}}{2} \bullet \dfrac{V_{OUT} + V_D}{V_{IN} - V_S + V_D}$	$\dfrac{I_{pk}}{2}$	$\dfrac{I_{pk}}{2} \bullet \dfrac{\lvert V_{OUT} \rvert + V_D}{V_{IN} + \lvert V_{OUT} \rvert + V_D - V_S}$
V_{ripple}	$\dfrac{I_P (t_{on} + t_{off})}{8\ C_O}$	$\dfrac{(I_P - I_{OUT})^2}{2\ I_{pk}} \bullet \dfrac{t_{off}}{C_O}$	$\dfrac{(I_P - I_{OUT})^2}{2\ I_{pk}} \bullet \dfrac{t_{off}}{C_O}$

RESISTOR SELECTION GUIDE

The following table is a quick reference guide for the selection of resistance values for given output voltages. The applicable circuits that can be used with the table are indicated (see Note 1).

OUTPUT VOLTAGE	APPLICABLE CIRCUITS	FIXED OUTPUT ±5%		OUTPUT ADJUSTABLE ±10%		
	(Note 1)	R1	R2	R1	P1	R2
3.0	3-48a 3-48b (3-49a) 3-49b 3-50 3-51b (3-52a) (3-52b) 3-55a 3-55b	4.12	3.01	1.8	0.5	1.2
3.6		3.57	3.65	1.5	0.5	1.5
5.0		2.15	4.99	.75	0.5	2.2
6.0		1.15	6.04	0.5	0.5	2.7
9.0	3-48c 3-49a (3-49b) (3-50) 3-51a 3-52a 3-52b	1.87	7.15	.75	1.0	2.7
12		4.87	7.15	2.0	1.0	3.0
15		7.87	7.15	3.3	1.0	3.0
28		21.0	7.15	5.6	1.0	2.0
45	3-53	3.57	48.7	2.2	10	39
75	3-63	3.57	78.7	2.2	10	68

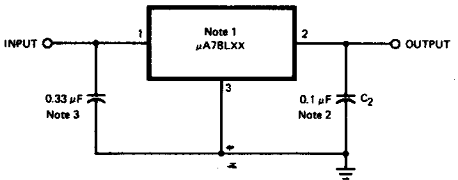
OUTPUT VOLTAGE	APPLICABLE CIRCUITS	FIXED OUTPUT ±5%		OUTPUT ADJUSTABLE ±10%		
		R1	R2	R1	P1	R2
100	3-53	3.57	102	2.2	10	91
250	3-63	3.57	255	2.2	10	240
−6 (Note 2)	3-56a 3-56b	3.57	2.43	1.2	0.5	.75
−9	3-56b	3.48	5.36	1.2	0.5	2.0
−12	3-57	3.57	8.45	1.2	0.5	3.3
−15	3-58	3.65	11.5	1.2	0.5	4.3
−28	3-59	3.57	24.3	1.2	0.5	10
−45	3-60	3.57	41.2	2.2	10	33
−100		3.57	97.6	2.2	10	91
−250		3.57	249	2.2	0	240

NOTES:
1. Circuits in parenthesis may be used if R1/R2 divider is placed on opposite side of error amplifier.
2. V^+ must be conncted to a +2.5 V or greater supply.

TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED POSITIVE 3-TERMINAL REGULATORS – μA78L00 SERIES

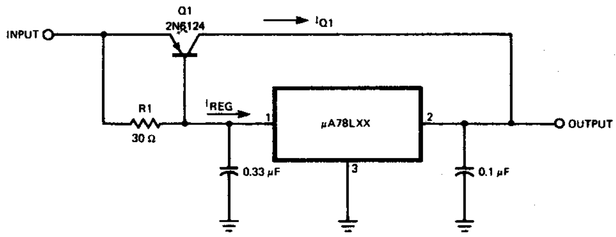
FIXED OUTPUT REGULATOR



NOTES:

1. To specify an output voltage, substitute voltage value for "XX".
2. Although no output capacitor is needed for stability, it does improve transient response.
3. Required if regulator is located an appreciable distance from power supply filter.

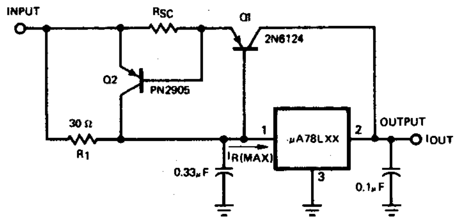
HIGH CURRENT VOLTAGE REGULATOR



For $I_{REG} \approx 23$ mA

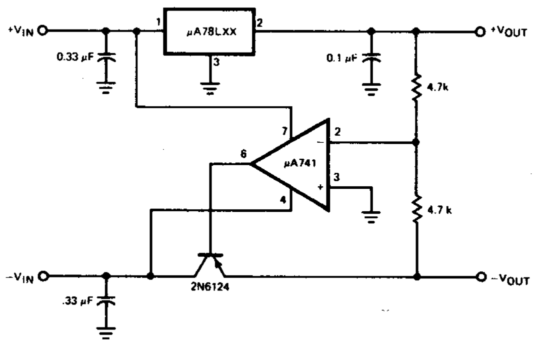
$I_{REG} = \frac{0.7}{R1}$ $\quad I_{Q1} = \beta I_{REG}$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED

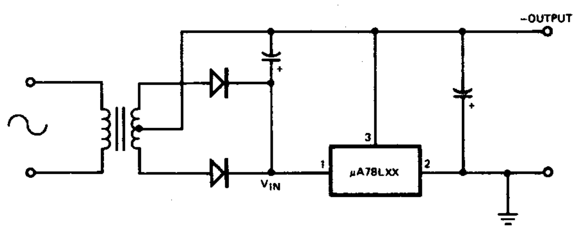


$R_{SC} = \frac{0.7}{I_{SC}}$ $\quad R1 = \frac{\beta V_{BE\,(Q2)}}{I_{R(MAX)}(\beta+1) - I_{OUT(MAX)}}$

±TRACKING VOLTAGE REGULATOR



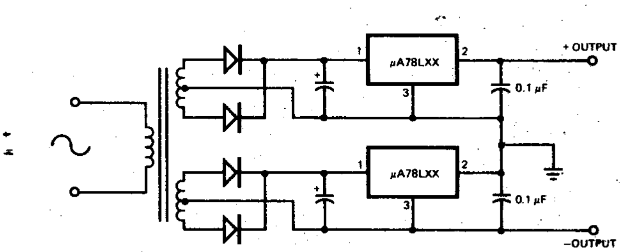
NEGATIVE OUTPUT VOLTAGE CIRCUIT



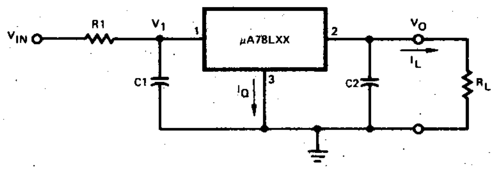
TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED POSITIVE 3-TERMINAL REGULATORS – μA78L00 SERIES

POSITIVE AND NEGATIVE REGULATOR



HIGH DISSIPATION APPLICATIONS



When it is necessary to operate a μA78L00 regulator with a large input-output differential voltage, the addition of series resistor R1 will extend the output current range of the device by sharing the total power dissipation between R1 and the regulator.

R1 may be calculated from

$$R1 = \frac{V_{IN(MIN)} - V_{OUT} - 2.0\text{ V}}{I_{L(MAX)} + I_Q}$$

where I_Q is the regulator quiescent current.

Regulator power dissipation at maximum input voltage and maximum load current is now

$$P_{D(MAX)} = (V_1 - V_{OUT})\, I_{L(MAX)} + V_1\, I_Q$$

where

$$V_1 = V_{IN(MAX)} - (I_{L(MAX)} + I_Q)\, R1$$

The presence of R1 will affect load regulation according to the equation:

load regulation (at constant V_{IN}) = load regulation (at constant V_1) + (line regulation, mV per V) x (R1) x (ΔI_L).

As an example, consider a 15 V regulator with a supply voltage of 30 ±5 V, required to supply a maximum load current of 30 mA. I_Q is 4.3 mA, and minimum load current is to be 10 mA.

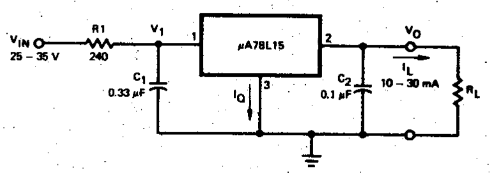
$$R1 = \frac{25 - 15 - 2}{30 + 4.3} = \frac{8}{34.3} \cong 240\ \Omega$$

$$V_1 = 35 - (30 + 4.3).24 = 35 - 8.2 = 26.8\text{ V}$$

$$P_{D(MAX)} = (26.8 - 15)\, 30 + 26.8\, (4.3)$$

$= 354 + 115$

$=$ 470 mW, which will permit operation up to 70°C in most applications.



Line regulation of this circuit is typically 110 mV for an input range of 25-35 V at a constant load current, i.e. 11 mV/V.

Load regulation = constant V_1 load regulation (typically 10 mV, 10-30 mA I_L)

+ (11 mV/V) x 0.24 x 20 mA (typically 53 mV)

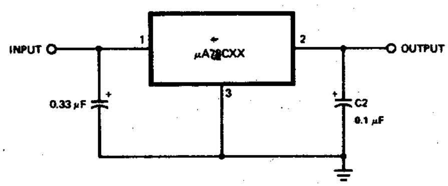
= 63 mV for a load current change of 20 mA at a constant V_{IN} of 30 V.

TYPICAL VOLTAGE REGULATOR APPLICATIONS

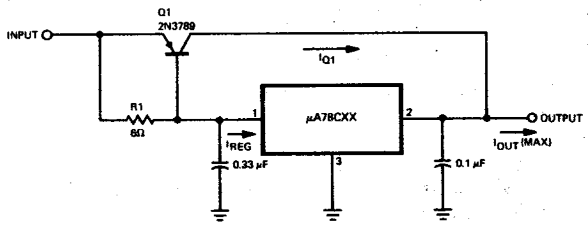
FIXED POSITIVE 3-TERMINAL REGULATORS – μA78C00 SERIES

In many μA78C00 applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33 μF and 0.1 μF, respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

FIXED OUTPUT REGULATOR



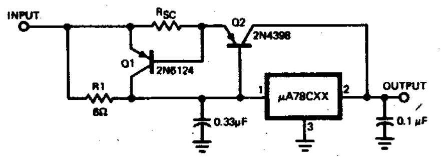
HIGH CURRENT VOLTAGE REGULATOR



$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}(\beta + 1) - I_{OUT}(MAX)}$$

$$\beta_{Q1} > \frac{I_{OUT}}{I_{REG}}$$

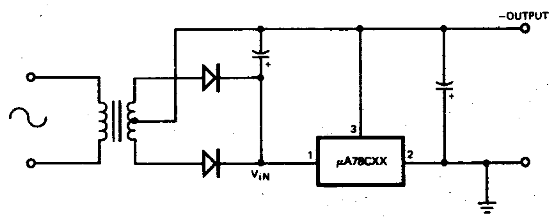
HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



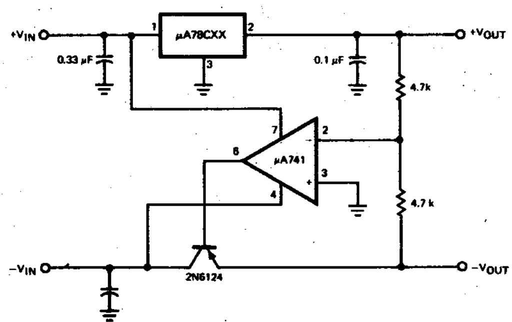
$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}(\beta + 1) - I_{OUT}(MAX)}$$

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{OUT}}$$

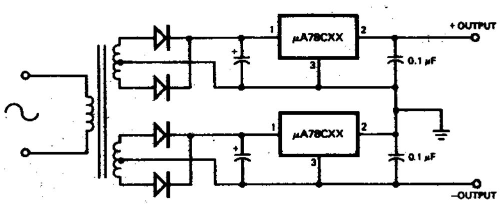
NEGATIVE OUTPUT VOLTAGE CIRCUIT



±TRACKING VOLTAGE REGULATOR



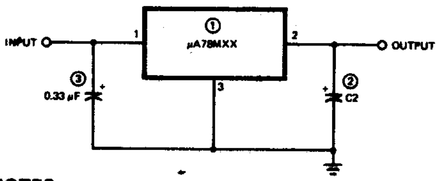
POSITIVE AND NEGATIVE REGULATOR



TYPICAL VOLTAGE REGULATOR APPLICATIONS

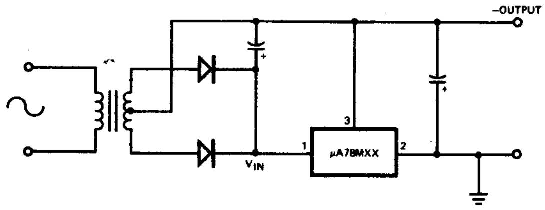
FIXED POSITIVE 3-TERMINAL REGULATORS — μA78M00 SERIES

FIXED OUTPUT REGULATOR

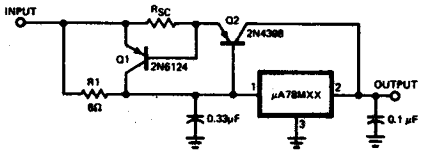


NOTES:
① To specify an output voltage, substitue voltage value for "XX".
② Although no output capacitor is needed for stability, it does improve transient response.
③ Required if regulator is located an appreciable distance from power supply filter.

NEGATIVE OUTPUT VOLTAGE CIRCUIT



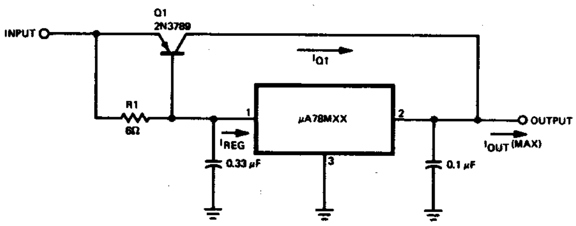
HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



$$R1^* = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\,(\beta + 1) - I_{OUT}(MAX)}$$

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{OUT}}$$

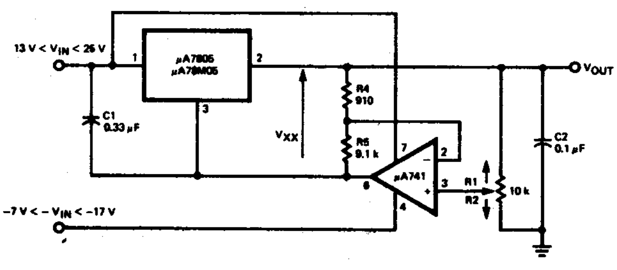
HIGH CURRENT VOLTAGE REGULATOR



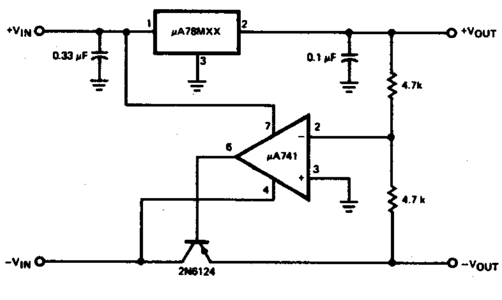
$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\,(\beta + 1) - I_{OUT}(MAX)}$$

$$\beta_{Q1} > \frac{I_{OUT}}{I_{REG}}$$

VARIABLE OUTPUT VOLTAGE, 0.5 TO 10 V



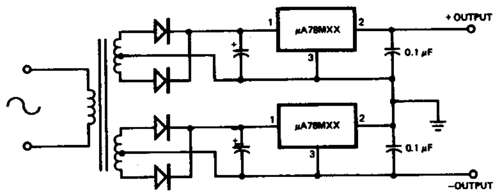
±TRACKING VOLTAGE REGULATOR



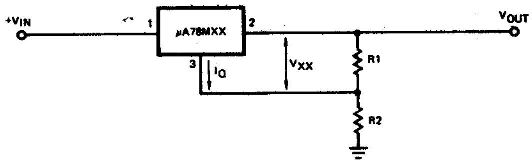
TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED POSITIVE 3-TERMINAL REGULATORS — μA78M00 SERIES

POSITIVE AND NEGATIVE REGULATOR

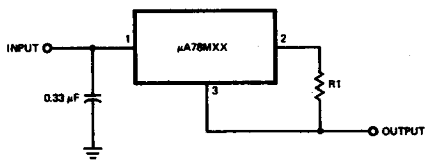


CIRCUIT FOR INCREASING OUTPUT VOLTAGE



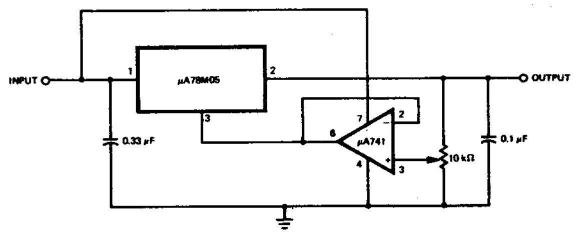
$$V_{OUT} = V_{XX}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

CURRENT REGULATOR



$$\text{Output Current} = \frac{V_{OUT}}{R1}$$

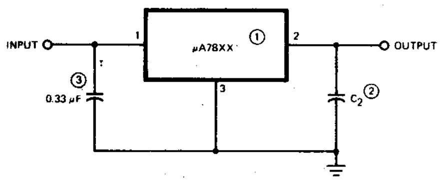
ADJUSTABLE OUTPUT REGULATOR, 7 V TO 30 V



TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED POSITIVE 3-TERMINAL REGULATORS – μA7800 SERIES

FIXED OUTPUT REGULATOR



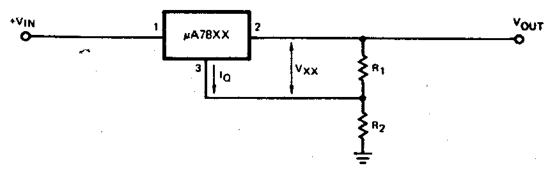
NOTES:

① To specify an output voltage, substitute voltage for "XX".

② Although no output capacitor is needed for stability, it does improve transient response.

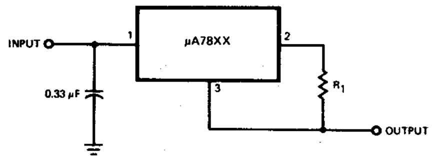
③ Required if regulator is located an appreciable distance from power supply filter.

CIRCUIT FOR INCREASING OUTPUT VOLTAGE



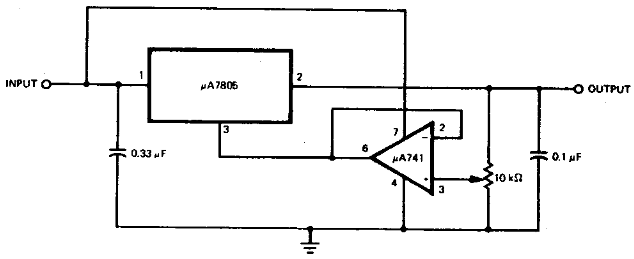
$$V_{OUT} = V_{XX}\left(1 + \frac{R_2}{R_1}\right) + I_Q R_2$$

CURRENT REGULATOR

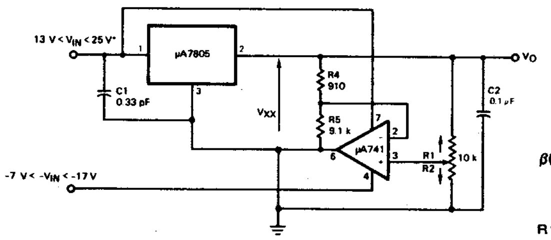


$$\text{Output Current} = \frac{V_{OUT}}{R_1}$$

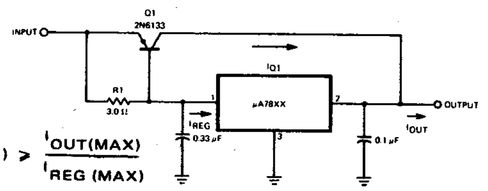
ADJUSTABLE OUTPUT REGULATOR, 7 TO 30 VOLTS



0.5 TO 10 V REGULATOR



HIGH CURRENT VOLTAGE REGULATOR



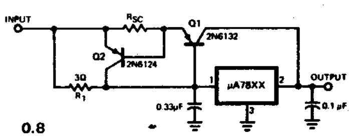
$$\beta(Q1) > \frac{I_{OUT(MAX)}}{I_{REG\,(MAX)}}$$

$$R1 = \frac{0.9}{I_{REG}} = \frac{\beta(Q1)\, V_{BE(Q1)}}{I_{REG(MAX)}\,(\beta+1) - I_{OUT(MAX)}}$$

TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED POSITIVE 3-TERMINAL REGULATORS — μA7800 SERIES

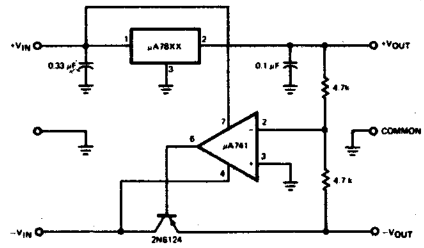
HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



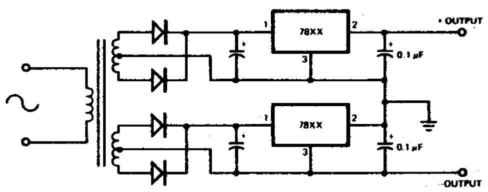
$$R_{SC} = \frac{0.8}{I_{SC}}$$

$$R1 = \frac{\beta V_{BE\,(Q1)}}{I_{REG(MAX)}\,(\beta+1) - I_{OUT(MAX)}}$$

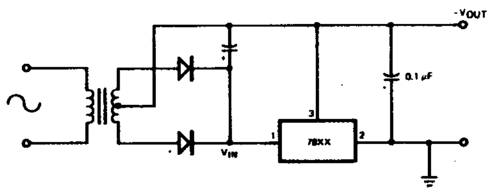
±TRACKING VOLTAGE REGULATOR



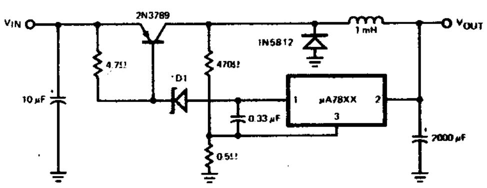
POSITIVE AND NEGATIVE REGULATOR



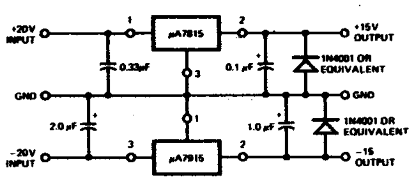
NEGATIVE OUTPUT VOLTAGE CIRCUIT



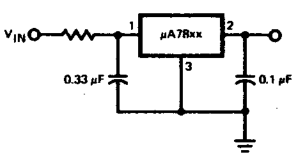
SWITCHING REGULATOR

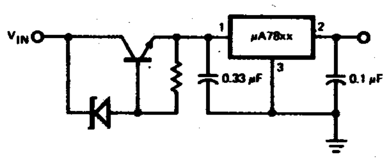


DUAL SUPPLY OPERATIONAL AMPLIFIER SUPPLY (±15 V @ 1.0 A)



HIGH INPUT VOLTAGE CIRCUITS

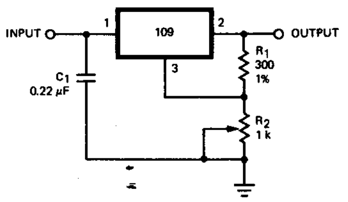




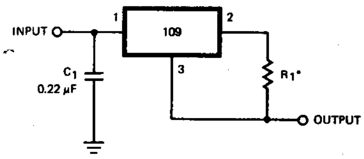
TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED POSITIVE 3-TERMINAL REGULATORS — μA109 SERIES

ADJUSTABLE OUTPUT REGULATOR

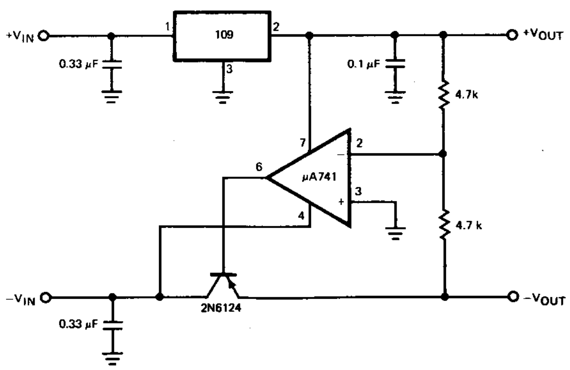


CURRENT REGULATOR

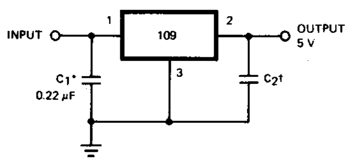


NOTE: *Determines output current.

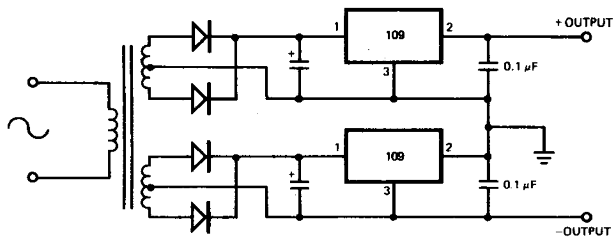
TRACKING VOLTAGE REGULATOR



FIXED 5 V REGULATOR



POSITIVE AND NEGATIVE REGULATOR



NOTES:

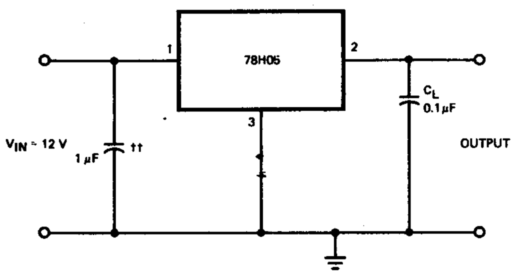
Required if regulator is located an appreciable distance from power supply filter.

†Although no output capacitor is needed for stability, it does improve transient response.

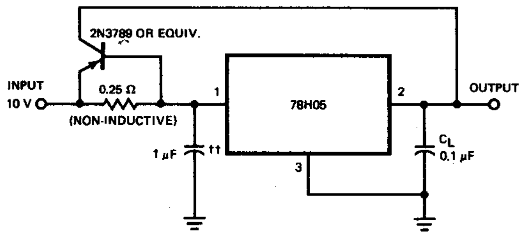
TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED POSITIVE 3-TERMINAL REGULATORS — 78H05 SERIES

5 AMP REGULATOR

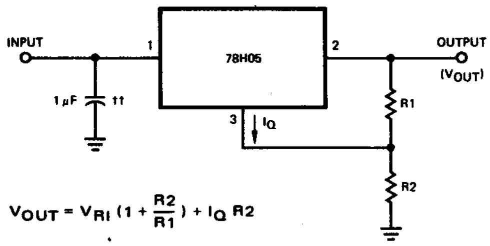


10+ AMP REGULATOR



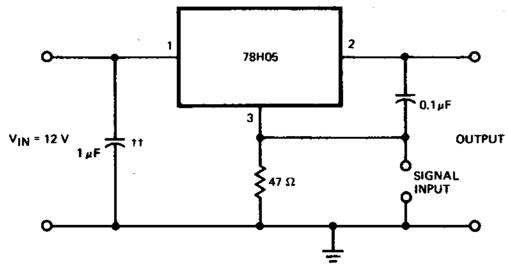
NOTES:
a. No current limit in effect
b. At 10 A out 78H05 passes 4.0 A
c. For 10 A output change, V_{OUT} changes approx. 80 mV

INCREASED OUTPUT VOLTAGE



$$V_{OUT} = V_{R1}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

SIGNAL DRIVER/MODULATOR



††Required if regulator is located an appreciable distance from power supply filter.

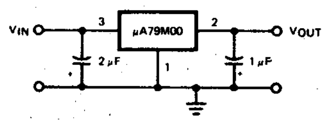
TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED NEGATIVE 3-TERMINAL REGULATORS — μA79M00 SERIES

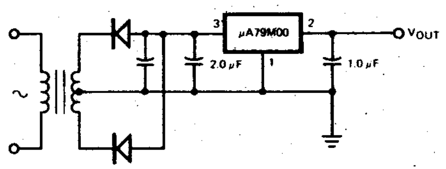
Bypass capacitors are recommended for stable operation of the 79M00 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (2 μF on the input, 1 μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10 μF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

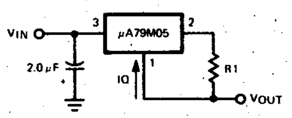
FIXED OUTPUT REGULATOR



NEGATIVE OUTPUT VOLTAGE CIRCUIT

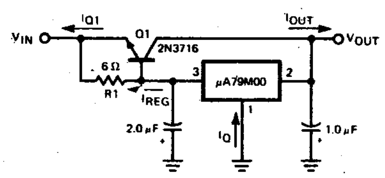


BASIC CURRENT REGULATOR



$$\text{OUTPUT CURRENT} = \frac{5.0\ \text{V}}{R1} + I_Q$$

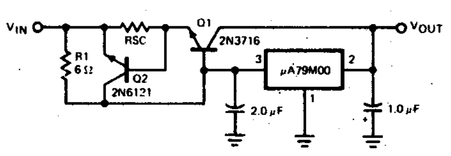
HIGH CURRENT VOLTAGE REGULATOR



$$I_{Q1} = \beta(Q1) I_{REG}$$

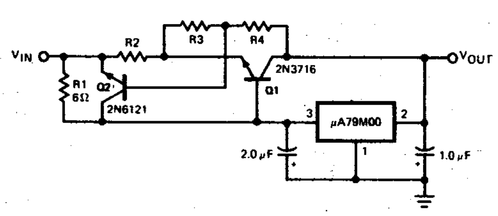
$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\,(\beta+1) - I_{OUT}(MAX)}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\,(\beta+1) - I_{OUT}(MAX)} \qquad R_{SC} = \frac{V_{BE(Q2)}}{I_{SC}}$$

HIGH OUTPUT CURRENT, FOLDBACK CURRENT LIMITED

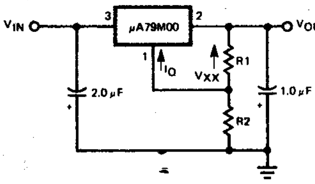


$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\,(\beta+1) - I_{OUT}(MAX)}$$

TYPICAL VOLTAGE REGULATOR APPLICATIONS

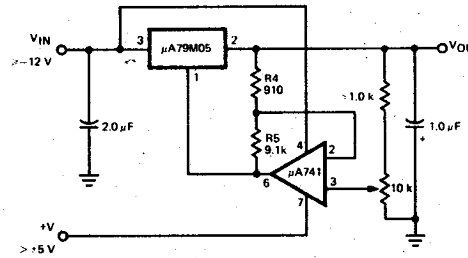
FIXED NEGATIVE 3-TERMINAL REGULATORS — μA79M00 SERIES

VARIABLE OUTPUT VOLTAGE REGULATOR

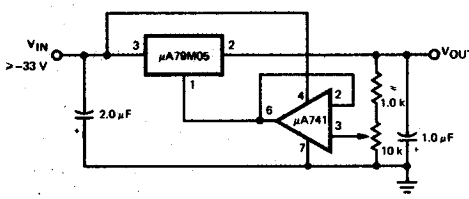


$$\left|V_{OUT}\right| = V_{XX}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

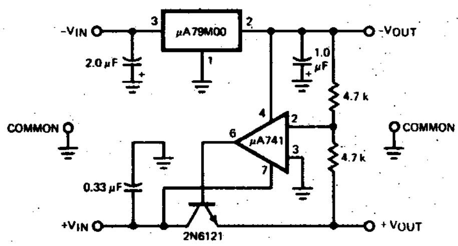
VARIABLE OUTPUT VOLTAGE, −0.5 V TO −10V



VARIABLE OUTPUT VOLTAGE, −30 V TO −7 V



POSITIVE AND NEGATIVE TRACKING VOLTAGE REGULATOR



3

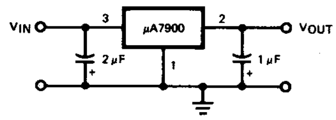
TYPICAL VOLTAGE REGULATOR APPLICATIONS

FIXED NEGATIVE 3-TERMINAL REGULATORS – µA7900 SERIES

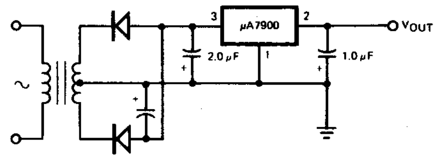
Bypass capacitors are recommended for stable operation of the µA7900 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (2 µF on the input, 1 µF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10 µF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

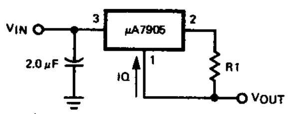
FIXED OUTPUT REGULATOR



NEGATIVE OUTPUT VOLTAGE CIRCUIT

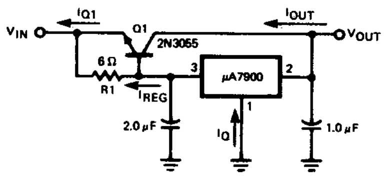


BASIC CURRENT REGULATOR



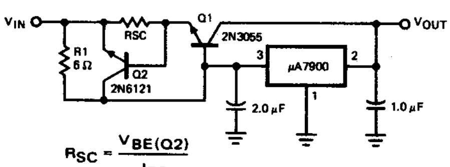
$$\text{OUTPUT CURRENT} = \frac{5.0\ \text{V}}{R1} + I_Q$$

HIGH CURRENT VOLTAGE REGULATOR



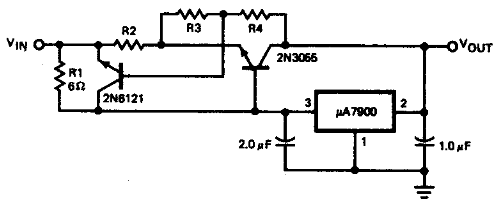
$$R1 = \frac{V_{BE(Q1)}}{I_{REG}} \qquad I_{Q1} = \beta(Q1) I_{REG}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



$$R_{SC} = \frac{V_{BE(Q2)}}{I_{SC}}$$

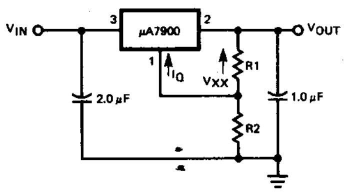
HIGH OUTPUT CURRENT, FOLDBACK CURRENT LIMITED



TYPICAL VOLTAGE REGULATOR APPLICATIONS

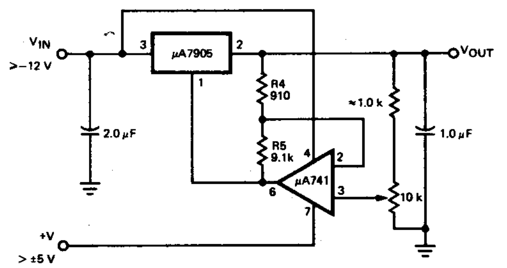
FIXED NEGATIVE 3-TERMINAL REGULATORS — μA7900 SERIES

VARIABLE OUTPUT VOLTAGE REGULATOR

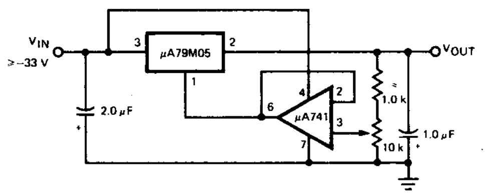


$$|V_{OUT}| = V_{XX}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

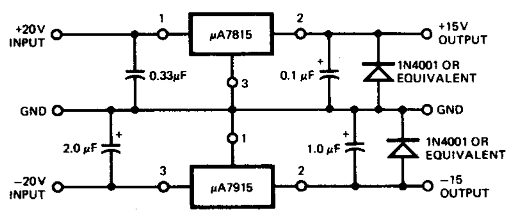
VARIABLE OUTPUT VOLTAGE, −0.5 V TO −10 V



VARIABLE OUTPUT VOLTAGE, −30 V TO −7 V



OPERATIONAL AMPLIFIER SUPPLY (±15 V @ 1.0 A)

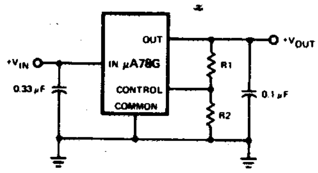


TYPICAL VOLTAGE REGULATOR APPLICATIONS

ADJUSTABLE POSITIVE 4-TERMINAL REGULATORS – μA78G SERIES

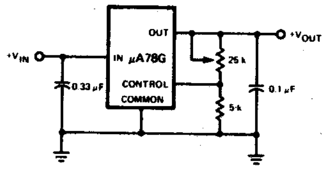
In many μA78G applications, compensation capacitors may be be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33 μF and 0.1 μF, respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

BASIC POSITIVE REGULATOR

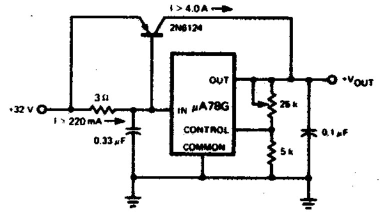


$$V_{OUT} = V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR

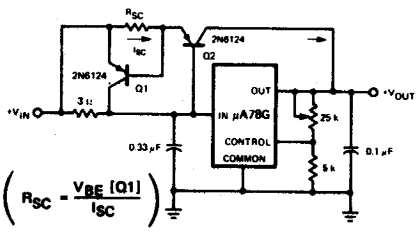


POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR $I_{OUT} > 5.0$ A



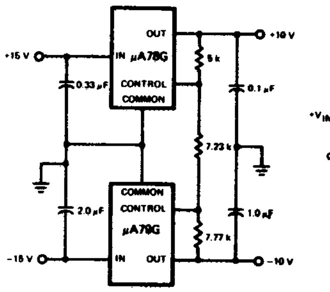
NOTE: External series pass device is not short circuit protected.

POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



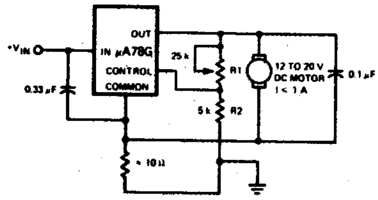
$$\left(R_{SC} = \frac{V_{BE}\,[Q1]}{I_{SC}}\right)$$

±10 V, 500 mA DUAL TRACKING REGULATOR



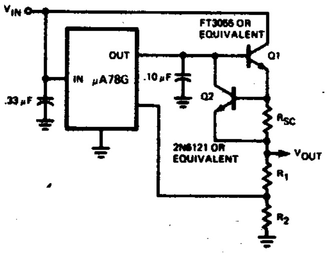
If load is not ground referenced, connect reverse biased diodes from outputs to ground.

MOTOR SPEED CONTROL

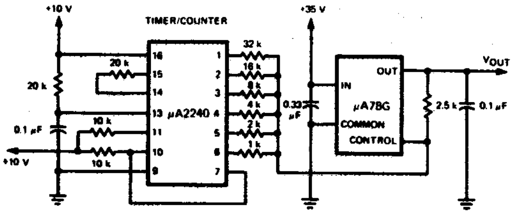


Use flyback diode across motor if necessary.

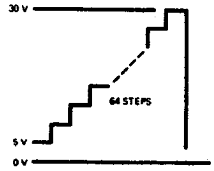
POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



PROGRAMMABLE SUPPLY



OUTPUT WAVEFORM



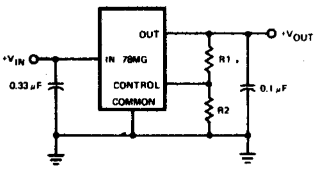
TYPICAL VOLTAGE REGULATOR APPLICATIONS

ADJUSTABLE POSITIVE 4-TERMINAL REGULATORS – μA78MG SERIES

In many μA78MG applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33 μF and 0.1 μF, respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

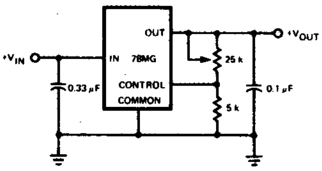
3

BASIC POSITIVE REGULATOR

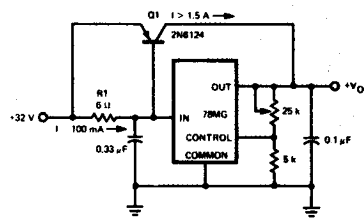


$$V_{OUT} = V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR



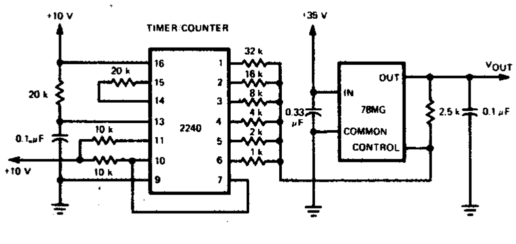
POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR $I_{OUT} > 1.5$ A



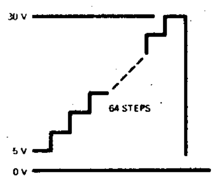
$$R1 = \frac{\beta V_{BE(Q1)}}{I_{R(MAX)}(\beta) - I_{OUT(MAX)}}$$

NOTE: External series pass device is not short circuit protected.

PROGRAMMABLE SUPPLY



OUTPUT WAVEFORM

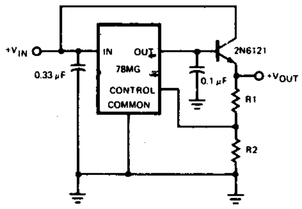


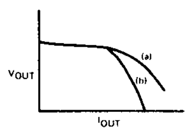
TYPICAL VOLTAGE REGULATOR APPLICATIONS

ADJUSTABLE POSITIVE 4-TERMINAL REGULATORS – μA78MG SERIES

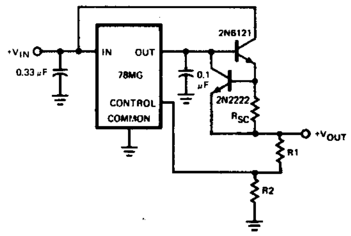
POSITIVE HIGH CURRENT VOLTAGE REGULATOR

EXTERNAL SERIES PASS (a)

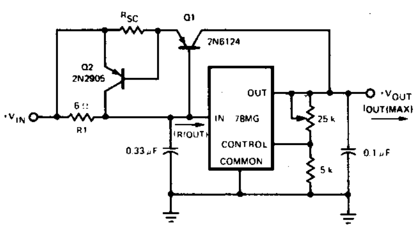




SHORT CIRCUIT LIMIT (b)

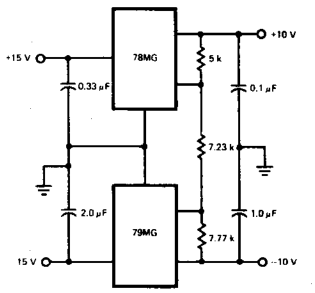


POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



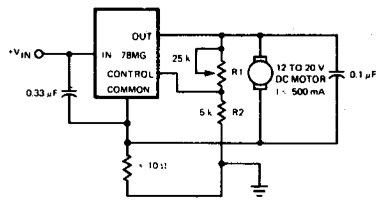
$$R1 = \frac{\beta V_{BE(Q1)}}{V_{R(MAX)}\,(\beta+1) - I_{OUT(MAX)}}$$

±10 V, 1.0 A DUAL TRACKING REGULATOR



If load is not ground referenced, connect reverse biased diodes from outputs to ground.

MOTOR SPEED CONTROL

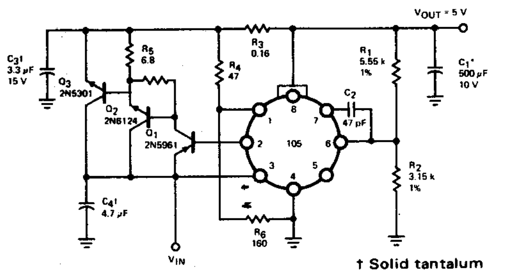


Use flyback diode across motor if necessary.

TYPICAL VOLTAGE REGULATOR APPLICATIONS

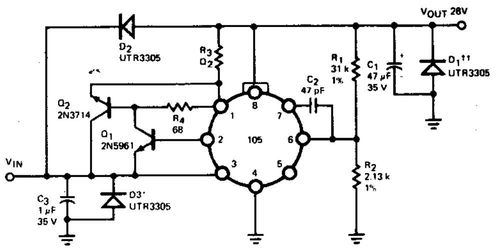
ADJUSTABLE POSITIVE REGULATORS — μA105 SERIES

10 A REGULATOR WITH FOLDBACK CURRENT LIMITING



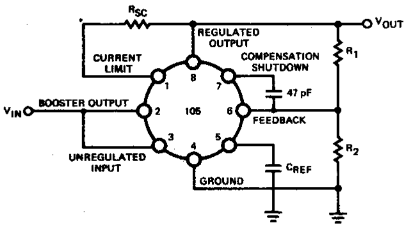
† Solid tantalum
* Electrolytic

1.0 A REGULATOR WITH PROTECTIVE DIODES



* Protects against input voltage reversal
†† Protects against output voltage reversal
† Protects against shorted input or inductive loads on unregulated supply

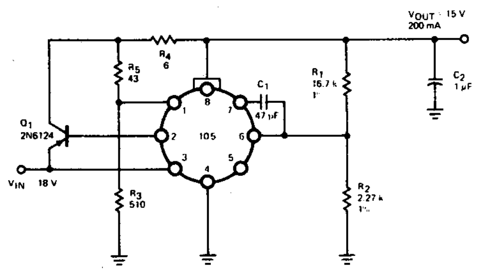
BASIC POSITIVE REGULATOR WITH CURRENT LIMITING



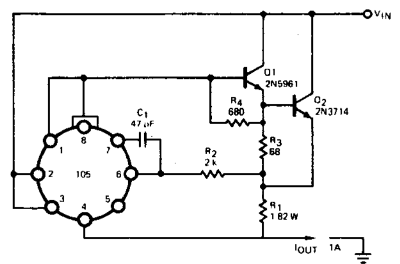
$$V_{OUT} \approx 1.72 \frac{R_1 + R_2}{R_2} V$$

$$I_{SC} \approx \frac{V_{SENSE}}{R_{SC}} mA$$

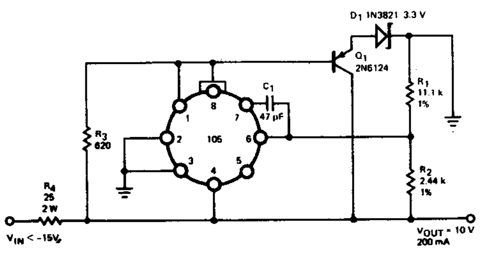
LINEAR REGULATOR WITH FOLDBACK CURRENT LIMITING



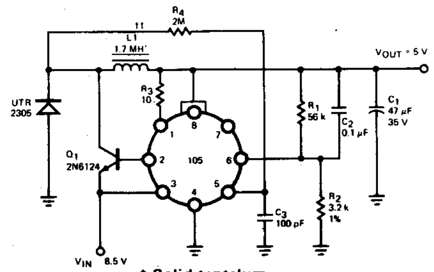
CURRENT REGULATOR



SHUNT REGULATOR



SWICHING REGULATOR



† Solid tantalum
†† 125 turns #22 on Arnold Engineering A262123-2 molybdenum permalloy core.

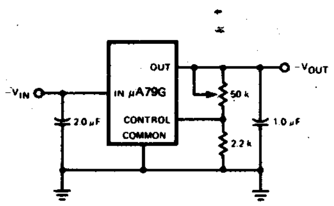
3

TYPICAL VOLTAGE REGULATOR APPLICATIONS

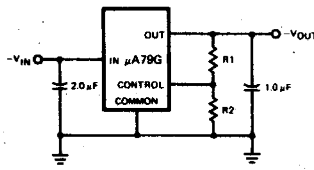
ADJUSTABLE NEGATIVE 4-TERMINAL REGULATORS – µA79G SERIES

All µA78G applications apply to the µA79G under the following conditions; R2 values are 2.2 kΩ, all external transistors and diodes reverse polarity.

−30 V TO −2.2 V ADJUSTABLE REGULATOR

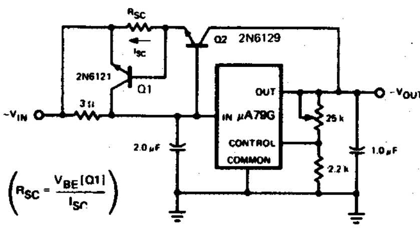


BASIC NEGATIVE REGULATOR

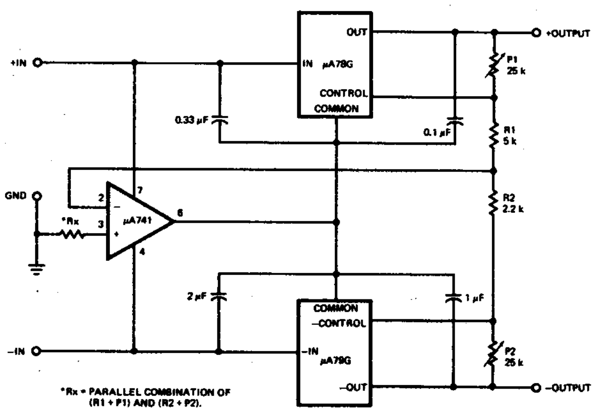


$$V_{OUT} = -V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

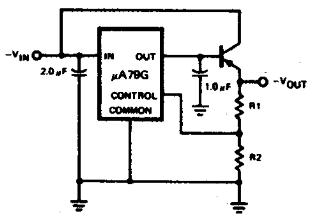
NEGATIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



ADJUSTABLE DUAL TRACKING REGULATOR



NEGATIVE HIGH CURRRENT VOLTAGE REGULATOR EXTERNAL SERIES PASS



NOTE:

Bypass capacitors are recommended for stable operation of the µA79G series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (2 µF on the input, 1 µF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10 µF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

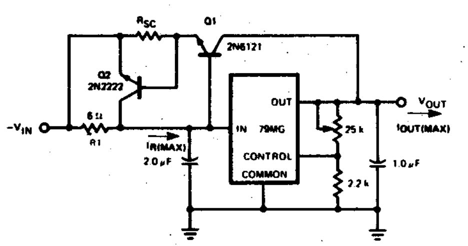
TYPICAL VOLTAGE REGULATOR APPLICATIONS

ADJUSTABLE NEGATIVE 4-TERMINAL REGULATORS — μA79MG SERIES

Bypass capacitors are recommended for stable operation of the μA79MG over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

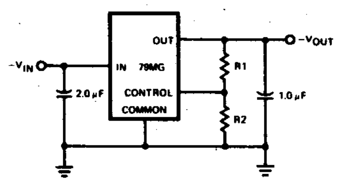
The bypass capacitors, (2 μF on the input, 1 μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10 μF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

NEGATIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



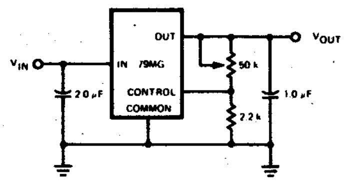
$$R1 = \frac{\beta V_{BE(Q1)}}{I_{R\,(MAX)}\,(\beta) - I_{OUT(MAX)}}$$

BASIC NEGATIVE REGULATOR

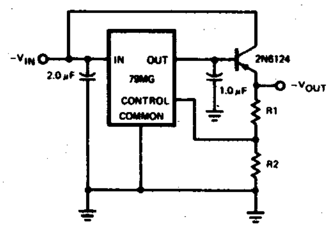


$$V_{OUT} = -V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

−30 V TO −2.2 V ADJUSTABLE REGULATOR



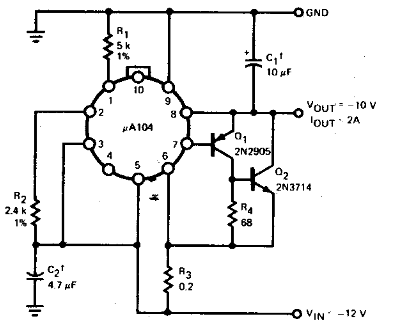
NEGATIVE HIGH CURRENT VOLTAGE REGULATOR EXTERNAL SERIES PASS



TYPICAL VOLTAGE REGULATOR APPLICATIONS

ADJUSTABLE NEGATIVE REGULATORS – μA104 SERIES

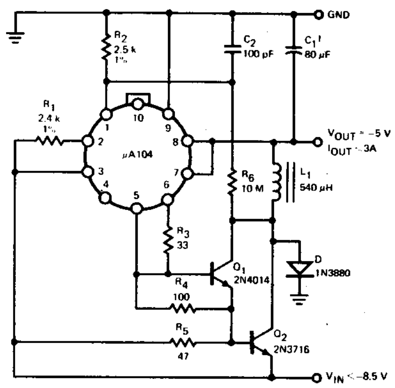
HIGH CURRENT REGULATOR



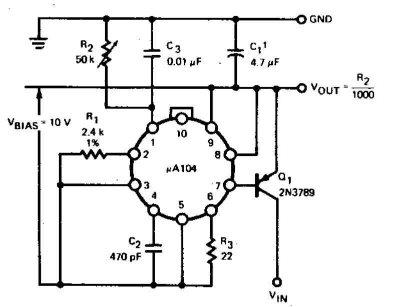
†Solid Tantalum

SWITCHING REGULATOR

†Solid Tantalum
*60 Turns #20 on Arnold Engineering A930157-2 Molybdenum Permalloy Core.



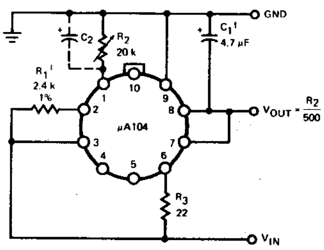
OPERATING WITH SEPARATE BIAS SUPPLY



†Solid Tantalum

BASIC REGULATOR CIRCUIT

†Solid Tantalum
‡Trim R1 for exact scale factor

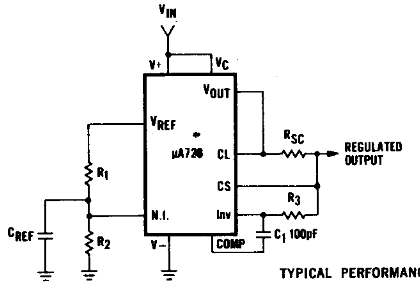


NOTE 1: A 0.01 μF capacitor may be required across the input if long leads are used from the unregulated power source. Line transient response, noise and ripple rejection can be improved by shunting R2 with a 10 μF capacitor C2.

TYPICAL VOLTAGE REGULATOR APPLICATIONS

PRECISION REGULATORS – μA723 SERIES

BASIC LOW VOLTAGE REGULATOR
(V_{OUT} = 2 TO 7 V)

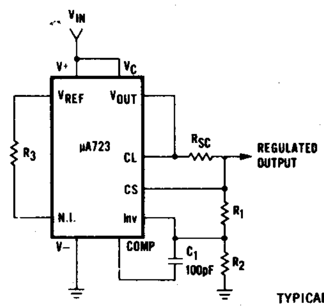


TYPICAL PERFORMANCE

Regulated Output Voltage	5 V
Line Regulation (ΔV_{IN} = 3 V)	0.5 mV
Load Regulation (ΔI_L=50 mA)	1.5 mV

Note: $R_3 = \frac{R_1 R_2}{R_1+R_2}$ for minimum temperature drift.

BASIC HIGH VOLTAGE REGULATOR
(V_{OUT} = 7 TO 37 V)



TYPICAL PERFORMANCE

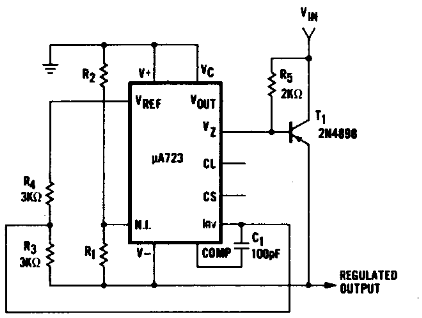
Regulated Output Voltage	15 V
Line Regulation (ΔV_{IN} = 3 V)	1.5 mV
Load Regulation (ΔI_L=50 mA)	4.5 mV

Note: $R_3 = \frac{R_1 R_2}{R_1+R_2}$ for minimum temperature drift.

R_3 may be eliminated for minimum component count.

3

NEGATIVE VOLTAGE REGULATOR

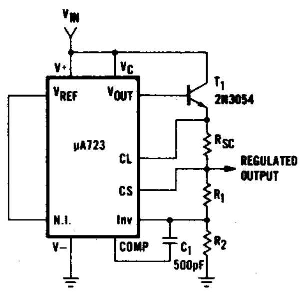


(NOTE 1)

TYPICAL PERFORMANCE

Regulated Output Voltage	–15 V
Line Regulation (ΔV_{IN} = 3 V)	1 mV
Load Regulation (ΔI_L = 100 mA)	2 mV

POSITIVE VOLTAGE REGULATOR
(External NPN Pass Transistor)



TYPICAL PERFORMANCE

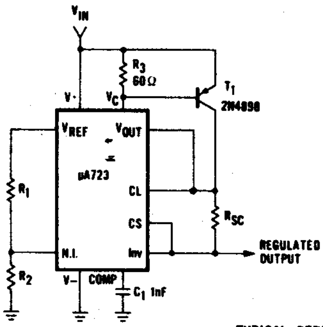
Regulated Output Voltage	+15 V
Line Regulation (ΔV_{IN} = 3 V)	1.5 mV
Load Regulation (ΔI_L = 1 A)	15 mV

NOTE 1: For metal can applications where V_Z is required, an external 6.2 V Zener diode should be connected in series with V_{OUT}.

TYPICAL VOLTAGE REGULATOR APPLICATIONS

PRECISION REGULATORS – μA723 SERIES

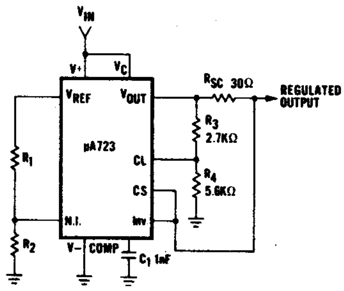
POSITIVE VOLTAGE REGULATOR (External NPN Pass Transistor)



TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation ($\Delta V_{IN} = 3$ V)	0.5 mV
Load Regulation ($\Delta I_L = 1$ A)	5 mV

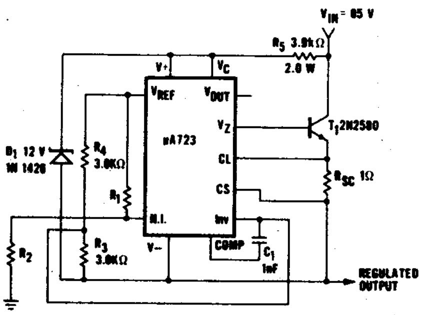
FOLDBACK CURRENT LIMITING



TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation ($\Delta V_{IN} = 3$ V)	0.5 mV
Load Regulation ($\Delta I_L = 10$ mA)	1 mV
Short Circuit Current	20 mA

POSITIVE FLOATING REGULATOR

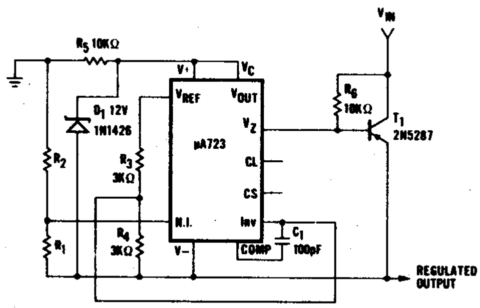


TYPICAL PERFORMANCE

Regulated Output Voltage	+50 V
Line Regulation ($\Delta V_{IN} = 20$ V)	15 mV
Load Regulation ($\Delta I_L = 50$ mA)	20 mV

(NOTE 1)

NEGATIVE FLOATING REGULATOR



TYPICAL PERFORMANCE

Regulated Output Voltage	−100 V
Line Regulation ($\Delta V_{IN} = 20$ V)	30 mV
Load Regulation ($\Delta I_L = 100$ mA)	20 mV

(NOTE 1)

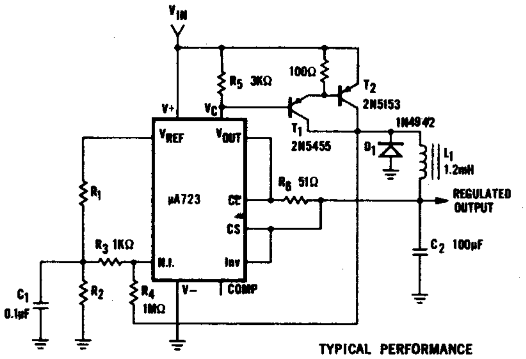
NOTES:

1. For metal can applications where V_Z is required, an external 6.2 V Zener diode should be connected in series with V_{OUT}.

TYPICAL VOLTAGE REGULATOR APPLICATIONS

PRECISION REGULATORS — μA723 SERIES

POSITIVE SWITCHING REGULATOR

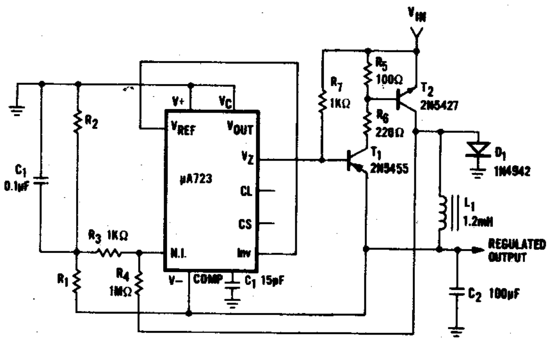


TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 30 V)	10 mV
Load Regulation (ΔI_L = 2 A)	80 mV

NOTE 1

NEGATIVE SWITCHING REGULATOR

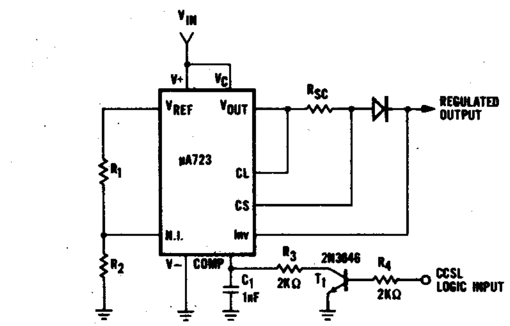


TYPICAL PERFORMANCE

Regulated Output Voltage	−15 V
Line Regulation (ΔV_{IN} = 20 V)	8 mV
Load Regulation (ΔI_L = 2 A)	6 mV

(NOTE 2)

REMOTE SHUTDOWN REGULATOR WITH CURRENT LIMITING



Current limit transistor may be used for shutdown if current limiting is not required.

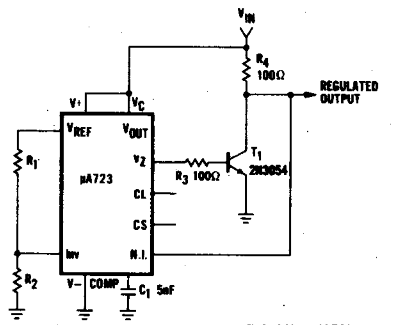
Add if Vout > 10V

TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 3 V)	0.5 mV
Load Regulation (ΔI_L=50 mA)	1.5 mV

NOTE 1

SHUNT REGULATOR

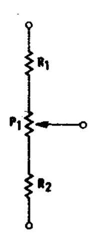


TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 10 V)	0.5 mV
Load Regulation (ΔI_L = 100 mA)	1.5 mV

(NOTE 2)

OUTPUT VOLTAGE ADJUST

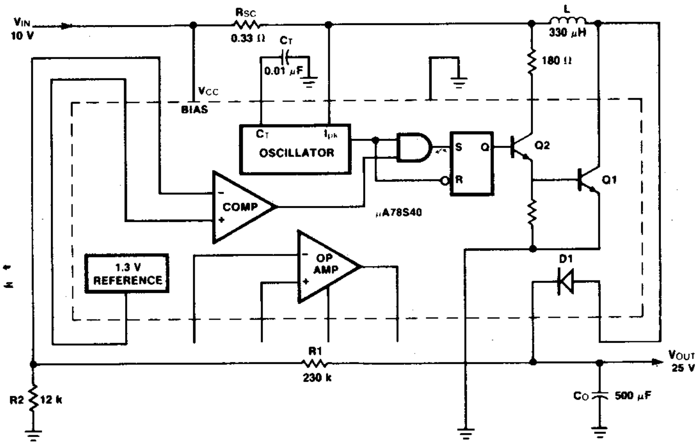


NOTES:

1. L_1 is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 pot core or equivalent with 0.009" air gap.
2. Figures in parentheses may be used if R1/R2 divider is placed on opposite side of error amp.

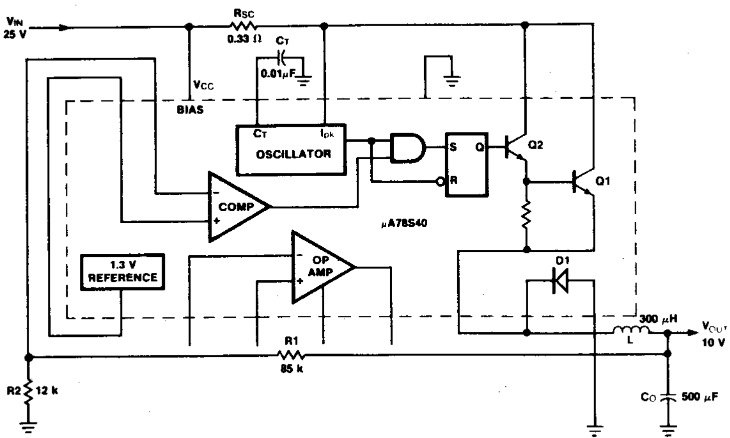
TYPICAL VOLTAGE REGULATOR APPLICATIONS

SWITCHING REGULATORS — μA78S40 SERIES



TYPICAL STEP-UP OPERATIONAL PERFORMANCE
$T_A = 25°C$

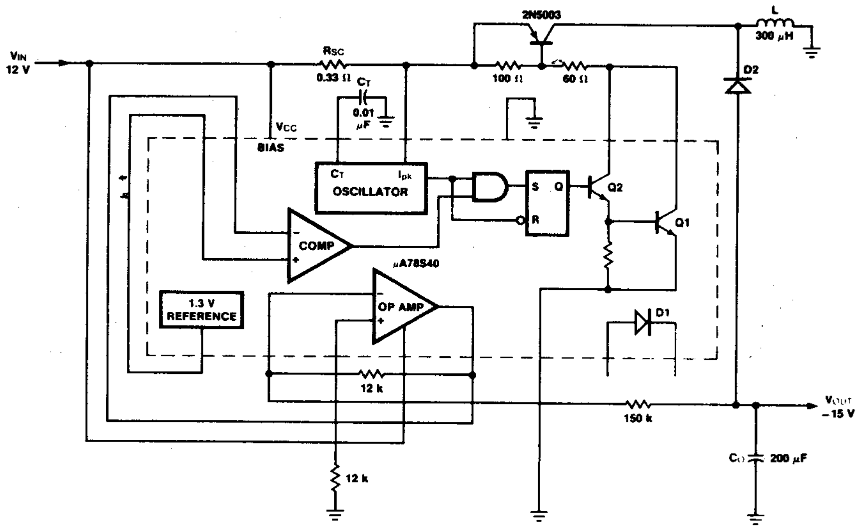
CHARACTERISTIC	CONDITION	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 50$ mA	25V
LINE REGULATION	$5V \leq V_{IN} \leq 15V$	4.0 mV
LOAD REGULATION	5 mA $\leq I_{OUT} \leq$ 100 mA	2.0 mA
MAX OUTPUT CURRENT	$V_{OUT} = 23.75$	160 mA
OUTPUT RIPPLE	$I_{OUT} = 50$ mA	30 mV
EFFICIENCY	$I_{OUT} = 50$ mA	79%
STANDBY CURRENT	$I_{OUT} = 50$ mA	2.6 mA



TYPICAL STEP-DOWN PERFORMANCE
TA = 25°

CHARACTERISTIC	CONDITION	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 200$ mA	10 V
LINE REGULATION	$20 \leq V_{IN} \leq 30$ V	1.5 mV
LOAD REGULATION	5 mA $\leq I_{OUT} \leq$ 300 mA	3.0 mV
MAX OUTPUT CURRENT	$V_{OUT} = 9.5$ V	500 mA
OUTPUT RIPPLE	$I_{OUT} = 200$ mA	50 mV
EFFICIENCY	$I_{OUT} = 200$ mA	74%
STANDBY CURRENT		2.8 mA

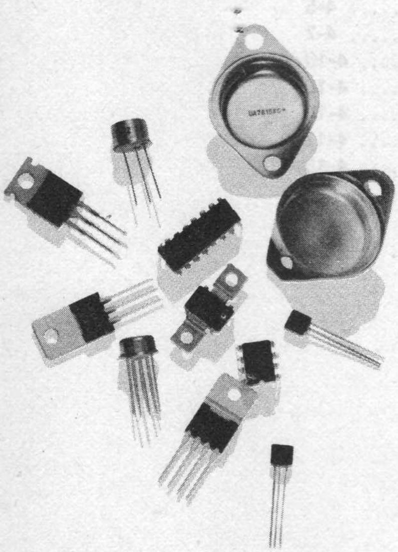
SWITCHING REGULATORS — μA78S40 SERIES



TYPICAL INVERSION OPERATIONAL PERFORMANCE

$T_A = 25°$

CHARACTERISTIC	CONDITIONS	TYPICAL VALUE
OUTPUT VOLTAGE	I_{OUT} = 100 mA	−15 V
LINE REGULATION	8 V ≤ V_{IN} ≤ 18 V	5.0 mV
LOAD REGULATION	5 mA ≤ I_{OUT} ≤ 150 mA	3.0 mV
MAX OUTPUT CURRENT	V_{OUT} = 14.25 V	160 mA
OUTPUT RIPPLE	I_{OUT} = 100 mA	20 mV
EFFICIENCY	I_{OUT} = 100 mA	70%
STANDBY CURRENT		2.3 mA



SELECTION GUIDES AND INDUSTRY CROSS REFERENCE

VOLTAGE REGULATORS 1

TESTING AND RELIABILITY 2

APPLICATIONS 3

POWER SUPPLY DESIGN 4

POWER TRANSISTORS 5

THERMAL CONSIDERATIONS 6

PRODUCT INFORMATION 7

DEFINITIONS, ORDERING INFORMATION AND PACKAGE OUTLINES 8

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POWER SUPPLY DESIGN

Chapter 4
POWER SUPPLY DESIGN

A power supply normally operates from an ac line. Therefore, this ac input voltage must be converted to unregulated dc by some form of rectifier/filter combination and then to regulated dc using a voltage regulator. This chapter discusses the performance characteristics of the most common forms of rectifier/filter combinations and provides appropriate design equations for any output voltage and current.

DEFINITION OF TERMS

Parameter	Definition
V_M	peak input voltage
V_O	dc output voltage
V_{pk}	transformer peak voltage
V_S	ac input voltage
F	form factor of the load current: I_{rms}/I_O
I_{ac}	effective value of all alternating components of load current, *i.e.*, the current reading on an ac meter
I_M	peak current through each rectifier
I_O	average value of the load current, the reading on a dc meter
I_{rms}	effective value of the total load current $\sqrt{I_{ac}^2 + I_O^2}$
P_{in}	ac input power
P_O	dc output power
R_L	load resistance
R_S	total series resistance, or the source resistance plus any added resistance plus the diode series resistance
γ	ripple factor in all charts normalized as 100% equal to 1, $\gamma = (F^2-1) = \left[\left(\frac{I_{rms}}{I_O}\right)^2 - 1\right]^{1/2}$
ηR	rectification efficiency, $\frac{P_O}{P_{in}} \times 100\%$
ω	$2\pi f$ where f = line frequency

SINGLE PHASE, HALF WAVE RECTIFIER

Figure 4-1 is a half wave rectifier and capacitor filter. Without the capacitor, peak current is

$$I_M = \frac{V_M}{R_S + R_L}$$

on the positive half cycle (or forward conduction cycle) of the input voltage. Some additional electrical characteristics follow.

$$I_{rms} = \frac{I_M}{2} \qquad I_O = \frac{I_M}{\pi} \qquad P_O = \frac{1}{\pi^2}\left(\frac{V_M{}^2 R_L}{(R_S+R_L)^2}\right) \qquad \eta R = \frac{40.6}{\left(1+\frac{R_S}{R_L}\right)}\ \% \qquad \gamma = 1.21$$

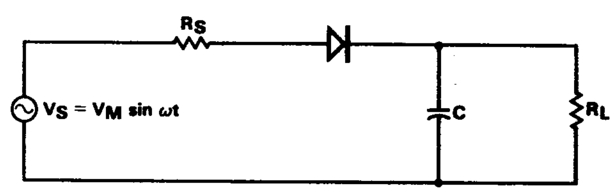


Fig. 4-1. Half-Wave Rectifier Circuit with Capacitive Filtering

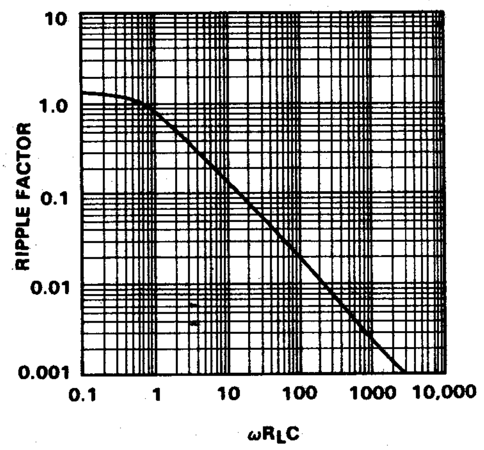


Fig. 4-2. Ripple Factor vs $\omega R_L C$

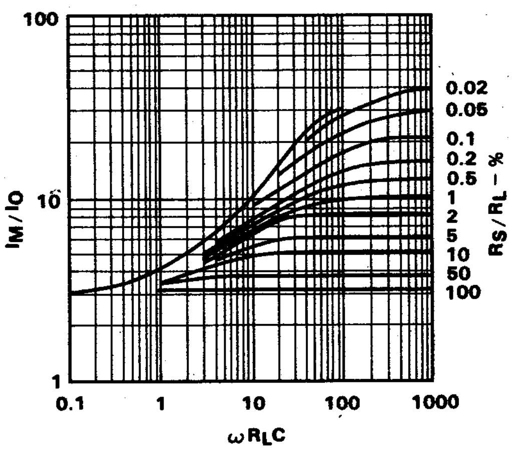


Fig. 4-3. I_M/I_O vs $\omega R_L C$

Note that for a resistive load, the maximum ripple factor is 121% which, under most circumstances, requires filtering. When the capacitor is added across the load resistor, the ripple is reduced proportionate to the $R_L C$ product (*Figure 4-2*).

One possible problem with any capacitive filter is the high peak current drawn due to the diode back-bias present throughout most of the input cycle. This is a result of the voltage stored across the filter capacitor. The rectifier conducts only during that short period of time when the input voltage exceeds the capacitor voltage by one diode drop. During conduction, the rectifier must supply the capacitor with sufficient energy to hold the ripple within specification until the next conduction cycle. *Figure 4-3* is a plot of the I_M/I_O ratio versus the $R_L C$ product with the R_S/R_L ratio as a variable. Notice that the surge-to-dc ratio of current increases as a function of both increasing capacitor value and of a reduced source-to-load impedance ratio.

When the ripple factor, load impedance, and ω are known, the required capacitance can be determined from *Figure 4-2*. Because of the high turn-on surge, an external series limiting resistor is normally needed. *Figure 4-4* is a plot of the dc-to-peak voltage ratio with the filter product as the X axis and the source/load impedance ratio as the third parameter. Note that the dc output-to-peak input voltage ratio approaches unity as the filter factor goes up and also as the source-to-load impedance ratio decreases. Because of the relatively large value of the filter capacitor required for a given ripple factor, the use of the half-wave capacitor filter is usually limited to low current applications such as the subsidiary power supply for the μA723 in a floating regulator configuration.

HALF WAVE RECTIFIER WITH SERIES INDUCTIVE FILTER

Figure 4-5 is a half-wave rectifier with series inductive filtering. The inductor, in series with the load, prevents any rapid changes in the current flow and thus reduces the ripple factor by acting as an energy storage device. When the current flow is above the average current required, energy is stored in the inductor, and when the current is below the average, the stored energy is released. *Figure 4-6* is the plot of ripple factor versus filter product for the inductor input filter. Because of the energy storage available with an inductor, the peak current through the rectifier is little more than the average current. However, the peak inverse voltage PIV seen by the rectifier is simply V_M, the peak input voltage. *Figure 4-7* is a plot of V_O/V_M ratio as a function of the inductor filter product.

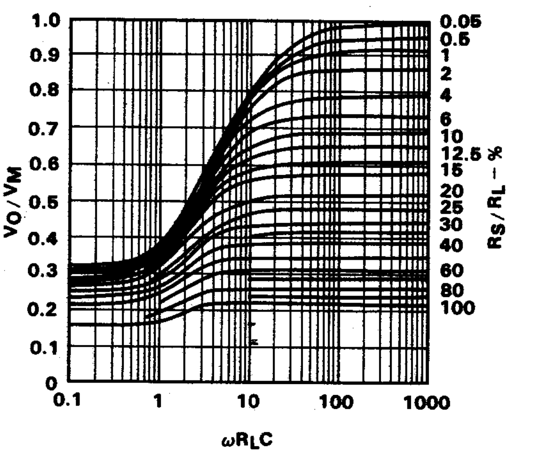


Fig. 4-4. DC-to-Peak Ratio

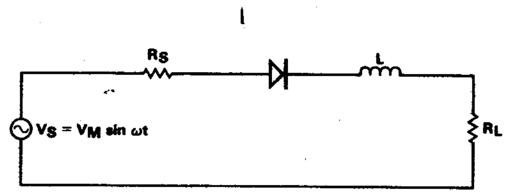


Fig. 4-5. Half-Wave Rectifier

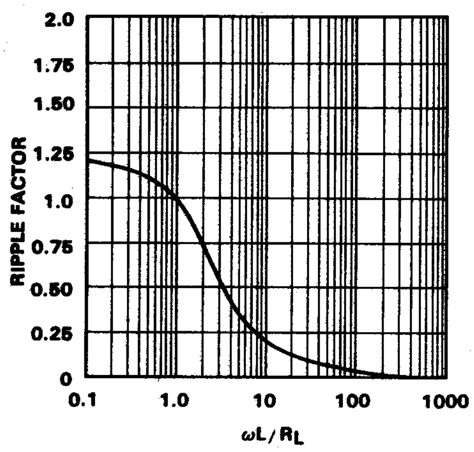


Fig. 4-6. Ripple Factor vs Filter Product

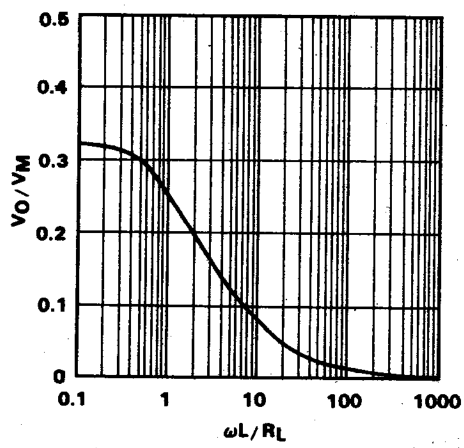


Fig. 4-7. V_O/V_M Ratio

SINGLE-PHASE FULL-WAVE RECTIFIER

Figure 4-8, a basic full wave rectifier, has the following electrical characteristics.

$$I_{rms} = \frac{I_M}{\sqrt{2}} \qquad I_O = \frac{2I_M}{\pi} \qquad P_O = \left(\frac{2}{\pi}\right)^2 \frac{V_M{}^2 R_L}{(R_S+R_L)^2} \qquad \eta R = \frac{81.2}{\left(1+\frac{R_S}{R_L}\right)}\ \% \qquad \gamma = 0.48$$

There are two interesting features. Efficiency has doubled, as can be expected when doubling the number of rectifiers. In addition, the ripple factor has decreased from 121% to 48% in comparison with the half-wave circuit. Even with ripple reduction, a 48% factor is normally too high to be useful and must be filtered. *Figure 4-9* is the filter product plot for both capacitive and inductive filters, assuming $R_S << R_L$. High peak currents are always associated with capacitive filters and *Figure 4-10* plots the ratio of peak-to-dc current as a function of the filter product. The relationship between the filter product, the R_S/R_L ratio and the dc output-to-peak input voltage is given in *Figure 4-11* for the capacitive input filter. Load regulation may also be determined from *Figure 4-11* by using the high and low limits for R_L.

Design Example

For a full-wave circuit with the following requirements,

$V_O = 20\ V$

$I_O = 1\ A$

$\gamma < 0.1$

with $R_S = 1\ \Omega$

proceed with the following steps.

Step 1 Find the filter product from *Figure 4-9*

for $\gamma < 0.1. (\omega R_L C = 10)$

Step 2 Calculate R_L

$$R_L = \frac{20}{1} = 20\ \Omega$$

Step 3 Calculate C

$$C = \frac{10}{\omega R_L} = \frac{10}{120 \times 20\pi} = \frac{1}{240\pi} = 1300\ \mu F$$

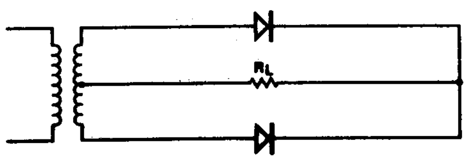


Fig. 4-8. Basic Full-Wave Rectifier

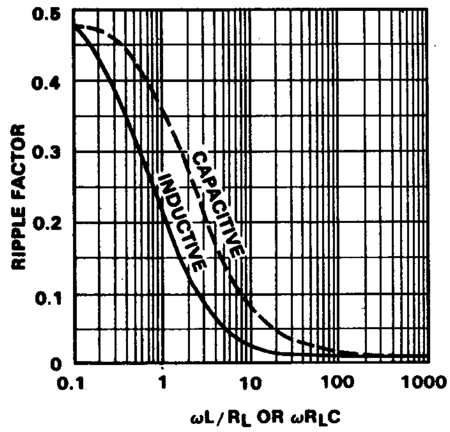


Fig. 4-9. Filter Product

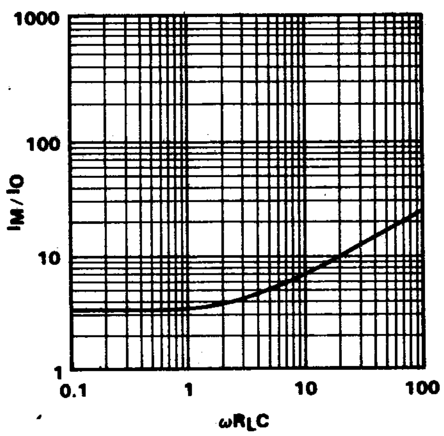


Fig. 4-10. Peak-to-DC Ratio

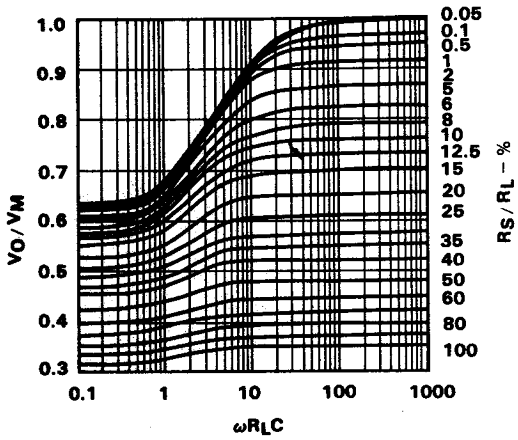


Fig. 4-11. Load Regulation

Step 4 Calculate $\frac{R_S}{R_L}$

$$\frac{R_S}{R_L} = \frac{1}{20} = 5\%$$

Step 5 Find the transformer peak input voltage from the following.

V_{pk} = diode forward voltage. One diode forward-voltage drop for a center-tapped full-wave input, two diode forward-voltage drops for a full-wave bridge

$$+ \frac{\Delta V_O}{V_O/V_M}$$

using the filter values from *Figure 4-11*.

$V_{pk} = 0.7 + \frac{.20}{0.82}$ (intersection of $5\%\ \frac{R_S}{R_L}$ and $\omega R_L C = 10$ from *Figure 4-11*.

$V_{pk} = 0.7 + 25.3 = 26$ V peak or
52 V pk-pk or
18.6 V_{rms}

Step 6 Check peak diode current from *Figure 4-10*. For this example at a filter product of 10, the peak current is seven times the dc current, or 7 A.

LC SECTION FILTER

The LC section filter is one method of reducing ripple levels without the need for single, large value filter components. The basic circuit is shown in *Figure 4-12*. As a general rule, the capacitive reactance should always be less than 10% of the load resistance at the second harmonic of the incoming frequency. All the succeeding information is based upon this ratio. The ripple factor for an L-section filter has the form:

4

$$\gamma = \frac{0.47}{4\omega^2 LC - 1}$$

or, if n L-section filters are cascaded, then the ripple factor is:

$$\gamma = \frac{0.47}{(4\omega^2 L1C1 - 1)(4\omega^2 L2C2 - 1) - (4\omega^2 L_nC_n - 1)}$$

Figure 4-13 is a plot of the filter factor versus the ω^2LC product. The one additional requirement is continuous current flow through the inductance. This says, in effect, that there is a critical inductor size. To assure this continuous current flow, a bleeder resistor R_K must be used at the filter output. The critical

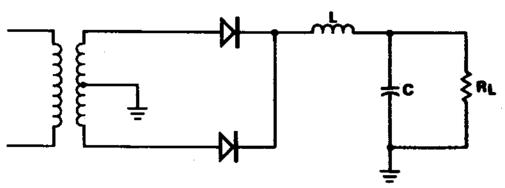


Fig. 4-12. LC Filter

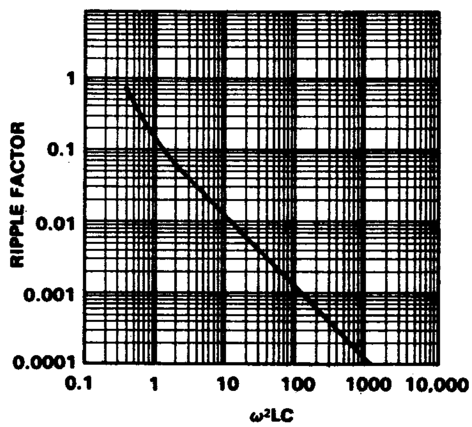


Fig. 4-13. Filter Factor vs ω^2 LC

value of inductance is

$$L_C = \frac{R_S + R_{eff}}{3\omega} \quad \text{where} \quad R_{eff} = \frac{R_K R_{L(max)}}{R_K + R_{L(max)}} \quad \text{and} \quad R_K = \frac{V_O}{I_K}$$

Bleeder current I_K may be assumed to be 10% of minimum load current or, if this is not a practical value, then some reasonable minimum bleeder current is selected. Once the critical inductance is found, then the capacitor value may be determined by the following steps: Set $L = 2\ L_C$. Determine ω^2LC from *Figure 4-13* for the required ripple factor. Solve for C from $\omega^2LC = X$, where X is the product from *Figure 4-13.*

The peak rectifier currents depend upon the size of the inductor selected such that if $L = L_C$ then $I_M = 2\ I_L$ and if $L = 2\ L_C$ then $I_M = 1.5\ I_L$. The transformer secondary voltage is given by

$$V_{rms} = 1.11 \left[V_O + R_S\,(I_{L(max)} + I_K)\right]$$

and the minimum PIV for the rectifier is 1.57 $V_{O(max)}$ for a full-wave bridge rectifier.

For minimum power dissipation, R_K should be as large as possible. In some cases, since the value of critical inductance is proportional to the value of the bleeder resistor, the selection of a high value results in an inductance too large to be practical. In this case, a swinging choke or a choke whose inductance decreases with increasing current flow is needed.

Design Example

Full wave, single-section, choke input filter design,

$V_O = 50$ V $\quad I_K = 100$ mA $\quad \gamma = 1\%$

$I_O = 1$ A $\quad R_S = 10\ \Omega$

Step 1 Calculate R_K

$$R_K = \frac{V_O}{I_K} = \frac{50\text{ V}}{100\text{ mA}} = 500\ \Omega$$

Step 2 Calculate R_{eff}

$$R_{eff} = \frac{R_K R_{L(max)}}{R_K + R_{L(max)}} = 500\ \Omega\ (R_{L(max)} = \infty)$$

Step 3 Calculate L_C

$$L_C = \frac{R_{eff} + R_S}{3\omega} = \frac{500 + 10}{1130} = \frac{510}{1130} \cong 0.5\text{ H}$$

Step 4 Calculate C

$$\gamma = 0.01$$

then, $\omega^2 L_C C = 12$ from *Figure 4-13*

$$C = \frac{12}{\omega^2 L_C} = \frac{12}{(120\pi)^2 0.5} = \frac{12}{142 \times 10^3 \times 0.5} =$$

$$0.169 \times 10^{-3} = 169\ \mu\text{F}$$

Step 5 Calculate I_M

Since $L = L_C$

then $I_M = 2\ (I_O + I_K)$

$I_M = 2 \times 1.1 = 2.2$ A

Step 6 Calculate voltage drop both at no load and full load

V_D no load $= I_K\ (R_S) = 0.1 \times 10 = 1$ V

V_D full load $= (I_O + I_K)\ R_S = 1.1 \times 10 = 11$ V

Step 7 Calculate transformer minimum rms voltages

$$V_{rms} = 1.11 \left[V_O + R_S\,(I_{O(max)} + I_K)\right]$$

$$V_{rms} = 1.11\ (50 + 10 \times 1.1)$$

$$V_{rms} = 1.11\ (61)$$

$$V_{rms} = 67.5\ V_{rms}$$

Step 8 Calculate maximum output voltage

$$V_{O(max)} = \frac{V_{rms}}{1.11} - I_K R_S$$

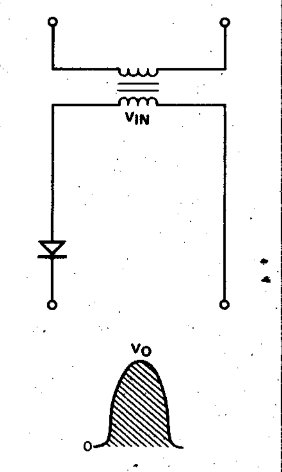
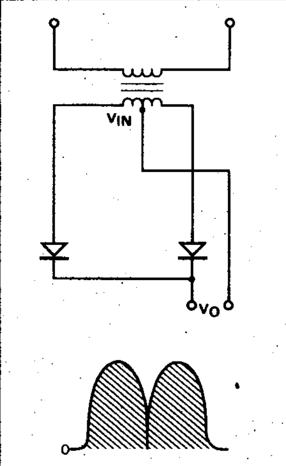
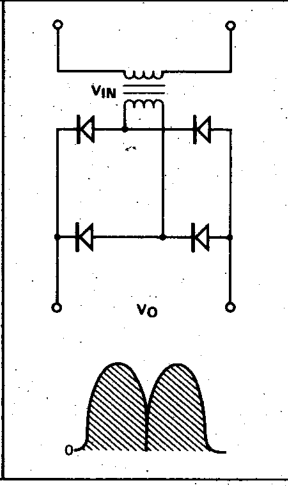
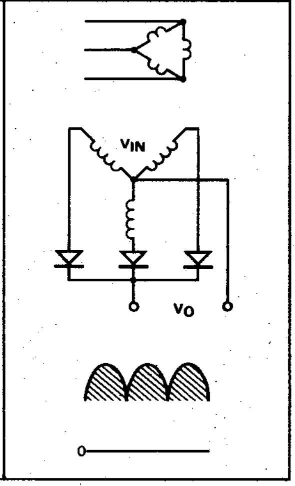
$$V_{O(max)} = \frac{67.5}{1.11} - 0.1 \times 10 = 61 - 1 = 60\text{ Vdc}$$

Step 9 Calcualte PIV rating required

PIV = (1.57) $V_{O(max)}$ (See Table 4-1)

PIV = 1.57 x 60 = 94 V

Transformer ratios are determined from *Table 4-1.*

SINGLE PHASE HALF WAVE (1-A)	SINGLE PHASE FULL WAVE CENTER TAP (1-B)	SINGLE PHASE FULL WAVE BRIDGE (1-C)	THREE PHASE STAR (HALF WAVE) (1-D)
			

Characteristic	Load	Single Phase Half Wave (See 1-A)	Single Phase Full Wave Center-Tap (See 1-B)	Single Phase Full Wave Bridge (See 1-C)	Three Phase Star (Half Wave) (See 1-D)	Three Phase Full Wave Bridge (See 1-E)	Six-Phase Star (Three Phase Diametric) (See 1-F)	Three Phase Double Wave With Interphase Transformer (See 1-G)
R M S Input Voltage Per Transformer Leg (V_I)	Resistive & Inductive	2.22 V_O	1.11 V_O	1.11 V_O	0.855 V_O	0.428 V_O	0.741 V_O	0.855 V_O
	Capacitive	0.707 V_O	0.707 V_O	0.707 V_O	0.707 V_O	0.408 V_O	0.707 V_O	0.707 V_O
Peak Inverse Voltage Per Rectifier (P I V)	R & L	3.14 V_O	3.14 V_O	1.57 V_O	2.09 V_O	1.05 V_O	2.09 V_O	2.09 V_O
	C	2.00 V_O	2.00 V_O	1.00 V_O	2.00 V_O	1.00 V_O	2.00 V_O	2.00 V_O
Average Current Through Rectifier I_F	R.L. & C	1.00 I_O	0.50 I_O	0.50 I_O	0.333 I_O	0.333 I_O	0.167 I_O	0.167 I_O
Peak Current Through Rectifier I_M	R	3.14 I_O	1.57 I_O	1.57 I_O	1.21 I_O	1.05 I_O	1.05 I_O	0.525 I_O
	L		1.00 I_O	1.00 I_O	1.00 I_O	1.00 I_O	1.00 I_O	0.500 I_O
	C	Depends on Size of Capacitor						
Transformer Total Secondary VA	Sine Wave	3.49 P_O	1.75 P_O	1.23 P_O	1.50 P_O	1.05 P_O	1.81 P_O	1.49 P_O
	Sq. Wave	3.14 P_O	1.57 P_O	1.11 P_O	1.48 P_O	1.05 P_O	1.81 P_O	1.48 P_O
Transformer Total Primary VA	Sine Wave	3.49 P_O	1.23 P_O	1.23 P_O	1.23 P_O	1.05 P_O	1.28 P_O	1.06 P_O
	Sq. Wave	3.14 P_O	1.11 P_O	1.11 P_O	1.21 P_O	1.05 P_O	1.28 P_O	1.05 P_O
% Ripple	Sine Wave Resistive Load	121%	47%	47%	17%	4%	4%	4%
Lowest Ripple Frequency	—	1 F_I	2 F_I	2 F_I	3 F_I	6 F_I	6 F_I	6 F_I
Conversion Efficiency	—	40.6%	81.2%	81.2%	97%	99.5%	99.5%	99.5%

Table 4-1. Electrical Reference Table and Rectifier Circuit Wave Shapes (Cont'd)

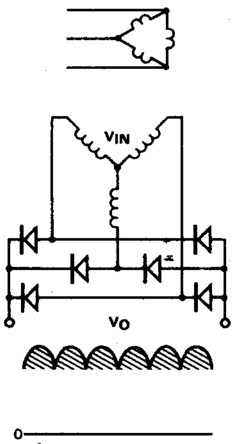
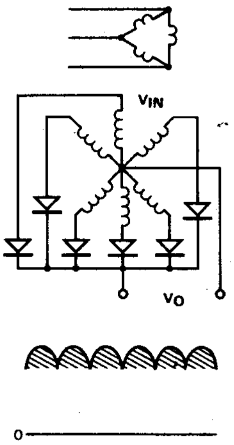
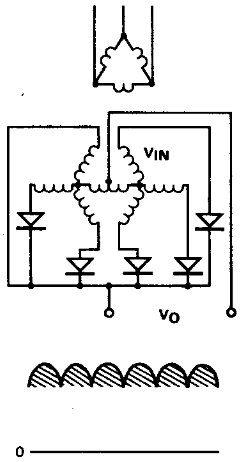
THREE PHASE FULL WAVE BRIDGE (1-E)	SIX PHASE STAR (THREE PHASE DIAMETRIC) (1-F)	THREE PHASE DOUBLE WAVE WITH INTERPHASE TRANSFORMER (1-G)
		

Table 4-1. Electrical Reference Table and Rectifier Circuit Wave Shapes (Cont'd)

SWINGING CHOKE LC SECTION FILTER

When designing a swinging choke section filter, the inductance required at the minimum and maximum output currents can be determined as follows.

1. Find L_C (critical inductance)

$$L_C = \frac{R_S + R_{eff}}{3\omega}$$

where, as before:

$$R_{eff} = \frac{R_K R_{L(max)}}{R_K + R_{L(max)}}$$

2. Find L2 (inductance at maximum load current)

$$L2 = \frac{R_S + R_{eff2}}{3\omega}$$

where:

$$R_{eff2} = \frac{R_{L(min)} R_K}{R_{L(min)} + R_K}$$

When L_C has been determined, then the capacitor value may be calculated as before. The condition $\omega^2 L_C \leqslant 1/4$ should be avoided due to possible filter instabilities.

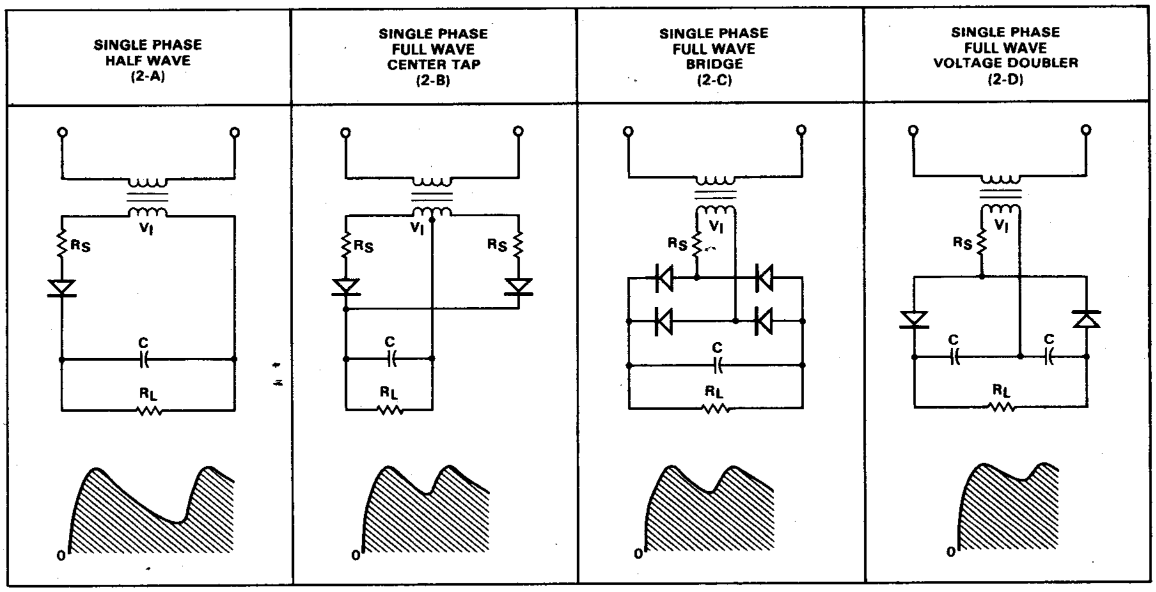
CAPACITIVE INPUT FILTER CHARACTERISTICS

$$R_S/R_{L(min)} = 0.02 \qquad \omega C R_{L(min)} = 12$$

When the voltage and current levels are known, *Table 4-2* can be used to select the optimum configuration and determine transformer and rectifier characteristics.

VOLTAGE DOUBLERS

Increased dc output voltage from a transformer winding can be obtained using a voltage multiplier circuit. However, this method requires additional components, *i.e.,* two filter capacitors, and reduces the output current. A full-wave doubler and a half-wave doubler are shown in *Figure 4-14*. The half-wave doubler is generally preferred since it has a common input and output terminal. In operation, C2 is



Characteristic	Single Phase Half Wave (See 2-A)	Single Phase Full Wave Center-Tap (See 2-B)	Single Phase Full Wave Bridge (See 2-C)	Single Phase Full Wave Voltage Doubler (See 2-D)
V_I	0.910 V_O	0.825 V_O	0.805 V_O	0.552 V_O
PIV	2.56 V_O	2.34 V_O	1.14 V_O	1.56 V_O
Ripple	0.12 V_O	0.06 V_O	0.06 V_O	0.09 V_O
I_M/Rect.	7.80 I_O	4.75 I_O	4.75 I_O	3.00 I_O
I_{RMS}/Rect.	2.50 I_O	1.33 I_O	1.33 I_O	1.10 I_O
SEC VA	2.35 P_O	2.16 P_O	2.16 P_O	1.22 P_O
PRI VA	2.35 P_O	3.05 P_O	2.16 P_O	1.72 P_O

Table 4-2. Capacitive Input Filter Characteristics and Rectifier Circuit Wave Shapes

Fig. 4-14. Voltage Doublers

charged on one half cycle; on the second half cycle, C1 is charged thereby summing the voltages across each capacitor. This provides a doubling effect since the output voltage is approximately twice the input voltage.

PRE-REGULATORS

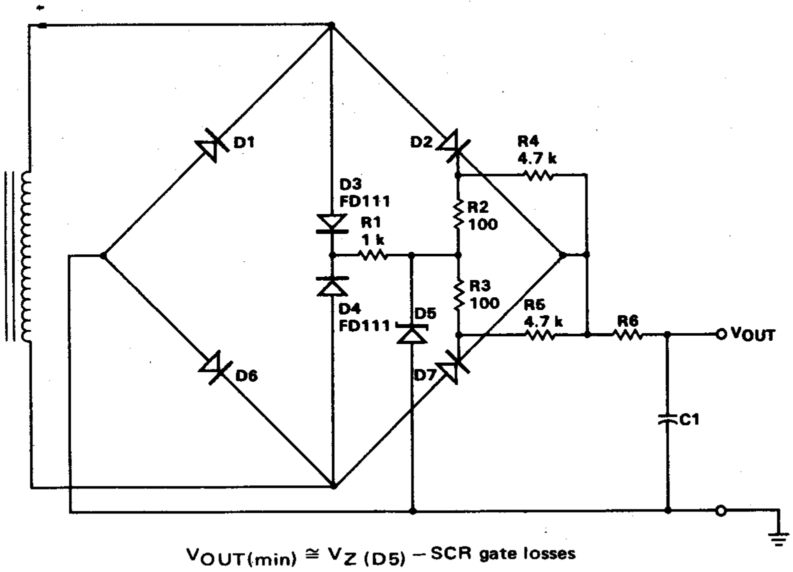
Pre-regulators for use in power supplies take one of two forms.

- Fixed output circuit for use with limited output adjustment range supplies (*Figure 4-15*).
- Tracking pre-regulators which maintain a fixed minimum input/output differential (*Figure 4-16*).

In both cases this circuitry operates by holding the SCR gates at some dc potential which fires the forward biased (anode to cathode) device whenever the ripple voltage on the filter capacitor drops to a level sufficient to exceed the gate-to-cathode threshold of the SCR.

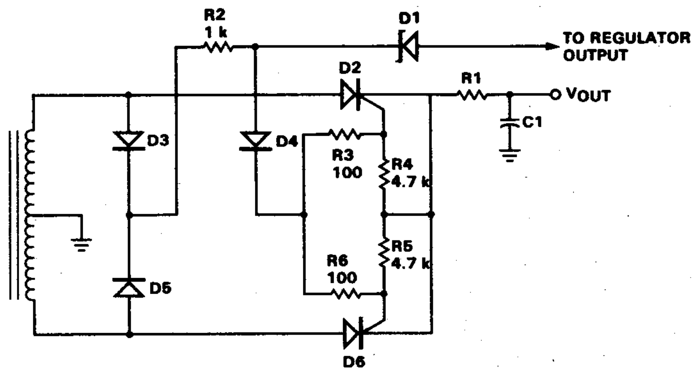
Two precautions are necessary when either pre-regulator circuit is used.

- The firing of the SCR is done on a dc drive basis, and represents a "soft fire" condition, *i.e.,* no gate overdrive; this should be considered when selecting power devices.
- RFI should be considered in the application of these circuits as the SCRs operate effectively as phase control devices.



$V_{OUT(min)} \cong V_{Z\ (D5)}$ − SCR gate losses

Fig. 4-15. Fixed Output Circuit



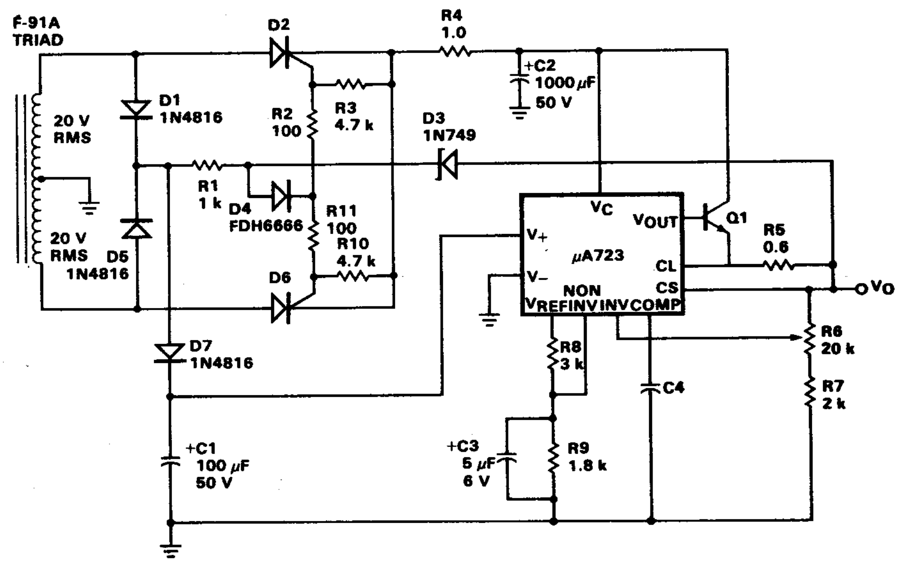
$V_{OUT(min)} \cong V_{OUT(reg)} + V_{Z\ (D1)}$ − SCR gate threshold

Fig. 4-16. Fixed Input/Output Differential

COMPLETE CIRCUITS

Two circuits are included to show combinations of several of the circuit techniques previously presented. *Figure 4-17* is a grounded, tracking pre-regulator design adjustable from 3 to 25 V using the transformer shown with the minimum input/output differential set by the 1N749 Zener diode. The power for the regulator control portion is provided by a separate voltage source to insure efficient operation at low output voltages, while maintaining a voltage greater than the 9.5 V minimum specified for the μA723 internal circuitry.

Figure 4-18 again provides a controlled voltage across the series-pass device. But, due to the floating configuration, the device is capable of regulation from 0 to 150 V using the specified isolation transformers. In this example, the power for the integrated circuit is provided by the combination of the voltage doubler C1, C2, D1, D2 and a transistor-buffered Zener diode which provides approximately 20 V for the regulator. In both *Figures 4-17* and *4-18*, the maximum output capability is limited by the power components; therefore the selection of a heavy-duty transformer, diodes, SCRs and output devices allows power capability expansion of the basic circuitry to fit almost any requirement.

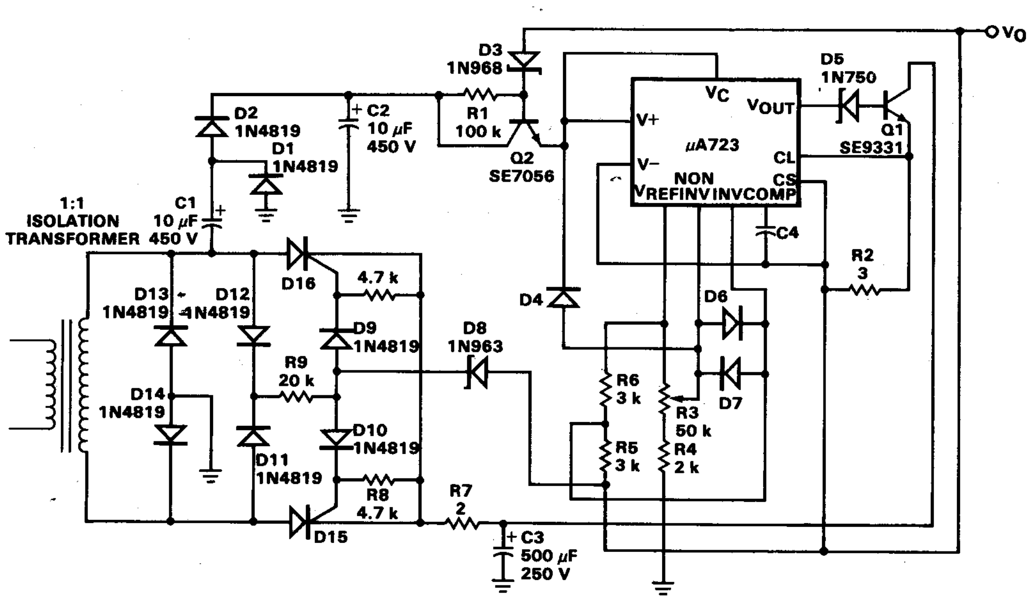


TYPICAL PERFORMANCE

V_O 3 V to 25 V (Transformer Limit)
I_{OUT} current limited at 0.8 A
Line Regulation < 1 mV any Voltage and Load
ΔV_{IN} = 95 Vrms to 125 Vrms

Load Regulation .04% of V_O
ΔI_{OUT} = 50 mA to 500 mA
Ripple and Noise = < 2 mV pk-pk over full V_O Range

Fig. 4-17. Tracking Pre-Regulator



TYPICAL PERFORMANCE

V_O = 0 to +150 V_O (Transformer Limit)
I_{OUT} current limited at 170 mA
Line Regulation = 0.04% of V_O
ΔV_{IN} = 95 Vrms to 125 Vrms

Load Regulation 0.1% of V_O
ΔI_{OUT} = 15 mA to 150 mA
Ripple < 0.05% of V_O

Fig. 4-18. High Voltage Tracking Regulator

REFERENCES

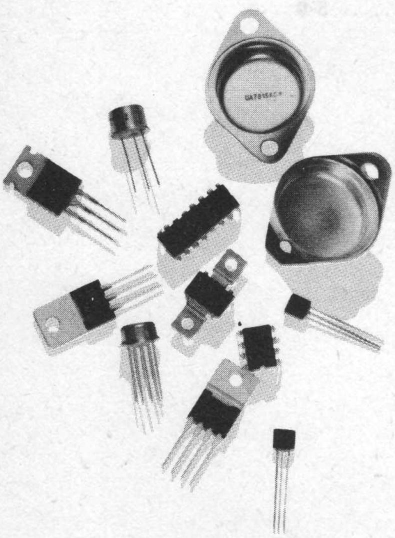
1. Schade, O.H., "Analysis of Rectifier Operation," Proc IRE, July 1943, Vol. 31, #7, pp. 341-361.

2. Ryder, John D., "Electronic Engineering Priniciples," Prentice Hall, Inc., 1947,, pp. 94-125.

3. Martin, Thomas L., Jr., "Electronic Circuits," Prentice Hall, Inc., 1955, pp. 506-541.

4. Seeley, Samuel, "Electron Tube Circuits," McGraw-Hill, 1958, pp. 194-230.

5. Gray, Truman, S., "Applied Electronics," John Wiley and Sons, Inc., 1954, pp. 250-277.



POWER TRANSISTORS

Chapter 5
POWER TRANSISTORS

When using power transistors in voltage regulators, the designer should be fully aware of the capabilities and limitations of these components, particularly the mechanisms affecting performance under high electrical and thermal stress. Power transistors are typically used in high current, high voltage and high temperature applications, *e.g.,* in resistive and clamped inductive switching circuits, unclampled inductive switching circuits, and Class B amplifiers. These conditions, separately or in combination, can be destructive; therefore, the power transistor selected for a specific application must be capable of safely withstanding all operating conditions forced by the circuit.

A number of factors such as second breakdown, dissipation capability, current and voltage ratings, and ambient temperature critically affect the performance of power transistors in circuit applications. These factors define the safe operating areas (SOA) for the forward-biased and reverse-biased modes within which each device can be safely operated without failure or degradation. Most manufacturers publish SOA curves to provide the circuit designer with an easy method for specifying power transistors.

DC FORWARD-BIASED SAFE OPERATING AREA

In a typical safe area diagram, *Figure 5-1,* collector current I_C is shown as a function of collector-to-emitter voltage V_{CE}. Each curve is labeled with the duration of the on pulse – from the worst-case dc condition to a minimum duration of 5 μs – at T_C = 100°C and a 1% duty cycle. The four factors limiting the dc forward-biased SOA of a particular power transistor are the collector current (1), thermal limitations (2), second breakdown limitation (3), and $V_{CEO(sus)}$ (4).

Operation above the I_C boundary (rated $I_{C(max)}$) may cause melting of the emitter lead wire, lifting of the lead wire bonds, or damage to the chip itself. Operation above the thermal limitation boundary causes overheating of the chip which may impair reliability. The second inclined portion of the right boundary

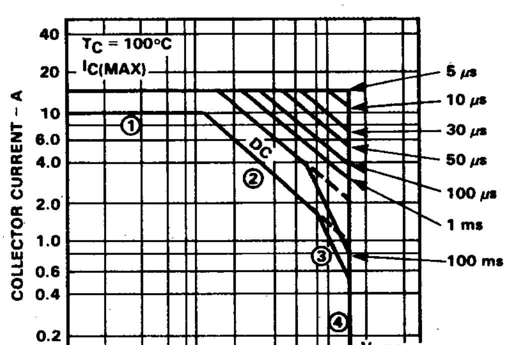


Fig. 5-1. Typical Safe Area

represents the second breakdown limitation. Operation to the right of this boundary causes second breakdown, which may destroy the device due to localized overheating. The vertical portion of the right boundary represents the primary voltage breakdown limitation, $V_{CEO(sus)}$. Operation to the right of this boundary results in voltage breakdown and excess current that may destory the device. Within these four boundaries, operation at any point (any combination of voltage and current) is safe. For example, 30 W (30 V x 1 A) can safely be dissipated in this example when the case temperature is 100°C.

Power dissipation at high voltages is limited by second breakdown, boundary (3) in *Figure 5-1*. Under second breakdown conditions, the output impedance changes almost instantaneously from a large value to a small limiting value. This condition is distinguished from normal transistor operation in that once it occurs, the base no longer controls normal collector characteristics. Physically, second breakdown is caused by localized current concentrations resulting in uncontrollable generation and multiplication of carriers causing a sudden reduction of collector impedance. As the duration of this phenomenon exceeds the thermal time constant of the area, the transistor is irreversibly damaged. The forward-bias second breakdown current I_{SB} is defined as the current at the onset of second breakdown. To increase the I_{SB} rating of a power device, wide base-width and uniform base-dopant concentration are key factors. Wide base width improves second breakdown capability in three ways. First, it reduces intensity of the transverse electric field; second, a wide base promotes fanning out of the current before it reaches the collector-base junction, thus tending to eliminate generation of hot spots; third, it also acts to thermally isolate the emitter-base junction from the hot spots generated in the collector base region, thus tending to prevent thermal runaway. Uniform base doping such as obtained by the Fairchild multiple epitaxial process, utilizing epitaxial base material, improves second breakdown capability by reducing the transverse electric field in the base.

The fourth limitation of the SOA area is the open-base breakdown voltage $V_{CEO(sus)}$ which can be written as a function of three variables, Q_B, N and W_C, where Q_B is the charge in the base, N is the collector impurity concentration and W_C is the metallurgical collector width. $V_{CEO(sus)}$ is reduced from the collector base breakdown voltage BV_{CBO} by a factor that decreases with increasing peak gain. The equation showing this relationship is

$$\frac{V_{CEO(sus)}}{BV_{CBO}} = (1 - \alpha)^{1/n}$$

where n has values ranging from 2 to 6 and α = common base current gain, which in turn is a function of Q_B, N and W_C.

PULSED FORWARD-BIASED SAFE OPERATING AREA

So far, discussion of forward-biased safe area has been limited to dc operation. Another forward-bias operating mode, namely, pulsed operation, must be considered. Refer to the typical safe area diagram in *Figure 5-1*. Very high peak power dissipation is possible during pulsed operation. For example, peak power of 360 W at 60 V is permissible for a pulse width of 0.1 ms, compared with maximum power of only about 115 W at 60 V for dc conditions. This high peak power capability arises from the inherent thermal capacitance of the device which enables it to absorb short bursts of energy without exceeding the maximum junction temperature or going into second breakdown. If the time between power pulses is relatively long (low duty cycle), most of the stored thermal energy is dissipated before the next power pulse arrives; thus, temperature build-up in the device is prevented. As indicated in *Figure 5-1*, allowable peak power increases as pulse width decreases. This follows from the fact that total energy absorbed is equal to the product of power and time. If the time duration of the pulse decreases, peak power can increase without increasing total energy absorbed.

REVERSE-BIASED SAFE OPERATING AREA

When the emitter-base junction of a transistor is reverse biased, the device begins to turn off. In an unclamped inductive circuit, an electrical stress occurs that can result in reverse-biased second breakdown. When the load is resistive or a clamped inductance, the transistor sees very little energy in the reverse-biased mode; but, when the load is an unclamped inductance, almost all of the energy contained in the coil is dumped into the transistor, *i.e.*,

$$E = 1/2\ LI_C^2.$$

Second breakdown energy E_{SB} is the guaranteed reverse-biased energy the transistor is capable of withstanding. When the emitter-base junction is reverse biased, a transverse voltage gradient appears in the base region forcing severe current crowding under the center of the emitter (*Figure 5-2*). This condition is further aggravated by thermal feedback. If the energy in this hot spot raises the temperature of the silicon above approximately 400°C, the emitter-base junction goes into avalanche and the sustaining voltage collapses within nanoseconds. Usually, the transistor is destroyed.

During reverse-bias operation, current is concentrated in a small centralized area rather than in a relatively larger area under the emitter periphery as is the case during forward-biased operation. Therefore, since the current crowding is greater, E_{SB} is much less than the energy capability when the transistor is forward biased.

The E_{SB} capability of a power transistor depends on both the transistor and the circuit design. For low E_{SB} stress, the transistor design must include a large emitter area, a high resistive collector and graded collector doping to reduce current crowding. The circuit should be designed with low inductance (*Figure 5-3*) and low J_C to maintain low energy, keeping in mind that for a specified energy level, as L increases, second breakdown stress on the transistor becomes more severe. To reduce the transverse voltage gradient in the base, and therefore reduce current crowding, low reverse bias V_{BE} and large base resistance R_{BE} are required.

The effective capacitance C_{eff} on the collector should be low, otherwise it takes too long for the C_{eff} to charge to $V_{CE(sus)}$ and the device turns off completely (Curve 3a in *Figure 5-4*). When this happens, the voltage rises to the blocking voltage and the C_{eff} discharges into the transistor (snap back). This is a very stressing situation since the collector current goes high during total cutoff thus causing extreme current crowding. Generally, an E_{SB} stress is safe as long as the dissipated energy is less than that specified on the data sheet and provided $L \leqslant L_{spec}$, $R_{BE} \geqslant R_{BE(spec)}$, $|V_{BE}| < |V_{BE(spec)}|$, and the device is operated in the sustaining mode and snapback is avoided by holding C_{eff} low (See *Figure 5-5*). When $L > L_{spec}$, the SOA limit follows an approximate curve, LI_C^{ϑ} = constant; it is usually safe to consider $\vartheta = 1$.

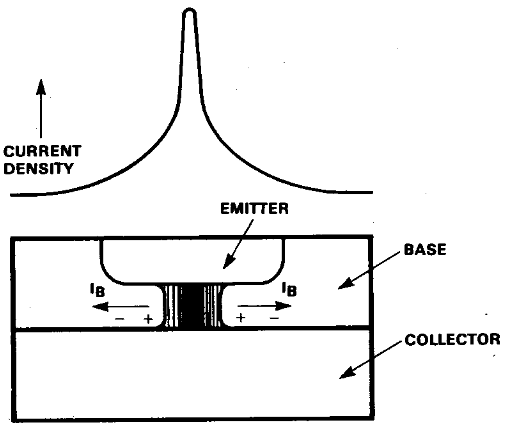


Fig. 5-2. Current Crowding During Reverse-Biased Cutoff

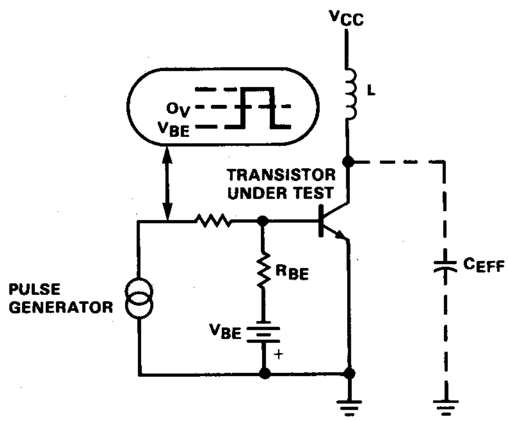


Fig. 5-3. Reverse-Biased Transistor with Inductive Load

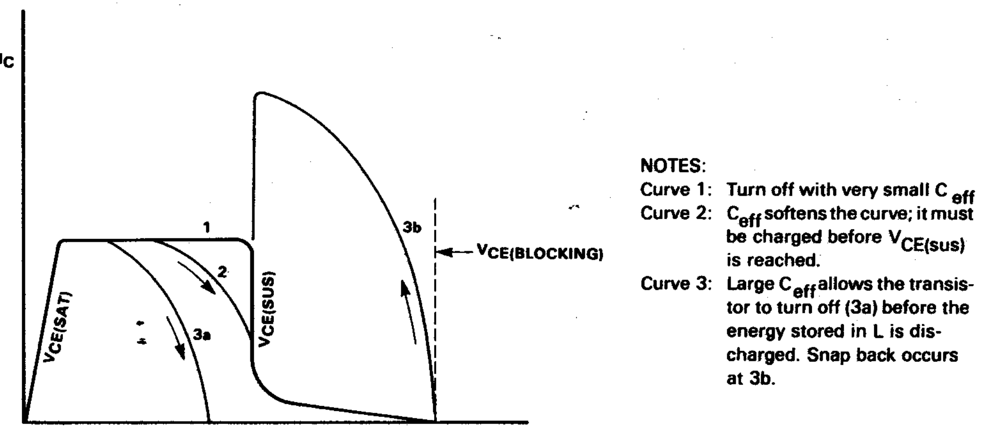


Fig. 5-4. Inductive Turn Off

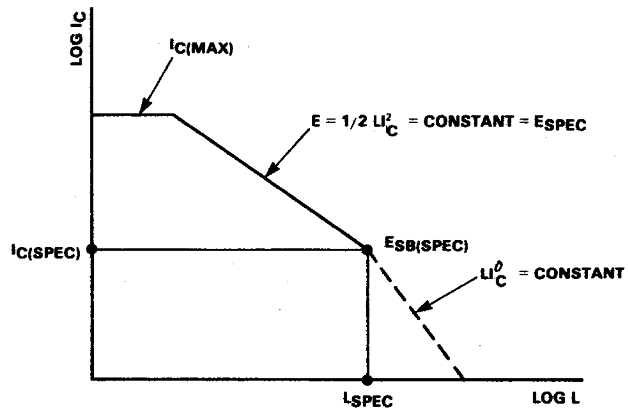


Fig. 5-5. Reverse-Biased Safe-Operating Area

Although this is a valid rating system, it is good design practice to avoid reverse-biased stress by clamping or waveshaping. While the power-transistor manufacturer can guarantee an E_{SB} rating, it must be kept in mind that non-destructive testing is difficult, lot-to-lot and unit-to-unit variations are significant and the fast high voltage power transistors, in particular, have limited E_{SB} capabilities.

THERMAL LIMITATION

The thermal limits placed on power dissipation are established to prevent overheating of the chip, and depend upon the junction-to-case thermal resistance θ_{JC} of the device. This resistance determines how readily the heat generated in the chip during operation is conducted to the outside surface of the case (package). It is measured by comparing, the temperature of the collector base junction with the temperature of the case at a known power dissipation level. θ_{JC} is expressed in units of degrees centigrade per watt. The industry specifies a maximum permissible junction temperature of 200°C for metal can power transistors and 150°C for plastic devices. Based on this limit and the θ_{JC} value, maximum allowable power dissipation in the thermally limited region can be determined for any case temperature. See Chapter 6 for additional information on the thermal resistance.

FAIRCHILD POWER TRANSISTORS *(Figure 5-6)*

*Double-Diffused Epitaxial Planar** power transistors, made by the same process used for small-signal transistors, are characterized by shallow diffusions into an expitaxial layer. The junctions are normally passivated with silicon dioxide to ensure low leakage currents and optimum stability. This is the most common form of Planar power transistor and both npn and pnp types can easily be made. The devices typically have very low leakage, high gain, low saturation voltage and high gain-bandwidth product. Typical values for the latter range from 20 to 200 MHz. Double-diffused epitaxial Planar transistors are primarily used in high frequency, high reliability switching and amplifying applications with f_T ratings greater than 30 MHz and maximum collector current ratings up to 10 A.

These transistors have a relatively poor safe operating area because of the narrow base region and the depletion of the entire voltage into the collector region. Maximum die yield depends on expert photo-resist techniques for diffusing impurities through an opening etched in the surface oxide. The oxide-masked and phosphorous-passivated Planar structures allow lower leakage than mesa junction devices. The structure is limited to approximately 400 V breakdown voltage. This is a result of uncontrolled surface charge introduced into the high field region associated with the finite radius of curvature of the impurity diffusion front. This results in premature breakdown. The use of metallic overlay (junction field plate) and resistive films is employed to combat these effects.

Single Epitaxial-Base Mesa transistors are manufactured by diffusing an emitter into an epitaxial base region deposited on the collector substrate. The collector voltage depletes into the base region. The device is fairly rugged with reasonable gain and medium f_T. The safe operating area capability is between Planar triple diffused and single diffused mesa. Epitaxial base devices gain ruggedness as a result of the wide and homogeneous base region. Both npn and pnp-type transistors can be made by this process. Performance is somewhat limited by low voltage ratings imposed by the abrupt base-collector junction formed between the heavily doped collector substrate and the epitaxially deposited base layer, and by the thickness of this layer.

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Multiple Epitaxial-Base Mesa processing uses two epitaxial layers to form the collector and base regions, a mesa etch to define the collector-base junction, and Planar processing to form the emitter-base junction. This produces low-cost, high-current devices with excellent safe-area capabilities. Epitaxial-base transistors gain ruggedness as the result of the wide homogeneous base region. When compared to conventional single-diffused devices, epitaxial-base mesa transistors exhibit higher working voltage capabilities, lower saturation voltages, and lower leakage currents. Beta linearity is also improved and npn and pnp complementary devices are readily produced. Maximum current ratings extend to 50 A and f_T ratings to 15 MHz.

Multiple-Epitaxial Double-Diffused Base Mesa structures are identical to the double-diffused epitaxial except that multiple-epitaxial layers are used in the collector region and the collector-base junction is formed by a mesa etch. A low resistivity thin layer is epitaxially grown between the highly doped substrate and the low-epitaxial collector region. The advantages of the multiple-epitaxial double-diffused structure are high speed (f_T = 50 MHz), low saturation voltage and increased E_{SB} capability due to the epitaxial intermediate collector.

SUMMARY

While the manufacturer can specify device performance limitations, it is imperative that the circuit designer operate the power transistor within its SOA and use appropriate heat sinking and careful mounting techniques to eliminate the threat of device failure or degradation. However, since each mode of operation has a specific set of electrical and thermal stress conditions, the SOA curves on the data sheet cannot possibly define all absolute maximum ratings. This is especially the case when the power transistor is used in pulsed operation.

*Planar is a patented Fairchild process.

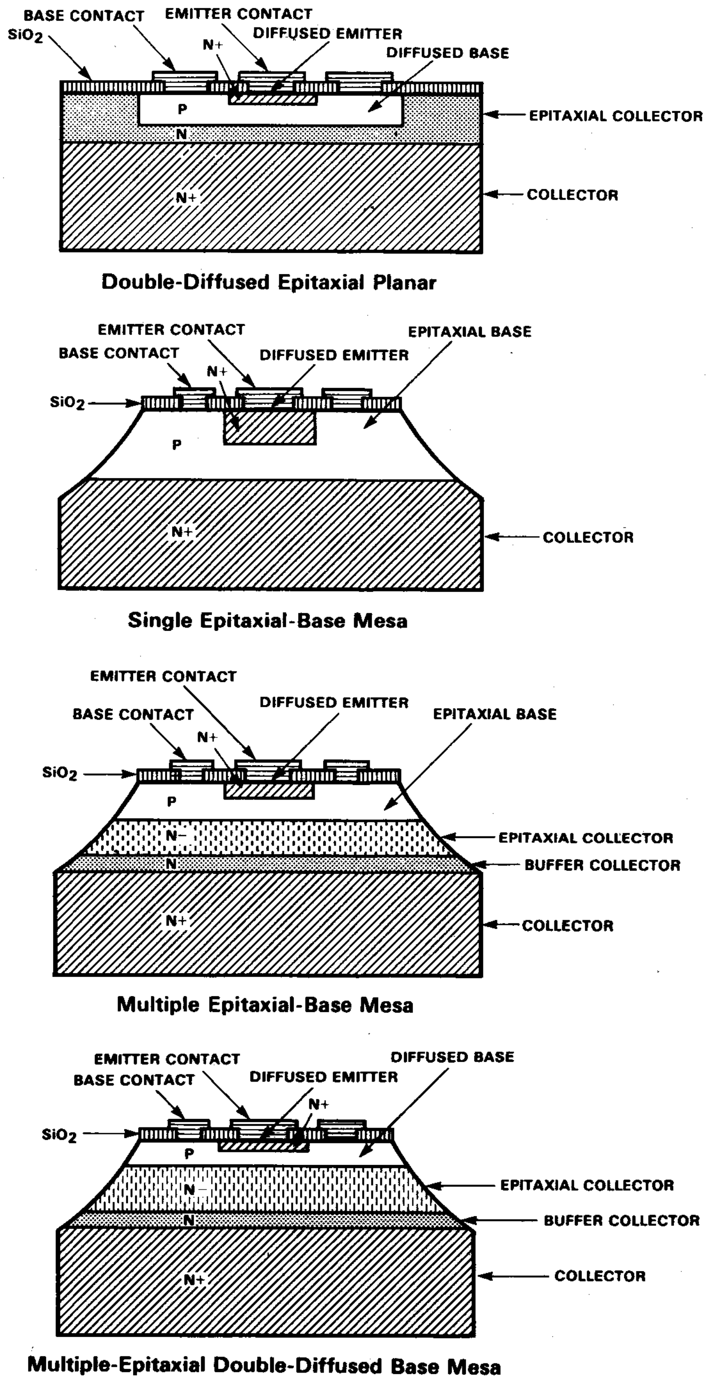

Fig. 5-6. Basic Power Transistor Structures

POWER

POWER TRANSISTORS (BY $I_C$max, POLARITY AND ASCENDING V_{CEO})

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	$P_{D(Max)}$ W T_C= 25°C	Package No.
I_C = 0.1 A Max Continuous										
1	**BF257**		160	25/-	0.03	1.0	0.03	75	1.0	TO-39
2	**BF336**		180	20/-	0.03	—	—	50	1.0	TO-39
3	**BF337**		200	20/-	0.03	—	—	50	1.0	TO-39
4	**BF338**		225	20/-	0.03	—	—	50	1.0	TO-39
5	**BF258**		250	25/-	0.03	1.0	0.03	75	1.0	TO-39
6	**D40N1F**		250	30/90	0.02	—	—	40	10	Dynawatt
7	**D40N2F**		250	60/180	0.02	—	—	40	10	Dynawatt
8	**BF259**		300	25/-	0.03	1.0	0.03	75	1.0	TO-39
9	**D40N3F**		300	30/90	0.02	—	—	40	10	Dynawatt
10	**D40N4F**		300	60/180	0.02	—	—	40	10	Dynawatt
I_C = 0.15 A Max Continuous										
11	**2N5059**		250	30/150	0.03	1.0	0.03	30	1.0	TO-39
12	**2N5058**		300	35/150	0.03	1.0	0.03	30	1.0	TO-39
I_C = 0.5 A Max Continuous										
13	**TIP61**	**TIP62**	40	40/-	0.05	0.07	0.50	3.0	15	TO-220
14	**TIP61A**	**TIP62A**	60	40/-	0.05	0.07	0.50	3.0	15	TO-220
15	**TIP61B**	**TIP62B**	80	40/-	0.05	0.07	0.50	3.0	15	TO-220
16	**TIP61C**	**TIP62C**	100	40/-	0.05	0.07	0.50	3.0	15	TO-220
17	**SE7055**		220	40/-	0.03	1.00	0.02	50	1.0	TO-39
18	**SE7056**		300	40/-	0.03	1.00	0.02	50	1.0	TO-39
19	**MPS-U10F**		300	40/-	0.03	—	—	40	10	Dynawatt
I_C = 1.0 A Max Continuous										
20	**FT427**		30	20/-	0.50	—	—	—	10	Dynawatt
21	**FT527**		30	20/-	0.50	—	—	—	10	TO-220
22	**D40D1F**	**D41D1F**	30	50/150	0.10	0.5	0.5	—	10	Dynawatt
23	**TIP29**	**TIP30**	40	15/75	1.00	0.7	1.0	3.0	30	TO-220
24		**2N4898**	40	20/100	0.50	0.6	1.0	3.0	25	TO-66
25	**2N4910**		40	20/100	0.50	0.6	1.0	4.0	25	TO-66
26	**D40D4F**	**D41D4F**	45	50/150	0.10	0.5	0.5	—	10	Dynawatt
27	**TIP29A**	**TIP30A**	60	15/75	1.00	0.7	1.0	3.0	30	TO-220
28		**2N3740**	60	30/100	0.25	0.6	1.0	4.0	25	TO-66

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POWER

POWER TRANSISTORS (BY $I_C$max, POLARITY AND ASCENDING V_{CEO}) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	$P_{D(Max)}$ W T_C=25°C	Package No.
I_C = 1.0 A Max Continuous (Cont'd)										
1	2N4911		60	20/100	0.50	0.5	1.0	4.0	25	TO-66
2		2N4899	60	20/100	0.50	0.6	1.0	3.0	25	TO-66
3	D40D7F	D41D7F	60	50/150	0.10	0.5	0.5	—	10	Dynawatt
4	D40D10F	D41D10F	75	50/150	0.10	0.5	0.5	—	10	Dynawatt
5	D40D13F	D41D13F	75	50/150	0.10	0.5	0.5	—	10	Dynawatt
6	TIP29B	TIP30B	80	15/75	1.00	0.7	1.0	3.0	30	TO-220
7		2N3741	80	30/100	0.25	0.6	1.0	4.0	25	TO-66
8		2N4900	80	20/100	0.50	0.6	1.0	3.0	25	TO-66
9	2N4912		80	20/100	0.50	0.6	1.0	4.0	25	TO-66
10	TIP29C	TIP30C	100	15/75	1.00	0.7	1.0	3.0	30	TO-220
11	2N5681	2N5679	100	40/150	0.25	1.0	0.5	30	10	TO-39
12	2N5682	2N5680	120	40/150	0.25	1.0	0.5	30	10	TO-39
13		2N5415	200	30/150	0.05	2.5	0.5	15	10	TO-39
14		FTD5415	200	30/150	0.05	2.5	0.05	15	10	Dynawatt
15	FTD3440		250	40/160	0.02	0.5	0.05	15	10	Dynawatt
16	2N3440		250	40/160	0.02	0.5	0.05	15	10	TO-39
17	FT47		250	30/150	0.30	1.0	1.0	10	40	TO-220
18	SE9331		300	30/250	0.10	2.5	0.10	10	20	TO-66
19	FT48		300	30/150	0.30	1.0	1.00	10	40	TO-220
20		2N5416	300	30/120	0.05	2.0	0.05	15	10	TO-39
21		FTD5416	300	30/120	0.05	2.0	0.05	15	10	Dynawatt
22	2N3439		350	40/160	0.02	0.5	0.05	15	10	TO-39
23	FT49		350	30/150	0.30	1.0	1.00	10	40	TO-220
24	FTD3439		350	40/160	0.02	0.5	0.05	15	10	Dynawatt
25	FT50		400	30/150	0.30	1.0	1.00	10	40	TO-220
I_C = 2.0 A Max Continuous										
26	FT428		25	20/-	0.5	—	—	—	10	Dynawatt
27	FT528		25	20/-	0.5	—	—	—	10	TO-220
28	FTD5321	FTD5323	50	40/250	0.5	0.8	0.5	40	10	Dynawatt
29	2N5321	2N5323	50	40/250	0.5	0.8	0.5	50	10	TO-39
30	MPS-U05F	MPS-U55F	60	50/-	0.25	0.5	0.25	40	10	Dynawatt

POWER TRANSISTORS (BY $I_C$max, POLARITY AND ASCENDING V_{CEO}) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	$P_{D(Max)}$ W T_C=25°C	Package No.
I_C = 2.0 A Max Continuous (Cont'd)										
1	TIP110*	TIP115*	60	1000/-	1.0	2.5	2.0	—	50	TO-220
2	2N5320	2N5322	75	30/130	0.5	0.5	0.5	50	10	TO-39
3	FTD5320	FTD5322	75	30/130	0.5	0.5	0.5	40	10	Dynawatt
4	MPS-U06F	MPS-U56F	80	50/-	0.25	0.5	0.25	40	10	Dynawatt
5	TIP111*	TIP116*	80	1000/-	1.0	2.5	2.0	—	50	TO-220
6	TIP112*	TIP117*	100	1000/-	1.0	2.5	2.0	—	50	TO-220
7	MPS-U07F	MPS-U57F	100	30/-	0.25	0.05	0.25	40	10	Dynawatt
8	FT401		300	20/100	0.5	0.8	0.5	2.0	100	TO-3
I_C = 3.0 A Max Continuous										
9	TIP31	TIP32	40	10/50	3.0	1.2	3.0	3.0	40	TO-220
10		2N4234	40	30/150	0.25	0.6	1.0	3.0	6.0	TO-39
11		2N4235	60	30/150	0.25	0.6	1.0	3.0	6.0	TO-39
12	2N3766		60	40/160	0.5	1.0	0.5	10	20	TO-66
13	2N5334		60	30/150	1.0	0.7	2.0	40	6.0	TO-39
14	TIP31A	TIP32A	60	10/50	3.0	1.2	3.0	3.0	40	TO-220
15	TIP31B	TIP32B	80	10/50	3.0	1.2	3.0	3.0	40	TO-220
16		2N4236	80	30/150	0.25	0.6	1.0	3.0	6.0	TO-39
17	2N3767		80	40/160	0.5	1.0	0.5	10	20	TO-66
18	2N5335		80	30/150	1.0	0.7	2.0	40	6.0	TO-39
19	TIP31C	TIP32C	100	10/50	3.0	1.2	3.0	3.0	40	TO-220
20	2N5838		250	8/40	3.0	1.0	3.0	5.0	100	TO-3
21	2N5839		275	10/50	2.0	1.5	2.0	5.0	100	TO-3
22	FT402		325	20/100	0.5	2.0	3.0	2.0	100	TO-3
23	2N5840		350	10/50	2.0	1.5	2.0	5.0	100	TO-3
I_C = 4.0 A Max Continuous										
24	2N5296		40	30/120	1.0	1.0	1.0	0.8	36	TO-220
25	BD221	BD224	40	30/120	1.0	1.0	1.0	0.8	36	TO-220
26	2N4231		40	25/100	1.5	0.7	1.5	4.0	35	TO-66
27	2N4237		40	30/150	0.25	0.6	1.0	1.0	6.0	TO-39
28	2N6121	2N6124	45	25/100	1.5	0.6	1.5	2.5	40	TO-220

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POWER

POWER TRANSISTORS (BY $I_C$max, POLARITY AND ASCENDING V_{CEO}) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	$P_{D(Max)}$ W T_C=25°C	Package No.
I_C = 4.0 A Max Continuous (Cont'd)										
1	2N3054		55	25/150	0.5	1.0	0.5	—	25	TO-66
2	2N5298		60	20/80	1.5	1.0	1.5	0.8	36	TO-220
3	BD222	BD225	60	20/80	1.5	1.0	1.5	0.8	36	TO-220
4	2N6122	2N6125	60	25/100	1.5	0.6	1.5	2.5	40	TO-220
5	2N4232		60	25/100	1.5	0.7	1.5	4.0	35	TO-66
6	2N4238		60	30/150	0.25	0.6	1.0	1.0	6.0	TO-39
7	2N5294		70	30/120	0.5	1.0	0.5	0.8	36	TO-220
8	BD220	BD223	70	30/120	0.5	1.0	0.5	0.8	36	TO-220
9	2N6123	2N6126	80	20/80	1.5	0.6	1.5	2.5	40	TO-220
10	2N4233		80	25/100	1.5	0.7	1.5	4.0	35	TO-66
11	2N4239		80	30/150	0.25	0.6	1.0	1.0	6.0	TO-39
12	FT317	FT417	100	35/-	1.0	0.5	1.0	20	40	TO-220
13	2N6473	2N6475	100	15/150	1.5	1.2	1.5	10	40	TO-220
14	FT317A	FT417A	120	35/-	1.0	0.5	1.0	20	40	TO-220
15	2N6474	2N6476	120	15/150	1.5	1.2	1.5	10	40	TO-220
16	FT317B	FT417B	140	35/-	1.0	0.5	1.0	20	40	TO-220
I_C = 5.0 A Max Continuous										
17	2N5067	2N4901	40	20/80	1.0	0.4	1.0	4.0	87.5	TO-3
18	2N4913	2N4904	40	25/100	2.5	1.5	5.0	4.0	87.5	TO-3
19	2N5490		40	20/100	2.0	1.0	2.0	0.8	50	TO-220
20	2N5494		40	20/100	3.0	1.0	3.0	0.8	50	TO-220
21	2N5492		55	20/100	2.5	1.0	2.5	0.8	50	TO-220
22	TIP120*	TIP125*	60	1000/-	0.5	2.0	3.0	—	65	TO-220
23	BC323		60	50/250	0.5	0.15	0.5	—	7.0	TO-39
24	2N5068	2N4902	60	20/80	1.0	0.4	1.0	4.0	87.5	TO-3
25	2N4895		60	40/120	2.0	1.0	5.0	50	7.0	TO-39
26	BFX34		60	40/150	2.0	1.0	0.5	70	5.0	TO-39
27	2N4896		60	100/300	2.0	1.0	5.0	80	7.0	TO-39
28	2N4914	2N4905	60	25/100	2.5	1.5	5.0	4.0	87.5	TO-3
29	2N5496		70	20/100	3.5	1.0	3.5	0.8	50	TO-220

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POWER

POWER TRANSISTORS (BY $I_{C}max$, POLARITY AND ASCENDING V_{CEO}) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	$P_{D(Max)}$ W T_C=25°C	Package No.
I_C = 5.0 A Max Continuous (Cont'd)										
1	TIP121*	TIP126*	80	1000/-	0.5	2.0	3.0	—	65	TO-220
2	2N5069	2N4903	80	20/80	1.0	0.4	1.0	4.0	87.5	TO-3
3	2N4897		80	40/120	2.0	1.0	5.0	50	7.0	TO-39
4	2N5336		80	30/120	2.0	0.7	2.0	30	6.0	TO-39
5	2N5337		80	60/240	2.0	0.7	2.0	30	6.0	TO-39
6	2N4915	2N4906	80	25/100	2.5	1.5	5.0	4.0	87.5	TO-3
7	TIP122*	TIP127*	100	1000/-	0.5	2.0	3.0	—	65	TO-220
8	2N5338		100	30/120	2.0	0.7	2.0	30	6.0	TO-39
9	2N5339		100	60/240	2.0	0.7	2.0	30	6.0	TO-39
I_C = 6.0 A Max Continuous										
10	TIP41	TIP42	40	30/-	0.3	1.5	6.0	3.0	65	TO-220
11	TIP41A	TIP42A	60	30/-	0.3	1.5	6.0	3.0	65	TO-220
12	TIP41B	TIP42B	80	30/-	0.3	1.5	6.0	3.0	65	TO-220
13	TIP41C	TIP42C	100	30/-	0.3	1.5	6.0	3.0	65	TO-220
I_C = 7.0 A Max Continuous										
14	2N6111		30	30/150	3.0	1.0	3.0	10	40	TO-220
15	2N6129	2N6132	40	20/100	2.5	1.4	7.0	2.5	50	TO-220
16	2N6109		50	30/150	2.5	1.0	2.5	10	40	TO-220
17	2N5873	2N5871	60	20/100	2.5	1.0	4.0	4.0	115	TO-3
18	2N6130	2N6133	60	20/100	2.5	1.4	7.0	2.5	50	TO-220
19	2N6107		70	30/150	2.0	1.0	2.0	10	40	TO-220
20	2N5874	2N5872	80	20/100	2.5	1.0	4.0	4.0	115	TO-3
21	2N6131	2N6134	80	20/100	2.5	2.8	7.0	2.5	50	TO-220
I_C = 7.5 A Max Continuous										
22	FT410		200	30/90	1.0	0.8	1.0	(5.0)	100	TO-3
23	FT411		300	30/90	1.0	0.8	1.0	(5.0)	100	TO-3
24	FT413		325	20/80	0.5	0.8	0.5	(5.0)	100	TO-3
25	FT423		325	30/90	1.0	0.8	1.0	(5.0)	100	TO-3
I_C = 8.0 A Max Continuous										
26	2N5877	2N5875	60	20/100	4.0	1.0	5.0	4.0	150	TO-3

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POWER

POWER TRANSISTORS (BY $I_C$max, POLARITY AND ASCENDING V_{CEO}) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	$P_{D(Max)}$ W T_C=25° C	Package No.
I_C = 8.0 A Max Continuous (Cont'd)										
1	**2N6055***	**2N6053***	60	750/18K	4.0	2.0	4.0	4.0	100	TO-3
2	**2N5878**	**2N5876**	80	20/100	4.0	1.0	5.0	4.0	150	TO-3
3	**2N6056***	**2N6054***	80	750/18K	4.0	2.0	4.0	4.0	100	TO-3
4	**2N6306**		250	15/75	3.0	0.8	3.0	5.0	125	TO-3
5	**2N6307M**		300	15/75	3.0	1.0	3.0	5.0	125	TO-3
6	**2N6308M**		350	12/60	3.0	1.5	3.0	5.0	125	TO-3
I_C = 10.0 A Max Continuous										
7	**2N6103**		40	15/60	8.0	2.5	16	—	75	TO-220
8	**2N6386***		40	1K/20K	3.0	2.0	3.0	20	40	TO-220
9		**2N4907**	40	20/80	4.0	0.75	4.0	4.0	150	TO-3
10	**2N6383***		40	1K/20K	5.0	2.0	5.0	20	100	TO-3
11	**2N3713**		60	25/75	1.0	1.0	5.0	4.0	150	TO-3
12		**2N3789**	60	25/90	1.0	1.0	5.0	4.0	150	TO-3
13	**2N6099**		60	20/80	4.0	2.5	10	—	75	TO-220
14	**2N3715**		60	50/150	1.0	0.8	5.0	4.0	150	TO-3
15		**2N3791**	60	50/180	1.0	1.0	5.0	4.0	150	TO-3
16	**2N6387***		60	1K/20K	3.0	2.0	3.0	20	40	TO-220
17	**MJE3055F**		60	20/70	4.0	1.1	4.0	2.0	70	TO-220
18		**2N4908**	60	20/80	4.0	0.75	4.0	4.0	150	TO-3
19	**SE9300***	**SE9400***	60	1000/-	4.0	2.0	4.0	1.0	70	TO-220
20	**SE9303***	**SE9403***	60	1000/-	4.0	2.0	4.0	1.0	100	TO-3
21	**2N6384***		60	1K/20K	5.0	2.0	5.0	20	100	TO-3
22	**MJ2500***	**MJ3000***	60	1000/-	5.0	2.0	10	—	150	TO-3
23	**2N6101**		70	20/80	5.0	2.5	10	—	75	TO-220
24	**2N3714**		80	25/75	1.0	1.0	5.0	4.0	150	TO-3
25		**2N3790**	80	25/90	1.0	1.0	5.0	4.0	150	TO-3
26	**2N3716**		80	50/150	1.0	0.8	5.0	4.0	150	TO-3
27		**2N3792**	80	50/180	1.0	1.0	5.0	4.0	150	TO-3
28	**2N6388***		80	1K/20K	3.0	2.0	3.0	20	40	TO-220
29		**2N4909**	80	20/80	4.0	0.75	4.0	4.0	150	TO-3

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POWER TRANSISTORS (BY I_{C}max, POLARITY AND ASCENDING V_{CEO}) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	$P_{D(Max)}$ W T_C=25°C	Package No.
I_C = 10.0 A Max Continuous (Cont'd)										
1	SE9304*	SE9404*	80	1K/-	4.0	2.0	4.0	1.0	100	TO-3
2	SE9301*	SE9401*	80	1K/-	4.0	2.0	4.0	1.0	70	TO-220
3	2N6385*		80	1K/20K	5.0	2.0	5.0	20	100	TO-3
4	MJ2501	MJ3001	80	1000/-	5.0	2.0	10		150	TO-3
5	SE9302*	SE9402*	100	1K/-	4.0	2.0	1.0		70	TO-220
6	SE9305*	SE9405*	100	1K/-	4.0	2.0	40	1.0	100	TO-3
7	2N6249		200	10/50	10	1.5	10	2.5	100	TO-3
8	2N6250		275	8/50	10	1.5	10	2.5	100	TO-3
9	FT430		300	15/45	2.5	0.9	2.5	—	125	TO-3
10	FT160		300	55/-	4.0	1.9	5.0	—	70	TO-220
11	FT431		325	15/35	2.5	0.7	2.5	—	125	TO-3
12	FT161		330	55/-	4.0	1.9	5.0	—	70	TO-220
13	FT162		350	55/-	4,0	1.9	5.0	—	70	TO-220
14	FT359*		350	250/-	3.0	2.8	7.0	—	125	TO-3
15	2N6251		350	6/50	10	1.5	10	2.5	100	TO-3
I_C = 12.0 A Max Continuous										
16	2N6569		40	15/200	0.2	1.5	4.0	1.5	100	TO-3
17	2N6057*	2N6050*	60	750/18K	6.0	2.0	6.0	4.0	150	TO-3
18	2N5881	2N5879	60	20/100	6.0	1.0	7.0	4.0	160	TO-3
19	2N5882	2N5880	80	20/100	6.0	1.0	7.0	4.0	160	TO-3
20	2N6058*	2N6051*	80	750/18K	6.0	2.0	6.0	4.0	150	TO-3
21	2N6059*	2N6052*	100	750/18K	6.0	2.0	6.0	4.0	150	TO-3
I_C = 15.0 A Max Continuous										
22	2N6486	2N6489	40	20/150	5.0	1.3	5.0	5.0	75	TO-220
23	MJ2955		60	20/70	4.0	1.1	4.0	4.0	150	TO-3
24	2N6576*		60	2K/20K	4.0	4.0	15	10	120	TO-3
25	2N3055SD		60	20/70	4.0	1.1	4.0	0.8	115	TO-3
26	FT3055	FT2955	60	20/70	4.0	1.1	4.0	2.0	70	TO-220
27	2N3055		60	20/70	4.0	1.1	4.0	—	117	TO-3
28	2N6487	2N6490	60	20/150	5.0	1.3	5.0	5.0	75	TO-220

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POWER

POWER TRANSISTORS (BY $I_C$max, POLARITY AND ASCENDING V_{CEO}) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	$P_{D(Max)}$ W T_C=25°C	Package No.
I_C = 15.0 A Max Continuous (Cont'd)										
1	2N6488	2N6491	80	20/150	5.0	1.3	5.0	5.0	75	TO-220
2	2N6577*		90	2K/20K	4.0	4.0	15	10	120	TO-3
I_C = 16.0 A Max Continuous										
3	2N5629		100	25/100	8.0	1.0	10	0.5	200	TO-3
4		2N6029	100	25/100	8.0	2.0	16	1.0	200	TO-3
5	2N5630		120	20/80	8.0	1.0	10	0.5	200	TO-3
6		2N6030	120	20/80	8.0	2.0	16	1.0	200	TO-3
7	2N5631		140	15/60	8.0	1.0	10	0.5	200	TO-3
8		2N6031	140	15/60	8.0	2.0	16	1.0	200	TO-3
I_C = 20.0 A Max Continuous										
9	2N3772		60	15/60	10	1.4	10	0.2	150	TO-3
10	2N5885	2N5883	60	20/100	10	1.0	15	4.0	200	TO-3
11	2N6282*	2N6285*	60	750/18K	10	2.0	10	4.0	160	TO-3
12	2N5039		75	20/100	10	1.0	10	60	140	TO-3
13	2N6283*	2N6286*	80	750/18K	10	2.0	10	4.0	160	TO-3
14	2N5886	2N5884	80	20/100	10	1.0	15	4.0	200	TO-3
15	2N5303		80	15/60	10	2.0	20	2.0	200	TO-3
16	2N5038		90	20/100	12	1.0	12	60	140	TO-3
17	2N6284*	2N6287*	100	750/18K	10	2.0	10	4.0	160	TO-3
I_C = 30.0 A Max Continuous										
18	2N3771		40	15/60	15	2.0	15	0.2	150	TO-3
19		2N4398	40	15/60	15	1.0	15	4.0	200	TO-3
20	2N5301		40	15/60	15	2.0	20	2.0	200	TO-3
21		2N4399	60	15/60	15	1.0	15	4.0	200	TO-3
22	2N5302		60	15/60	15	2.0	20	2.0	200	TO-3
23	SE9306	SE9406	60	1000/-	10	2.0	10	4.0	160	TO-3
24	SE9307	SE9407	80	1000/-	10	2.0	10	4.0	160	TO-3
25	MJ802	MJ4502	90	25/100	7.5	0.8	7.5	2.0	200	TO-3
26	SE9308	SE9408	100	1000/-	10	2.0	10	4.0	160	TO-3

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POWER

POWER TRANSISTORS (BY $I_C$max, POLARITY AND ASCENDING V_{CEO}) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	$V_{CE(sat)}$ V Max	@ I_C A	f_T MHz Min(Typ)	P_D(Max) W T_C=25° C	Package No.
I_C = 50.0 A Max Continuous (Cont'd)										
1	2N5685	2N5683	60	15/60	25	1.0	25	2.0	300	TO-3
2	2N5686	2N5684	80	15/60	25	1.0	25	2.0	300	TO-3

POWER SWITCHING TRANSISTORS (BY $I_C$max, POLARITY)

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	Switching Times (Typ) t_{on} μs	t_s μs	t_f μs	@I_C A	P_D W T_C=25°C	Package No.
I_C Max = 1.0 A											
3	2N3440		250	40/160	0.2	0.07	2.2	0.35	0.1	10	TO-39
4	FT47		250	30/150	0.3	0.08	1.8	0.4	1.0	40	TO-220
5	FT48		300	30/150	0.3	0.08	1.8	0.4	1.0	40	TO-220
6	FT49		350	30/150	0.3	0.08	1.8	0.4	1.0	40	TO-220
7	FT50		400	30/150	0.3	0.08	1.8	0.4	1.0	40	TO-220
I_C Max = 3.0 A											
8	2N5839		275	10/50	2.0	0.45	3.0	0.3	2.0	100	TO-3
9	2N5840		350	10/50	2.0	0.45	3.0	0.3	2.0	100	TO-3
I_C Max = 10 A											
10	2N3716		80	50/150	1.0	0.4	.8	0.4	5.0	150	TO-3
11	FT430		300	115/45	2.5	0.5	2.6	0.3	2.5	125	TO-3
12	FT431		325	15/35	2.5	0.5	2.6	0.3	2.5	125	TO-3
13	2N6249		200	10/50	10	0.5	1.0	0.4	10	175	TO-3
14	2N6250		275	8/50	10	0.5	1.0	0.4	10	175	TO-3
15	2N6251		350	6/50	10	0.5	1.0	0.4	10	175	TO-3
16	FT3055	FT2955	60	20/70	4.0	.65/.35	.5/.25	.4/.15	10	70	TO-220
17	2N6386*		40	1K/20K	3.0	0.8	4.0	5.0	3.0	40	TO-220
18	2N6387*		60	1K/20K	5.0	0.8	3.5	5.0	5.0	40	TO-220
19	2N6388*		80	1K/20K	5.0	0.8	3.5	5.0	5.0	40	TO-220

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POWER

POWER SWITCHING TRANSISTORS (BY I_C max, POLARITY) Continued

Item	DEVICE NO. Polarity NPN	PNP	V_{CEO} V Max	h_{FE} Min/Max	@ I_C A	Switching Times t_{on} µs Typ	t_s µs Typ	t_f µs Typ	@I_C A Typ	P_D W T_C=25°C	Package No.
I_C Max = 20 A											
1	2N5038	-	90	20/100	10	0.30	0.75	0.15	10	140	TO-3
2	2N6282*	2N6285*	60	750/18K	10	.8/.6	3.3/2.5	4/1.5	10	160	TO-3
3	2N6283*	2N6286*	80	750/18K	10	.8/.6	3.3/2.5	4/1.5	10	160	TO-3
4	2N6284*	2N6287*	100	750/18K	10	.8/.6	3.3/2.5	4/1.5	10	160	TO-3
I_C Max = 30 A											
5	2N5301	2N4398	40	15/60	15	.35/.3	1.2/.7	.5/.4	10	200	TO-3

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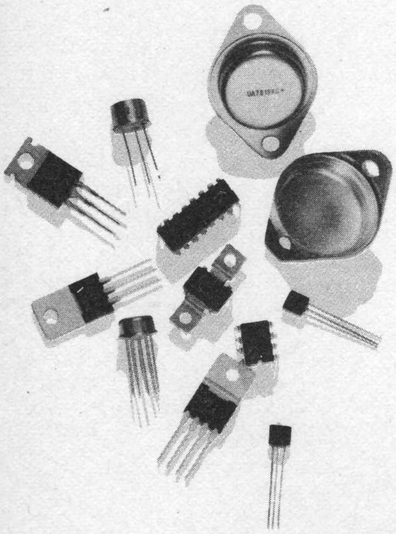

SELECTION GUIDES AND INDUSTRY CROSS REFERENCE

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THERMAL CONSIDERATIONS

Chapter 6
THERMAL CONSIDERATIONS

To fully utilize the various available regulator packages, sufficient attention must be paid to proper heat removal. For efficient thermal management, the user must rely on important parameters supplied by the manufacturer, such as junction-to-case and junction-to-ambient thermal resistance and maximum operating junction temperature. The device temperature depends on the power dissipation level, the means for removing the heat generated by this power dissipation and the temperature of the body (heat sink) to which this heat is removed.

Figure 6-1 shows a simplified equivalent circuit for a typical semiconductor device in equilibrium. The power dissipation, which is analogous to current flow in electrical terms, is caused by a heat source similar to a voltage source. Temperature is analogous to voltage potential and thermal resistance to ohmic resistance. Extending the analogy of Ohm's law to

$$\theta_{JA(tot)} = \theta_{JC} + \theta_{CS} + \theta_{SA} = \left| \frac{T_J - T_A}{P_D} \right.$$

Thermal resistance, then, is the rise in the temperature of a package above some reference level per unit of power dissipation in that package, usually expressed in degrees centigrade per watt. The reference temperature may be ambient or it may be the temperature of a heat sink to which the package is connected. There are several factors that affect thermal resistance including die size, the size of the heat source on the die (series-pass transistor in an IC regulator), die-attach material and thickness, leadframe material, construction and thickness.

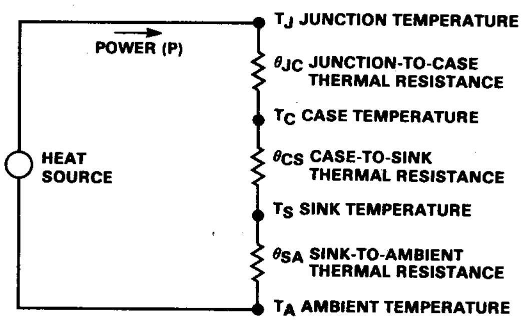


Fig. 6-1. Simplified Thermal Circuit

THERMAL EVALUATION OF REGULATORS

To measure thermal resistance, the difference between the junction temperature and the chosen reference temperature, case, sink or ambient, must be determined. Ambient or sink temperature measurement is straightforward. For case-temperature measurement, the device should have a sufficiently large heat sink and the power level should be close to the specified rating of the package-die combination. The case or tab temperature can be measured by an infrared microradiometer or by using a thermocouple soldered to a point in the center of the case or tab at the tab-heat-sink interface as close to the die as practical.

Measurement of the junction temperature, unfortunately, is not as simple and involves some calibrations. There are several methods available for junction-temperature measurement; the two most commonly used are described here.

Thermal Shutdown Method

With this method, the thermal shutdown temperature of each device is used as the thermometer in determining the thermal resistance. The device is first heated externally, with as little internal power dissipation as practical, until it reaches thermal shutdown. Then, with the device mounted on a heat sink, the regulator is powered externally until it reaches thermal shutdown again. With some packages, the ambient of the device and its heat sink may have to be elevated sufficiently to force the regulator into shutdown. The thermal resistance of the device can then be calculated by using

$$\theta_{JC} = \frac{T_J - T_C}{P_D}$$

where θ_{JC} is the junction-to-case thermal resistance
T_J is the measured thermal shutdown temperature
T_C is the measured case temperature
P_D is the power dissipated to force the device into shutdown and is equal to

$$(V_{IN} - V_{OUT})\, I_{OUT} + V_{IN}\, I_Q$$

I_Q is the quiescent current of the device and can be neglected for low thermal resistance packages such as the TO-3 and TO-220.

Substrate or Isolation Diode Method

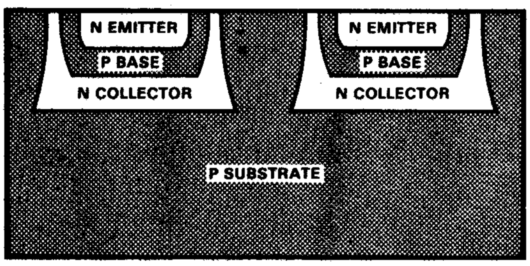
The second method of thermal-resistance measurement utilizes the isolation diodes within the integrated circuits as temperature sensing element*. Under normal operating conditions, the substrate diodes are reverse biased and separate or "isolate" active as well as passive components within an integrated circuit. (See *Figure 6-2*). When the regulator is reverse biased and a constant current is forced through the device between the input terminal and ground, the substrate diodes become forward biased; naturally, when the forward drop is measured, the diode with the highest temperature (lowest forward drop) is detected. Measurement of the thermal resistance of the regulator then involves two steps:

Calibrating the substrate diode at a fixed I_{SUBS} level in an oven or bath at two temperatures, preferably near the device operating junction temperature. It is assumed that this voltage drop changes linearly with temperature.

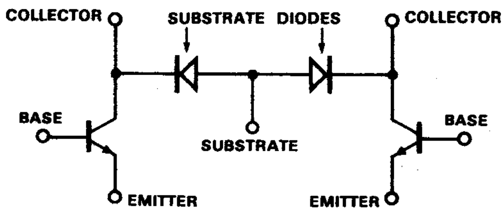
Measuring the junction temperature. The device is powered through a switching circuit S1 at a duty cycle greater than 99% (*Figure 6-3*); thus the device is electrically heated until it reaches equilibrium. During short measuring intervals (< 1% duty cycle), the switching circuit de-energizes the device and the forward drop of the substrate diode is measured at the previously calibrated I_{SUBS} current level. This voltage drop must be measured as soon as possible (several microseconds) after the

*For more detailed explanation of this method, see Fairchild Application Note 205, "Thermal Evaluation of Integrated Circuits". For μA723 thermal considerations, see page 3-29.

removal of the power pulse to avoid inaccurate readings due to cooling of the chip. Diode D1 prevents reverse current from flowing through the load resistor R_L during the substrate-diode measuring interval. Since the change in the isolation diode drop is assumed to be linear with temperature, the measured voltage drop can be converted to its corresponding junction temperature by interpolation or extrapolation. Thermal resistance can then be calculated by the same formula used in the thermal-shutdown method.



Cross-sectional Diagram Showing Two Monolithic Transistors Isolated by Substrate Diodes



Equivalent Circuit

Fig. 6-2 Monolithic Transistor Isolation

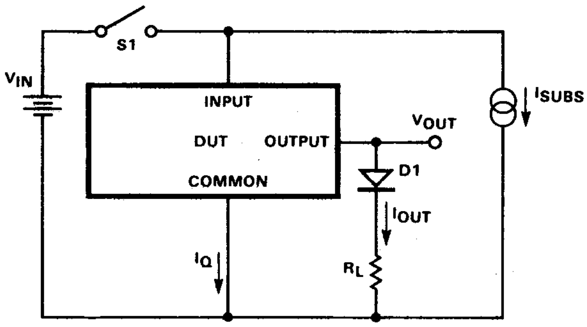


Fig. 6-3. Thermal Resistance Measurement Circuit Using Substrate Diode Technique

6

HEAT SINK REQUIREMENTS

When is a heat sink necessary, and what type of a heat sink should one use? The answers to these questions depend on reliability and cost requirements. Heat sinking is necessary to keep the operating junction temperature T_J of the regulator below the specified maximum value. Since semiconductor reliability improves as operating junction temperature is lowered, a reliability/cost compromise is usually made in the device design.

Table 6-1 is a tabulation by package of the various regulators available from Fairchild. It also lists the average and maximum values of thermal resistance for the regulator chip-package combinations and can be used as a guide in selecting a suitable package when designing a regulator circuit.

Thermal characteristics of voltage-regulator chips and packages determine that some form of heat sinking is mandatory whenever the power dissipation exceeds the following.

0.67 W for the TO-39 package
0.69 W for the TO-92 package
1.56 W for the Mini Batwing and Power Watt (similar to TO-202) packages
1.8 W for the TO-220 package
2.8 W for the TO-3 package

at 25°C ambient or lower power levels at ambients above 25°C.

To choose or design a heat sink, the designer must determine the following regulator parameters.

$P_{D(max)}$ – Maximum power dissipation: $(V_{IN} - V_{OUT}) I_{OUT} + V_{IN} I_Q$

$T_{A(max)}$ – Maximum ambient temperature the regulator will encounter during operation.

$T_{J(max)}$ – Maximum operating junction temperature, specified by the manufacturer.

θ_{JC}, θ_{JA} – Junction-to-case and junction-to-ambient thermal resistance values, also specified by the regulator manufacturer.

θ_{CS} – Case-to-heat-sink thermal resistance which, for large packages, can range from about 0.2°C/W to about 1°C/W depending on the quality of the contact between the package and the heat sink.

θ_{SA} – Heat-sink-to-ambient thermal resistance, specified by heat-sink manufacturer.

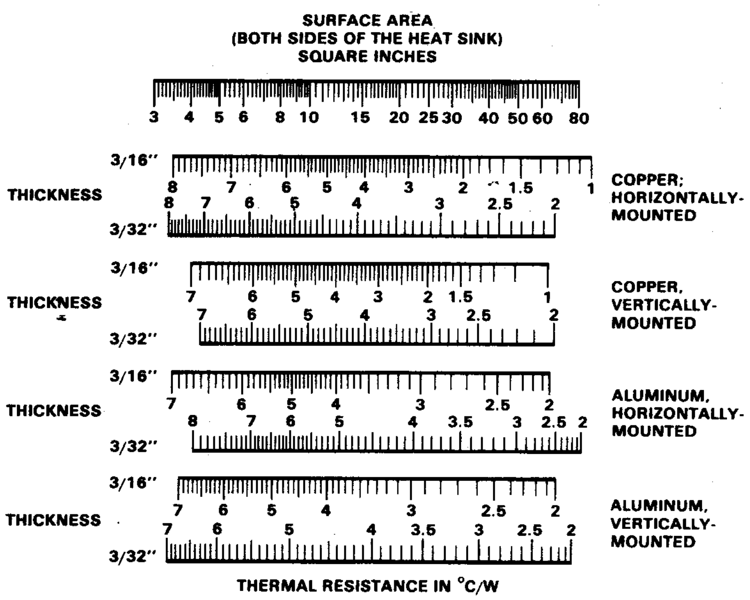
Maximum permissible dissipation without a heat sink is determined by

$$P_{D(max)} = \frac{T_{J(max)} - T_{A(max)}}{\theta_{JA}}$$

If the device dissipation P_D exceeds this figure, a heat sink is necessary. The total required thermal resistance may then be calculated.

$$\theta_{JA(tot)} = \theta_{JC} + \theta_{CS} + \theta_{SA} = \frac{T_{J(max)} - T_{A(max)}}{P_D}$$

Case-to-sink and sink-to-ambient thermal resistance information on commercially available heat sinks is normally provided by the heat sink manufacturer. A summary of some commercially available heat sinks is shown in *Table 6-2*. However, if a chassis or other conventional surface is used as a heat sink, *Figure 6-4* can be used as a guide to estimate the required surface area.



NOTE:
To determine either area required or thermal resistance of a given area, draw a vertical line between the top (or area) line down to the material of interest.

Fig. 6-4. Heat Sink Material Selection Guide

How to Choose a Heat Sink – Example

Determine the heat sink required for a regulator which has the following system requirements:

Operating ambient temperature range: 0°C–60°C
Maximum junction temperature: 125°C
Maximum output current: 800 mA
Maximum input to output differential: 10 V

From *Table 6-1*, the choice is narrowed down to the μA7800 family, available in TO-3 and TO-220 packages. The TO-220 package is sufficient (lower cost, better thermal resistance).

θ_{JC} = 5°C/W maximum (from data sheet or *Table 6-1*)

$$\theta_{JA(tot)} = \theta_{JC} + \theta_{CS} + \theta_{SA} = \frac{T_J - T_A}{P_D}$$

$$\theta_{CS} + \theta_{SA} = \frac{125 - 60}{0.8 \times 10} - 5 = 3.13°C/W$$

Assuming θ_{CS} = 0.13°C/W then θ_{SA} = 3°C/W

This thermal resistance value can be achieved by using either 22 square inches of 3/16 inch thick vertically mounted aluminum (*Figure 6-4*) or a commercial heat sink (*Table 6-2*).

Tips for Better Regulator Heat Sinking

Avoid placing heat-dissipating components such as power resistors next to regulators.

When using low dissipation packages such as TO-5, TO-39, and TO-92, keep lead lengths to a minimum and use the largest possible area of the printed board traces or mounting hardware to provide a heat dissipation path for the regulator.

When using larger packages, be sure the heat sink surface is flat and free from ridges or high spots. Check the regulator package for burrs or peened-over corners. Regardless of the smoothness and flatness of the package and heat-sink contact, air pockets between them are unavoidable unless a lubricant is used. Therefore, for good thermal conduction, use a thin layer of thermal lubricant such as Dow Corning DC-340, General Electric 662 or Thermacote by Thermalloy.

In some applications, especially with negative regulators, it is desirable to electrically insulate the regulator case from the heat sink. Hardware kits for this purpose are commercially available for such packages as the TO-3 and TO-220. They generally consist of a 0.003 to 0.005 inch thick piece of mica or bonded fiberglass to electrically isolate the two surfaces, yet provide a thermal path between them. As expected, the thermal resistance will increase but, as in the direct metal-to-metal joint, some improvement can be realized by using thermal lubricant on each side of the mica.

If the regulator is mounted on a heat sink with fins, the most efficient heat transfer takes place when the fin is in a vertical plane, as this type of mounting forces the heat transfer from fin to air in a combination of radiation and convection.

If it is necessary to bend any of the regulator leads, handle them carefully to avoid straining the package. Furthermore, lead bending should be restricted since repeated bending will fatigue and eventually break the leads.

TABLE 6-1 THERMAL RESISTANCE (θ_{JC}, θ_{JA}) BY DEVICE AND PACKAGE*

RESISTANCES LISTED AS FOLLOWS:
$\theta_{JC(TYP)}$ $\theta_{JC(MAX)}$
$\theta_{JA(TYP)}$ $\theta_{JA(MAX)}$ in °C/W

REG. TYPE	DEVICE NO./SERIES	I_{OUT} (A)	TO-3 K	4-LEAD TO-3 K	TO-220 U	MINI BATWING T2	POWER WATT U1*	TO-39 H	4-LEAD TO-39 H	TO-92 W	TO-99 8-LEAD TO-5 H	TO-100 10-LEAD TO-5 H	TO-116 14-PIN PLASTIC D	TO-116 14-PIN CERAMIC D	8 PIN MINIDIP T
POS. 3-TERM.	μA78LXX	0.1						20 40 140 190		- - 160 180					
	μA78MXX	0.5			3.0 5.0 62 70			18 25 120 185							
	μA78CXX	0.5					6 8 75 80								
	μA109, μA209, μA309, 5 V	1	3.5 5.5 40 45												
	μA78XX	1	3.5 5.5 40 45		3.0 5.0 60 65										
	μA78CB	2	3.5 5.5 40 45		3.0 5.0 60 65										
	78H05, 5V	5	1.5 2.0 37 40												
	μA78HXX	5	2.0 2.5 32 38												
NEG. 3-TERM.	μA79MXX	0.5			3.0 5.0 62 70			18 25 120 185							
	μA79XX	1	3.5 5.5 40 45		3.0 5.0 60 65										
POS. ADJ.	μA105/305/376	0.012 to 0.045									25 40 150 190				- - 160 190
	μA723	0.125										25 50 150 190	- - 150 190	- - 125 160	
	μA78MG 4-TERM.	0.5				7.5 11 75 80	6 8 75 80		18 25 125 185						
	μA78G 4-TERM.	1		4.0 6.0 44 47			6 8 75 80								
	μA78HG	5	2.0 2.5 32 38												
NEG. ADJ.	μA104/304	0.020										25 50 150 190			
	μA79MG 4-TERM.	0.5				7.5 11 75 80	6 8 75 80		18 25 125 185						
	μA79G 4-TERM.	1		4.0 6.0 44 47			6 8 75 80								

*Similar to TO-202

TABLE 6-2
HEAT SINK SELECTION GUIDE

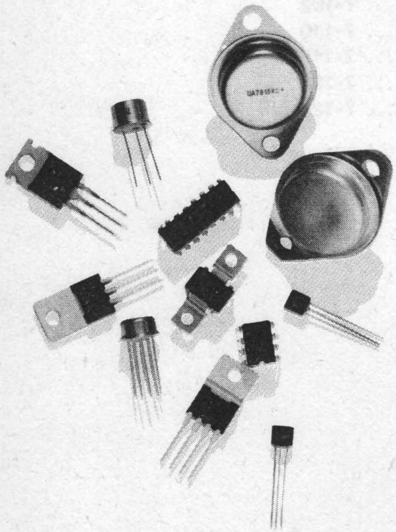
This list is only representative. No attempt has been made to provide a complete list of all heat sink manufacturers. All values are typical as given by manufacturer or as determined from characteristic curves supplied by manufacturer.

θ_{SA} Approx. (°C/W)	Manufacturer and Type
	TO-3 Packages
0.4 (9" length)	Thermalloy (Extruded) 6590 Series
0.4 − 0.5 (6" length)	Thermalloy (Extruded) 6660, 6560 Series
0.56 − 3.0	Wakefield 400 Series
0.6 (7.5" length)	Thermalloy (Extruded) 6470 Series
0.7 − 1.2 (5 − 5.5" length)	Thermalloy (Extruded) 6423, 6443, 6441, 6450 Series
1.0 − 5.4 (3" length)	Thermalloy (Extruded) 6427, 6500, 6123, 6401, 6403, 6421, 6463, 6176, 6129, 6141, 6169, 6135, 6442 Series
1.9	IERC E2 Series (Extruded)
2.1	IERC E1, E3 Series (Extruded)
2.3 − 4.7	Wakefield 600 Series
4.2	IERC HP3 Series
4.5	Staver V3-5-2
4.8 − 7.5	Thermalloy 6001 Series
5 − 6	IERC HP3 Series
5 − 10	Thermalloy 6013 Series
5.6	Staver V3-3-2
5.9 − 10	Wakefield 680 Series
6	Wakefield 390 Series
6.4	Staver V3-7-224
6.5 − 7.5	IERC UP Series
8	Staver V1-5
8.1	Staver V3-5
8.8	Staver V3-7-96
9.5	Staver V3-3
9.5 − 10.5	IERC LA Series
9.8 − 13.9	Wakefield 630 Series
10	Staver V1-3
11	Thermalloy 6103, 6117 Series
	TO-220 Packages (See Note 1)
4.2	IERC HP3 Series
5 − 6	IERC HP1 Series
6.4	Staver V3-7-225
6.5 − 7.5	IERC VP Series
7.1	Thermalloy 6070 Series
8.1	Staver V3-5
8.8	Staver V3-7-96
9.5	Staver V3-3
10	Thermalloy 6032, 6034 Series
12.5 − 14.2	Staver V4-3-192
13	Staver V5-1
15	Thermalloy 6030 Series
15.1 − 17.2	Staver V4-3-128
16	Thermalloy 6072, 6106 Series
18	Thermalloy 6038, 6107 Series
19	IERC PB Series
20	Staver V6-2
20	Thermalloy 6025 Series
25	IERC PA Series

1. Most TO-3 heat sinks can also be used with TO-220 packages with appropriate hole patterns.
2. Most TO-220 heat sinks can be used with the Power Watt package.

θ_{SA} Approx. (°C/W)	Manufacturer and Type
	TO-92 Packages
30	Staver F2-7
46	Staver F5-7A, F5-8-1
50	IERC RUR Series
57	Staver F5-7D
65	IERC RU Series
72	Staver F1-7
85	Thermalloy 2224 Series
	Mini Batwing
10	Thermalloy 6069 Series
10.6	Thermalloy 6068 Series
11.7	Thermalloy 6067 Series
13	Thermalloy 6066 Series
20	Thermalloy 6062 Series
26	Thermalloy 6064 Series
	TO-5 and TO-39 Packages
12	Thermalloy 1101, 1103 Series
12 − 16	Wakefield 260-5 Series
15	Staver V3A-5
22	Thermalloy 1116, 1121, 1123 Series
22	Thermalloy 1130, 1131, 1132 Series
24	Staver F5-5C
25	Thermalloy 2227 Series
26 − 30	IERC Thermal Links
27 − 83	Wakefield 200 Series
28	Staver F5-5B
34	Thermalloy 2228 Series
35	IERC Clip Mount Thermal Link
39	Thermalloy 2215 Series
41	Thermalloy 2205 Series
42	Staver F5-5A
42 − 65	Wakefield 296 Series
46	Staver F6-5, F6-5L
50	Thermalloy 2225 Series
50 − 55	IERC Fan Tops
53	Thermalloy 2211 Series
55	Thermalloy 2210 Series
56	Thermalloy 1129 Series
58	Thermalloy 2230, 2235 Series
60	Thermalloy 2226 Series
68	Staver F1-5
72	Thermalloy 1115 Series
	Power Watt (similar to TO-202) Packages (See Note 2)
12.5 − 14.2	Staver V4-3-192
13	Thermalloy 6063 Series
13	Staver V5-1
15.1 − 17.2	Staver V4-3-128
19	Thermalloy 6106 Series
20	Staver V6-2
24	Thermalloy 6047 Series
25	Thermalloy 6107 Series
37	IERC PA1-7CB with PVC-1B Clip
40 − 42	Staver F7-3
40 − 43	Staver F7-2
42	IERC PA2-7CB with PVC-1B Clip
42 − 44	Staver F7-1

IERC: 135 W. Magnolia Blvd., Burbank, CA 91502
Staver Co. Inc.: 41-51 N. Saxon Ave., Bay Shore, N.Y. 11706
Thermalloy Inc.: 2021 W. Valley View Lane, Dallas, TX 75234
Wakefield Engineering, Inc.: Audubon Rd., Wakefield, MA 01880



VOLTAGE REGULATOR DATA SHEETS

μA78L00 SERIES

3-TERMINAL POSITIVE VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

GENERAL DESCRIPTION – The μA78L00 series of 3-Terminal Positive Voltage Regulators is constructed using the Fairchild Planar* epitaxial process. These regulators employ internal current limiting and thermal shutdown, making them essentially indestructible. If adequate heat sinking is provided, they can deliver up to 100 mA output current. They are intended as fixed voltage regulators in a wide range of applications including local or on card regulation for elimination of noise and distribution problems associated with single point regulation. In addition, they can be used with power pass elements to make high current voltage regulators. The μA78L00 used as a Zener diode/resistor combination replacement, offers an effective output impedance improvement of typically two orders of magnitude, along-with lower quiescent current and lower noise.

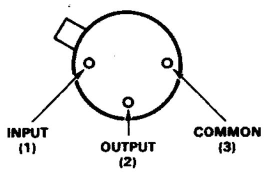
- **OUTPUT CURRENT UP TO 100 mA**
- **NO EXTERNAL COMPONENTS**
- **INTERNAL THERMAL OVERLOAD PROTECTION**
- **INTERNAL SHORT CIRCUIT CURRENT LIMITING**
- **AVAILABLE IN JEDEC TO-92 AND LOW PROFILE TO-39 PACKAGES**
- **OUTPUT VOLTAGES OF 2.6 V, 5 V, 6.2 V, 8.2 V, 9 V, 12 V, 15 V, 18 V and 24 V**
- **OUTPUT VOLTAGE TOLERANCES OF ±5% OVER THE TEMPERATURE RANGE**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	
2.6 V to 15 V	35 V
18 V to 24 V	40 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	
Metal Can (TO-39 Type)	−65°C to +150°C
Molded TO-92	−55°C to +150°C
Operating Junction Temperature Ranges	
μA78L00C (Commercial)	0°C to +150°C
μA78L00V (Vehicular-Automotive)	−40°C to +150°C
Lead Temperatures	
Metal Can (Soldering, 60 s)	300°C
Molded TO-92 (Soldering, 10 s)	260°C

CONNECTION DIAGRAM

TO-39 TYPE METAL CAN
(TOP VIEW)

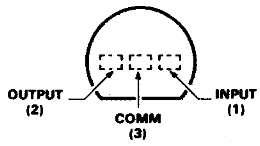


ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
2.6 V	μA78L26AC	μA78L26AHC
5.0 V	μA78L05AC	μA78L05AHC
6.2 V	μA78L62AC	μA78L62AHC
8.2 V	μA78L82AC	μA78L82AHC
9.0 V	μA78L09AC	μA78L09AHC
12 V	μA78L12AC	μA78L12AHC
15 V	μA78L15AC	μA78L15AHC
18 V	μA78L18AC	μA78L18AHC
24 V	μA78L24AC	μA78L24AHC

CONNECTION DIAGRAM

JEDEC (TO-92) PACKAGE
(TOP VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
2.6 V	μA78L26AC	μA78L26AWC
5.0 V	μA78L05AC	μA78L05AWC
6.2 V	μA78L62AC	μA78L62AWC
8.2 V	μA78L82AC	μA78L82AWC
9.0 V	μA78L09AC	μA78L09AWC
12 V	μA78L12AC	μA78L12AWC
15 V	μA78L15AC	μA78L15AWC
18 V	μA78L18AC	μA78L18AWC
24 V	μA78L24AC	μA78L24AWC
2.6 V	μA78L26AV	μA78L26AWV
5.0 V	μA78L05AV	μA78L05AWV
6.2 V	μA78L62AV	μA78L62AWV
8.2 V	μA78L82AV	μA78L82AWV
9.0 V	μA78L09AV	μA78L09AWV
12 V	μA78L12AV	μA78L12AWV
15 V	μA78L15AV	μA78L15AWV
18 V	μA78L18AV	μA78L18AWV
24 V	μA78L24AV	μA78L24AWV

*Planar is a patented Fairchild process.

μA78L26AC and μA78L26AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 9.0 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		2.5	2.6	2.7	V
Line Regulation		T_J = 25°C	4.75 V ≤ V_{IN} ≤ 20 V		40	100	mV
			5 V ≤ V_{IN} ≤ 20 V		30	75	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		10	50	mV
			1 mA ≤ I_{OUT} ≤ 40 mA		4.0	25	mV
Output Voltage		4.75 V ≤ V_{IN} ≤ 20 V	1 mA ≤ I_{OUT} ≤ 40 mA	2.45		2.75	V
			1 mA ≤ I_{OUT} ≤ 70 mA	2.45		2.75	V
Quiescent Current		T_J = 25°C			3.6	6.0	mA
		T_J = 125°C				5.5	mA
Quiescent Current Change	with line	5 V ≤ V_{IN} ≤ 20 V				2.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			30		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			−0.4		mV/°C
Ripple Rejection		f = 120 Hz, 6 V ≤ V_{IN} ≤ 16 V, T_J = 25°C		43	51		dB
Dropout Voltage		T_J = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C			140		mA

μA78L05AC and μA78L05AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 10 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		4.8	5.0	5.2	V
Line Regulation		T_J = 25°C	7 V ≤ V_{IN} ≤ 20 V		55	150	mV
			8 V ≤ V_{IN} ≤ 20 V		45	100	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		11	60	mV
			1 mA ≤ I_{OUT} ≤ 40 mA		5.0	30	mV
Output Voltage		7 V ≤ V_{IN} ≤ 20 V	1 mA ≤ I_{OUT} ≤ 40 mA	4.75		5.25	V
			1 mA ≤ I_{OUT} ≤ 70 mA	4.75		5.25	V
Quiescent Current		T_J = 25°C			3.8	6.0	mA
		T_J = 125°C				5.5	mA
Quiescent Current Change	with line	8 V ≤ V_{IN} ≤ 20 V				1.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			40		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			−0.65		mV/°C
Ripple Rejection		f = 120 Hz, 8 V ≤ V_{IN} ≤ 18 V, T_J = 25°C		41	49		dB
Dropout Voltage		T_J = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C			140		mA

μA78L62AC and μA78L62AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 12 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		5.95	6.2	6.45	V
Line Regulation		T_J = 25°C	8.5 V ≤ V_{IN} ≤ 20 V		65	175	mV
			9 V ≤ V_{IN} ≤ 20 V		55	125	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		13	80	mV
			1 mA ≤ I_{OUT} ≤ 40 mA		6.0	40	mV
Output Voltage		8.5 V ≤ V_{IN} ≤ 20 V	1 mA ≤ I_{OUT} ≤ 40 mA	5.90		6.5	V
			1 mA ≤ I_{OUT} ≤ 70 mA	5.90		6.5	V
Quiescent Current		T_J = 25°C			3.9	6.0	mA
		T_J = 125°C				5.5	mA
Quiescent Current Change	with line	9.0 V ≤ V_{IN} ≤ 20 V				1.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			50		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			–0.75		mV/°C
Ripple Rejection		f = 120 Hz, 10 V ≤ V_{IN} ≤ 20 V, T_J = 25°C		40	46		dB
Dropout Voltage		T_J = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C			140		mA

μA78L82AC and μA78L82AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 14 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		7.87	8.2	8.53	V
Line Regulation		T_J = 25°C	11 V ≤ V_{IN} ≤ 23 V		80	175	mV
			12 V ≤ V_{IN} ≤ 23 V		70	125	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		15	80	mV
			1 mA ≤ I_{OUT} ≤ 40 mA		8.0	40	mV
Output Voltage		11 V ≤ V_{IN} ≤ 23 V	1 mA ≤ I_{OUT} ≤ 40 mA	7.8		8.5	V
			1 mA ≤ I_{OUT} ≤ 70 mA	7.8		8.6	V
Quiescent Current		T_J = 25°C			3.9	6.0	mA
		T_J = 125°C				5.5	mA
Quiescent Current Change	with line	12 V ≤ V_{IN} ≤ 23 V				1.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			60		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			–0.8		mV/°C
Ripple Rejection		f = 120 Hz, 12 V ≤ V_{IN} ≤ 22 V, T_J = 25°C		39	45		dB
Dropout Voltage		T_J = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C				140	mA

μA78L09AC and μA78L09AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 15 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		8.64	9.0	9.36	V
Line Regulation		T_J = 25°C	11.5 V ≤ V_{IN} ≤ 24 V		90	200	mV
			13 V ≤ V_{IN} ≤ 24 V		100	150	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		20	90	mV
			1 mA ≤ I_{OUT} ≤ 40 mA		10	45	mV
Output Voltage		11.5 V ≤ V_{IN} ≤ 24 V	1 mA ≤ I_{OUT} ≤ 40 mA	8.55		9.45	V
			1 mA ≤ I_{OUT} ≤ 70 mA	8.55		9.45	V
Quiescent Current		T_J = 25°C			4.2	6.5	mA
		T_J = 125°C				6.0	mA
Quiescent Current Change	with line	11.5 V ≤ V_{IN} ≤ 24 V				1.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz < f < 100 kHz			70		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			−.9		mV/°C
Ripple Rejection		f = 120 Hz, 15 V ≤ V_{IN} ≤ 25 V, T_J = 25°C		38	44		dB
Dropout Voltage		T_J = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C			140		mA

μA78L12AC and μA78L12AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 19 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		11.5	12	12.5	V
Line Regulation		T_J = 25°C	14.5 V ≤ V_{IN} ≤ 27 V		120	250	mV
			16 V ≤ V_{IN} ≤ 27 V		100	200	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		20	100	mV
			1 mA ≤ I_{OUT} ≤ 40 mA		10	50	mV
Output Voltage		14.5 V ≤ V_{IN} ≤ 27 V	1 mA ≤ I_{OUT} ≤ 40 mA	11.4		12.6	V
			1 mA ≤ I_{OUT} ≤ 70 mA	11.4		12.6	V
Quiescent Current		T_J = 25°C			4.2	6.5	mA
		T_J = 125°C				6.0	mA
Quiescent Current Change	with line	16 V ≤ V_{IN} ≤ 27 V				1.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			80		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			−1.0		mV/°C
Ripple Rejection		f = 120 Hz, 15 V ≤ V_{IN} ≤ 25 V, T_J = 25°C		37	42		dB
Dropout Voltage		T_J = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C			140		mA

μA78L15AC and μA78L15AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 23 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		14.4	15	15.6	V
Line Regulation		T_J = 25°C	17.5 V ≤ V_{IN} ≤ 30 V		130	300	mV
			20 V ≤ V_{IN} ≤ 30 V		110	250	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		25	150	mV
			1 mA ≤ I_{OUT} ≤ 40 mA		12	75	mV
Output Voltage		17.5 V ≤ V_{IN} ≤ 30 V	1 mA ≤ I_{OUT} ≤ 40 mA	14.25		15.75	V
			1 mA ≤ I_{OUT} ≤ 70 mA	14.25		15.75	V
Quiescent Current		T_J = 25°C			4.4	6.5	mA
		T_J = 125°C				6.0	mA
Quiescent Current Change	with line	20 V ≤ V_{IN} ≤ 30 V				1.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			90		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			−1.3		mV/°C
Ripple Rejection		f = 120 Hz, 18.5 V ≤ V_{IN} ≤ 28.5 V, T_J = 25°C		34	39		dB
Dropout Voltage		T_J = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C			140		mA

μA78L18AC and μA78L18AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 27 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	LIMITS
Output Voltage		T_J = 25°C		17.3	18	18.7	V
Line Regulation		T_J = 25°C	21 V ≤ V_{IN} ≤ 33 V		45	300	mV
			22 V ≤ V_{IN} ≤ 33 V		35	250	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		30	170	mV
			1 mA ≤ I_{OUT} ≤ 40 mA		15	85	mV
Output Voltage		21 V ≤ V_{IN} ≤ 33 V	1 mA ≤ I_{OUT} ≤ 40 mA	17.1		18.9	V
			1 mA ≤ I_{OUT} ≤ 70 mA	17.1		18.9	V
Quiescent Current		T_J = 25°C			3.1	6.5	mA
		T_J = 125°C				6.0	mA
Quiescent Current Change	with line	21 V ≤ V_{IN} ≤ 33 V				1.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz			150		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			−1.8		mV/°C
Ripple Rejection		f = 120 Hz, 23 V ≤ V_{IN} ≤ 33 V, T_J = 25°C		34	48		dB
Dropout Voltage		T_A = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C			140		mA

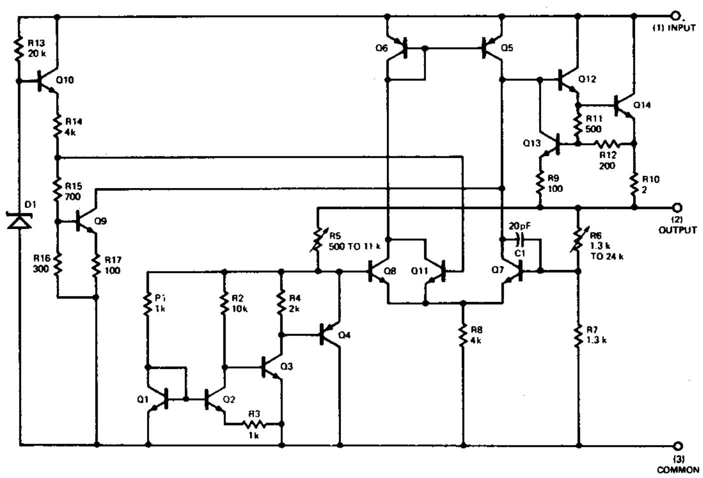
μA78L24AC and μA78L24AV (Note 2)

ELECTRICAL CHARACTERISTICS: V_{IN} = 33 V, I_{OUT} = 40 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified. Note 1

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	LIMITS
Output Voltage		T_J = 25°C		23	24	25	V
Line Regulation		T_J = 25°C	27 V ≤ V_{IN} ≤ 38 V		60	300	mV
			28 V ≤ V_{IN} ≤ 38 V		50	250	mV
Load Regulation		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 100 mA		40	200	mV
		T_J = 25°C	1 mA ≤ I_{OUT} ≤ 40 mA		20	100	mV
Output Voltage		27 V ≤ V_{IN} ≤ 38 V	1 mA ≤ I_{OUT} ≤ 40 mA	22.8		25.2	V
			1 mA ≤ I_{OUT} ≤ 70 mA	22.8		25.2	V
Quiescent Current		T_J = 25°C			3.1	6.5	mA
		T_J = 125°C				6.0	mA
Quiescent Current Change	with line	28 V ≤ V_{IN} ≤ 38 V				1.5	mA
	with load	1 mA ≤ I_{OUT} ≤ 40 mA				0.1	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz (Note 2)			200		μV
Temp. Coef. of V_{OUT}		I_{OUT} = 5 mA			−2.0		mV/°C
Ripple Rejection		f = 120 Hz, 28 V ≤ V_{IN} ≤ 38 V, T_J = 25°C		34	45		dB
Dropout Voltage		T_A = 25°C			1.7		V
Peak Output/Short Circuit Current		T_J = 25°C			140		mA

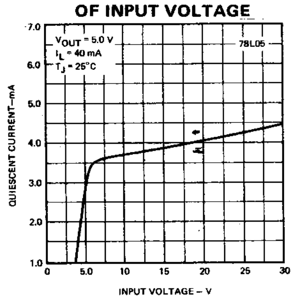
NOTES:
1. The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with junction temperatures as indicated at the initiation of tests.
2. Vehicular product grade is guaranteed to have output voltage tolerance less than ± 8% @ −40°C.

EQUIVALENT CIRCUIT

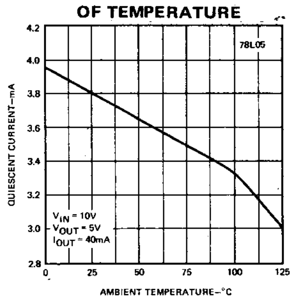


TYPICAL ELECTRICAL PERFORMANCE CURVES

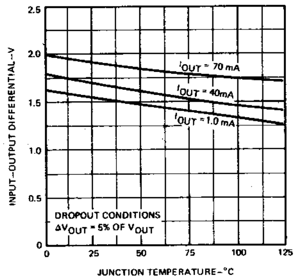
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



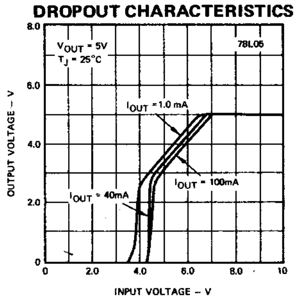
QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE



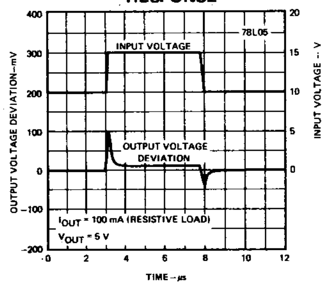
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



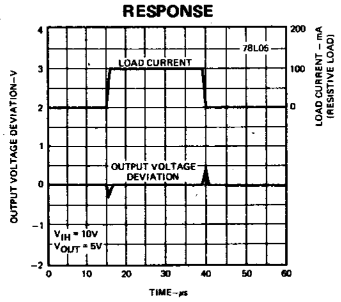
DROPOUT CHARACTERISTICS



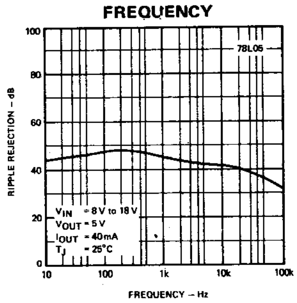
LINE TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE

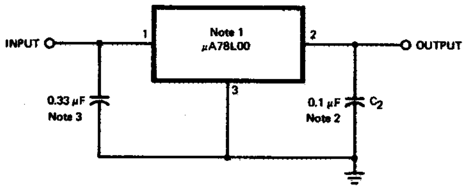


RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



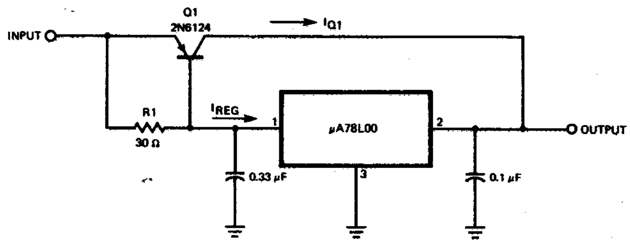
NOTE: Other μA78L00 Series Device have similar curves.

APPLICATIONS



NOTES:
1 To specify an output voltage, substitute voltage value for "XX".
2 Although no output capacitor is needed for stability, it does improve transient response.
3 Required if regulator is located an appreciable distance from power supply filter.

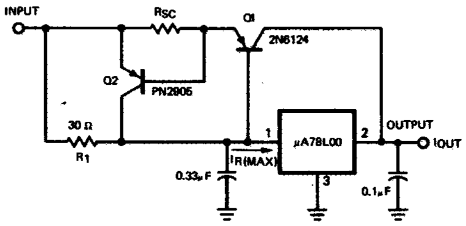
FIXED OUTPUT REGULATOR



For $I_{REG} \approx 23$ mA

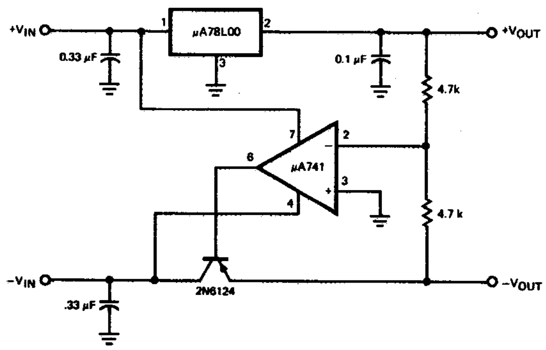
$$I_{REG} = \frac{0.7}{R1} \qquad I_{Q1} = \beta I_{REG}$$

HIGH CURRENT VOLTAGE REGULATOR

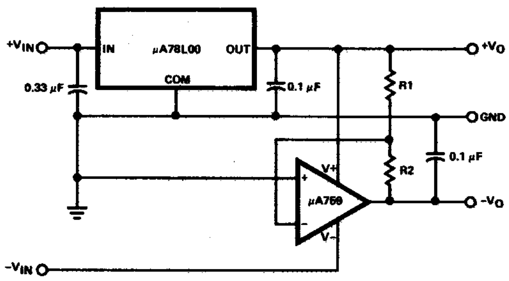


$$R_{SC} = \frac{0.7}{I_{SC}} \qquad R1 = \frac{\beta V_{BE(Q2)}}{I_{R(MAX)}(\beta+1) - I_{OUT(MAX)}}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED

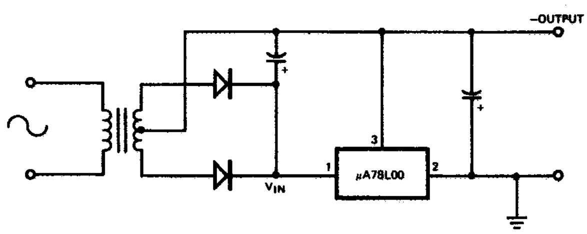


± TRACKING VOLTAGE REGULATOR

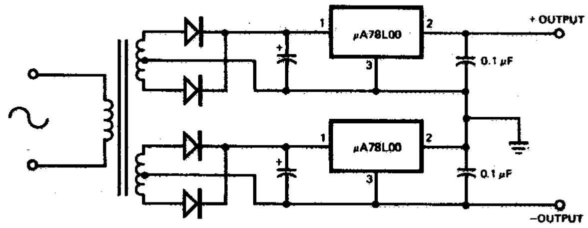


For Symmetrical Outputs $R_1 = R_2$
$+I_{OUT} > 100$ mA
$-I_{OUT} > 250$ mA

DUAL TRACKING SUPPLY USING A 78L00 REGULATOR WITH A POWER OP AMP



NEGATIVE OUTPUT VOLTAGE CIRCUIT



POSITIVE AND NEGATIVE REGULATOR

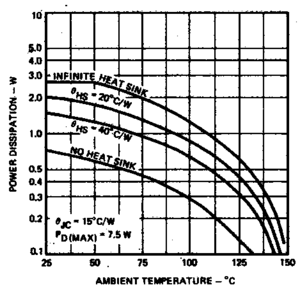
DESIGN CONSIDERATIONS

The μA78L series regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across each pass transistor is increased.

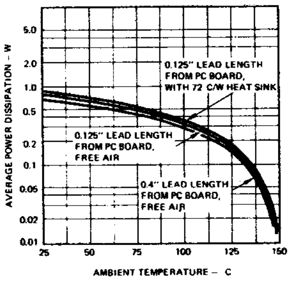
Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (125°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	Typ θ_{JC}	Max θ_{JC}	Typ θ_{JA}	Max θ_{JA}
TO-39	20	40	140	190
TO-92			180	190

TO-39
WORST CASE POWER
DISSIPATION VERSUS
AMBIENT TEMPERATURE



TO-92
WORST CASE POWER
DISSIPATION VERSUS
AMBIENT TEMPERATURE



THERMAL CONSIDERATIONS

The TO-92 molded package manufactured by Fairchild is capable of unusually high power dissipation due to the lead frame design. However, its thermal capabilities are generally overlooked because of a lack of understanding of the thermal paths from the semiconductor junction to ambient temperature. While thermal resistance is normally specified for the device mounted 1 cm above an infinite heat sink, very little has been mentioned of the options available to improve on the conservatively rated thermal capability.

An explanation of the thermal paths of the TO-92 and comparison of the thermal equivalent circuit of the TO-39 metal package with that of the TO-92 will allow the designer to determine the thermal stress he is applying in any given application.

THE METAL CAN THERMAL MODEL

In the TO-39 case, where the die is attached directly to the base of a metal package, the thermal equivalent circuit is often represented simply as a series connection of the junction-to-case thermal resistance, θ_{JC}, and the case-to-ambient thermal resistance, θ_{CA}, as shown in Figure 1.

In this model, the current source represents the thermal energy source; T_J is the junction temperature, assuming a constant surface temperature across the die; θ_{JC} is the junction-to-case thermal resistance, measured at a point on the case directly beneath the die location; θ_{CA} is the thermal resistance from the case to the ultimate heat sink, ambient temperature, as represented by the battery. The heat flow is analogous to electrical current, and temperature to voltage. The total thermal resistance from junction to ambient is then:

$$\theta_{JA} = \theta_{JC} + \theta_{CA}$$

The maximum power dissipation is a function of the maximum permissible junction temperature (which is a function of the package materials and construction) and the total thermal resistance from the junction to ambient temperature. Junction temperature is assumed to be the limiting factor.

Thus: maximum power dissipation $P_D = \dfrac{T_{J(MAX)} - T_A}{\theta_{JC} + \theta_{CA}}$

Since $\theta_{JA} = \theta_{JC} + \theta_{CA}$

Then $\theta_{JA} = \dfrac{T_{J(MAX)} - T_A}{P_D}$

Or $\theta_{JA} P_D = T_J - T_A$

$$P_D = \frac{T_J - T_A}{\theta_{JA}}$$

Therefore, using the V_{BE} method of junction temperature sensing, and attaching a thermocouple to the case at the location specified, the relative values of θ_{JC} and θ_{CA} can readily be determined.

The thermal ratings of the metal can package are normally presented with the case attached to an infinite heat sink at still air ambient temperature. This causes θ_{CA} to go to zero resulting in θ_{JC} representing the total θ_{JA}. The infinite heat sink is an unrealizable condition in the practical world, but serves to project a goal.

7

THE TO-92 PACKAGE

The TO-92 package thermal paths are considerably more complex than those of the TO-39 metal can package. In addition to the path through the molding compound to ambient temperature, there is another path through the leads, in parallel with the case path, to ambient temperature, as shown in Figure 2.

The total thermal resistance in this model is then:

$$\theta_{JA} = \frac{(\theta_{JC} + \theta_{CA})\,(\theta_{JL} + \theta_{LA})}{\theta_{JC} + \theta_{CA} + \theta_{JL} + \theta_{LA}} \qquad (3)$$

Where: θ_{JC} = thermal resistance of the case between the regulator die and a point on the case directly above the die location.

θ_{CA} = thermal resistance between the case and air at ambient temperature.

θ_{JL} = thermal resistance from transistor die through the collector lead to a point 1/16" below the regulator case.

θ_{LA} = total thermal resistance of the collector-base-emitter leads to ambient temperature.

θ_{JA} = junction to ambient thermal resistance.

As one can see from Figure 1, the metal can package generally does not have the lead cooling path because of the high thermal resistances resulting from the construction of the header, case and leads. Normally, this material is kovar. Now, θ_{JC} and θ_{JL} are within the package and not variable by the user. However, θ_{CA} and θ_{LA} are outside the package and can be effectively used to control the total thermal resistance and, therefore, junction temperature.

Replacing θ_{JA} of equation (1) with θ_{JA} of equation (3) gives:

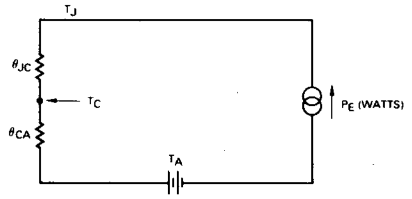
$$\theta_{JA} = \frac{(\theta_{JC} + \theta_{CA})\,(\theta_{JL} + \theta_{LA})}{\theta_{JC} + \theta_{CA} + \theta_{JL} + \theta_{LA}} = \frac{T_J - T_A}{P_D} \qquad (4)$$

The maximum T_J allowed in equation (4) is 150°C. The maximum power dissipation is determined by the net total thermal resistance θ_{JA}, the parallel equivalent networks of the case series path and lead series path, divided into the difference of the maximum junction temperature, 150°C, and ambient temperature generally specified as 25°C. In the case of the 78LXX, the maximum dissipation in a .4 inch condition is:

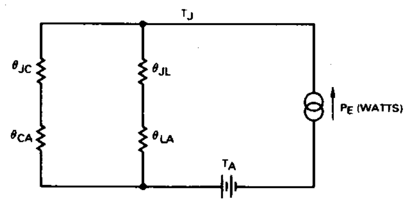
$$P_D = \frac{150-25}{\theta_{JA}}, \ \theta_{JA} = 180°\text{C/W}$$

$$P_D = 0.7\ \text{W}$$

If lead length is reduced to .125 inch θ_{JA} becomes 160°C, and $P_{D(MAX)}$ = 0.78 W.



THERMAL EQUIVALENT CIRCUIT TO-39 PACKAGE (DIE ATTACHED TO METAL PACKAGE BASE)
Fig. 1



TO-92 THERMAL EQUIVALENT CIRCUIT
Fig. 2

METHODS OF HEAT SINKING

With two external thermal resistances in each leg of a parallel network available to the circuit designer as variables, he can choose the method of heat sinking most applicable to his particular situation. To demonstrate, consider the effect of placing a small 72°C/W flag type heat sink, such as the Staver F1-7D-2, on the 78LXX molded case. The heat sink effectively replaces the θ_{CA} (Figure 2) and the new thermal resistance, θ'_{JA}, is:

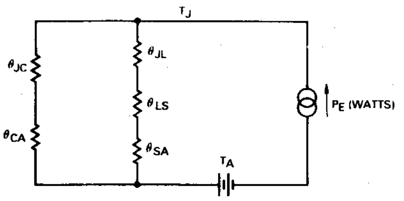
$$\theta'_{JA} = 145°\text{C/W} \quad \text{(assuming .125 inch lead length)}$$

The net change of 15°C/W increases the allowable power dissipation to 0.86 W with an inserted cost of 1-2 cents. A still further decrease in θ_{JA} could be achieved by using a sink rated at 46°C/W, such as the Staver FS-7A. Also, if the case sinking does not provide an adequate reduction in total θ_{JA}, the other external thermal resistance, θ_{LA}, may be reduced by shortening the lead length from package base to mounting medium. However, one point must be kept in mind. The lead thermal path includes a thermal resistance, θ_{SA}, from the leads at the mounting point to ambient, that is, the mounting medium. θ_{LA} is then equal to $\theta_{LS} + \theta_{SA}$. The new model is shown in Figure 3.

In the case of a socket, θ_{SA} could be as high as 270°C/W, thus causing a net increase in θ_{JA} and a consequent decrease in the maximum dissipation capability. Shortening the lead length may return the net θ_{JA} to the original value, but lead sinking would not be accomplished.

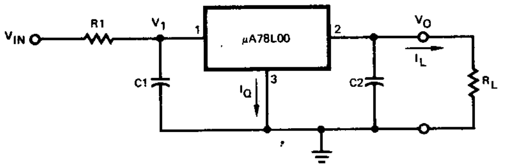
In those cases where the regulator is inserted into a copper clad printed circuit board, it is advantageous to have a maximum area of copper at the entry points of the leads. While it would be desirable to rigorously define the effect of PC board copper, the real world variables are too great to allow anything more than a few general observations.

The best analogy for PC board copper is to compare it with parallel resistors. Beyond some point, additional resistors are not significantly effective; beyond some point, additional copper area is not effective.



TO-92 THERMAL EQUIVALENT CIRCUIT (LEAD AT OTHER THAN AMBIENT TEMPERATURE)
Fig. 3

HIGH DISSIPATION APPLICATIONS



When it is necessary to operate a μA78L00 regulator with a large input-output differential voltage, the addition of series resistor R1 will extend the output current range of the device by sharing the total power dissipation between R1 and the regulator.

R1 may be calculated from

$$R1 = \frac{V_{IN(MIN)} - V_{OUT} - 2.0\ V}{I_{L(MAX)} + I_Q}$$

where I_Q is the regulator quiescent current.

Regulator power dissipation at maximum input voltage and maximum load current is now

$$P_{D(MAX)} = (V_1 - V_{OUT})\ I_{L(MAX)} + V_1\ I_Q$$

where

$$V_1 = V_{IN(MAX)} - (I_{L(MAX)} + I_Q)\ R1$$

The presence of R1 will affect load regulation according to the equation:

load regulation (at constant V_{IN}) = load regulation (at constant V_1) + (line regulation, mV per V) x (R1) x (ΔI_L).

As an example, consider a 15 V regulator with a supply voltage of 30 ±5 V, required to supply a maximum load current of 30 mA. I_Q is 4.3 mA, and minimum load current is to be 10 mA.

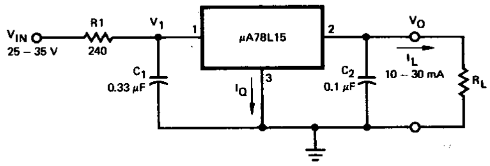
$$R1 = \frac{25 - 15 - 2}{30 + 4.3} = \frac{8}{34.3} \approx 240\ \Omega$$

$$V_1 = 35 - (30 + 4.3).24 = 35 - 8.2 = 26.8\ V$$

$$P_{D(MAX)} = (26.8 - 15)\ 30 + 26.8\ (4.3)$$

$$= 354 + 115$$

= 470 mW, which will permit operation up to 70°C in most applications.



Line regulation of this circuit is typically 110 mV for an input range of 25-35 V at a constant load current, i.e. 11 mV/V.

Load regulation = constant V_1 load regulation (typically 10 mV, 10-30 mA I_L)

\+ (11 mV/V) x 0.24 x 20 mA (typically 53 mV)

= 63 mV for a load current change of 20 mA at a constant V_{IN} of 30 V.

7

μA78C00 SERIES

3-TERMINAL POSITIVE VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

DESCRIPTION — The μA78C00 series is a 3-terminal positive voltage regulator capable of delivering 500mA of output current. It is similar in performance to the popular μA78M00 series but has a zener reference as opposed to a band gap reference. Because of this the μA78C00 has a noise level higher than that of the μA78M00 and is not available in the 5 V and 6 V options.

The μA78C00 employs internal current limiting, thermal shut-down, and safe area compensation that make the part virtually indestructable.

The μA78C00 is intended for use in the low cost consumer applications such as T.V., stereo, etc. and is offered in the plastic Power Watt (similar to TO-202)package.

The fixed voltage series designated 78C00 is available in 10 options form 8-24 V and is capable of delivering 500 mA.

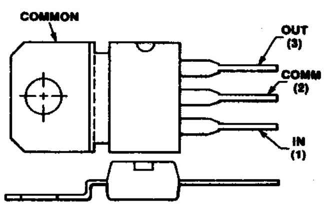
A 0.33 μF decoupling capacitor should be used at the input pin. a 0.1 μF capacitor at the output pin will improve the transient response.

- **OUTPUT CURRENT IN EXCESS OF 0.5 A**
- **EXCELLENT TRANSIENT RESPONSE**
- **1/2% LOAD AND LINE REGULATION**
- **MAX DROPOUT VOLTAGE 2.5 V**
- **THERMAL OVERLOAD PROTECTION**
- **OUTPUT TRANSISTOR SAFE AREA PROTECTION**
- **INTERNAL SHORT CIRCUIT CURRENT LIMIT**
- **LOW OUTPUT IMPEDANCE**

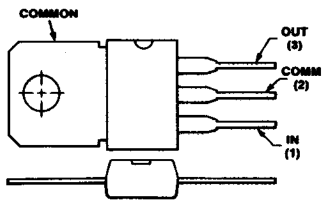
ABSOLUTE MAXIMUM RATINGS

Input Voltage	
(V_O 8 V thru 18 V)	35 V
(V_O 20 V thru 24 V)	40 V
Internal Power Dissipation	Internally Limited
Operating Temperature Range	0°C to +125°C
Maximum Junction Temperature	+150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 s)	230°C
Maximum Power Dissipation (P_D)	7.5 W

CONNECTION DIAGRAMS



U1



U2

ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.*
8.0 V	μA78C08C	μA78C08U1C
8.2 V	μA78C82C	μA78C82U1C
10.0 V	μA78C10C	μA78C10U1C
12.0 V	μA78C12C	μA78C12U1C
15.0 V	μA78C15C	μA78C15U1C
17.0 V	μA78C17C	μA78C17U1C
18.0 V	μA78C18C	μA78C18U1C
20.0 V	μA78C20C	μA78C20U1C
22.0 V	μA78C22C	μA78C22U1C
24.0 V	μA78C24C	μA78C24U1C

*or U2C for stratight heatsink

ELECTRICAL CHARACTERISTICS: I_O = 350 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.3 μF, C_O = 0.1 μF, V_{IN} = V_O + 5 V unless otherwise specified (Note 1)

SYMBOL	CHARACTERISTICS	CONDITIONS	8 V			8.2 V			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	7.7	8.0	8.3	7.9	8.2	8.5	V
		5 mA ≤ I_O ≤ 350 mA 2.5 V ≤ V_{IN} - V_O ≤ 15 V (V_{IN} Max = 35 V)	7.6		8.4	7.8		8.6	V
ΔV_O	Line Regulation	T_J = 25°C, V_{IN} = 11 -21 V V_{IN} = 12 -22 V			40			40	mV
ΔV_O	Load Regulation	T_J = 25°C, 5 mA < I_O < 500 mA			80			85	mV
		T_J = 25°C, 100 mA < I_O < 300 mA			40			40	mV
I_Q	Quiescent Current	T_J = 25°C, I_O = 0		2.5	6.0		2.5	6.0	mA
ΔI_Q	Quiescent Current Change	3 V ≤ V_{IN} - V_O ≤ 13 V			0.8			0.8	mA
		5 mA to 500 mA			0.5			0.5	mA
e_n	Output Noise Voltage	T_J = 25°C, 10 Hz ≤ f ≤ 100 kHz		200			200		μV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	T_J = 25°C, 3 V ≤ V_{IN} -V_O ≤ 13 V (V_{IN} Max = 39 V), f = 120 Hz	46	54		46	54		dB
V_{IN} - V_O	Dropout Voltage	T_J = 25°C, Note 3			2.5			2.5	V
I_{SC}	Short Circuit Current	T_J = 25°C, V_{IN} = 35 V, Note 2		400			400		mA
I_O Max	Peak Output Current	T_J = 25°C, V_{IN} - V_O = 8 V		1.0			1.0		A
$\frac{\Delta V_O}{\Delta T}$	Avg. Temp. Coefficient of Output Voltage			-2.1			-2.2		mV/°C
Cont'd)			10 V			12 V			
V_O	Output Voltage	T_J = 25°C	9.6	10	10.4	11.5	11	12.5	V
		5 mA ≤ I_O ≤ 350 mA 2.5 V ≤ V_{IN} - V_O ≤ 15 V (V_{IN} Max = 35 V)	9.5		10.5	11.4		12.6	V
ΔV_O	Line Regulation	T_J = 25°C, V_{IN} = 13 -23 V V_{IN} = 15 -25 V			50			50	mV
ΔV_O	Load Regulation	T_J = 25°C, 5 mA < I_O < 500 mA			100			120	mV
		T_J = 25°C, 100 mA < I_O < 300 mA			50			60	mV
I_Q	Quiescent Current	T_J = 25°C, I_O = 0		2.5	6.0		2.5	6.0	mA
ΔI_Q	Quiescent Current Change	3 V ≤ V_{IN} - V_O ≤ 13 V			0.8			0.8	mA
		5 mA to 500 mA			0.5			0.5	mA
e_n	Output Noise Voltage	T_J = 25°C, 10 Hz ≤ f ≤ 100 kHz		250			300		μV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	T_J = 25°C, 3 V ≤ V_{IN} - V_O ≤ 13 V (V_{IN} Max = 39 V), f = 120 Hz	46	54		46	54		dB
V_{IN} - V_O	Dropout Voltage	T_J = 25°C, Note 3			2.5			2.5	V
I_{SC}	Short Circuit Current	T_J = 25°C, V_{IN} = 35 V, Note 2		400			400		mA
I_O Max	Peak Output Current	T_J = 25°C, V_{IN} - V_O = 8 V		1.0			1.0		A
$\frac{\Delta V_O}{\Delta T}$	Avg. Temp. Coefficient of Output Voltage			-2.3			-2.3		mV/°C

NOTES:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_W ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.
2. Refer to peak output current vs $\Delta(V_{IN} - V_{OUT})$ curves for temperature relationships.
3. Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.

ELECTRICAL CHARACTERISTICS: I_O = 350 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.3 μF, C_O = 0.1 μF, V_{IN} = V_O + 5 V unless otherwise specified (Note 1)

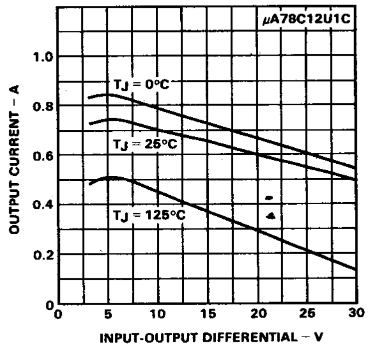
SYMBOL	CHARACTERISTICS	CONDITIONS	15 V			17 V			18 V			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	14.4	15	15.6	16.3	17	17.7	17.3	18	18.7	V
		5 mA ≤ I_O ≤ 350 mA 2.5 V ≤ $V_{IN} - V_O$ ≤ 15 V (V_{IN} Max = 39 V)	14.25		15.75	16.15		17.85	17.1		18.9	V
ΔV_O	Line Regulation	T_J = 25°C, V_{IN} = 20-30 V V_{IN} = 21-31 V V_{IN} = 22-32 V			50			50			50	mV
ΔV_O	Load Regulation	T_J = 25°C, 5 mA < I_O < 500 mA			150			170			180	mV
		T_J = 25°C, 100 mA < I_O < 300 mA			75			85			90	mV
I_Q	Quiescent Current	T_J = 25°C, I_O = 0		2.5	6.0		2.5	6.0		2.5	6.0	mA
ΔI_Q	Quiescent Current Change	3 V ≤ $V_{IN} - V_O$ ≤ 13 V			0.8			0.8			0.8	mA
		5 mA to 500 mA			0.5			0.5			0.5	mA
e_n	Output Noise Voltage	T_J = 25°C, 10 Hz ≤ f ≤ 100 kHz		375			400			450		μV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	T_J = 25°C, 3 V ≤ $V_{IN}-V_O$ ≤ 13 V (V_{IN} Max = 39 V), f = 120 Hz	46	54		46	54		46	54		dB
$V_{IN} - V_O$	Dropout Voltage	T_J = 25°C, Note 3			2.5			2.5			2.5	V
I_{SC}	Short Circuit Current	T_J = 25°C, V_{IN} = 35 V, Note 2		400			400			400		mA
I_OMax	Peak Output Current	T_J = 25°C, $V_{IN} - V_O$ = 8 V		1.0			1.0			1.0		A
$\frac{\Delta V_O}{\Delta T}$	Avg. Temp. Coefficient of Output Voltage			-4.0			-4.5			-4.8		mV/°C

(Cont'd)			20 V			22 V			24 V			
V_O	Output Voltage	T_J = 25°C	19.2	20	20.8	21.1	22	22.9	23	24	25	V
		5 mA ≤ I_O ≤ 350 mA 2.5 V ≤ $V_{IN} - V_O$ ≤ 15 V (V_{IN} Max = 39 V)	19		21	20.9		23.1	22.8		25.2	V
ΔV_O	Line Regulation	T_J = 25°C, V_{IN} = 24-34 V V_{IN} = 26-36 V V_{IN} = 28-38 V			50			50			50	mV
ΔV_O	Load Regulation	T_J = 25°C, 5 mA < I_O < 500 mA			200			220			240	mV
		T_J = 25°C, 100 mA < I_O < 300 mA			100			110			120	mV
I_Q	Quiescent Current	T_J = 25°C, I_O = 0		2.5	6.0		2.5	6.0		2.5	6.0	mA
ΔI_Q	Quiescent Current Change	3 V ≤ $V_{IN} - V_O$ ≤ 13 V			0.8			0.8			0.8	mA
		5 mA to 500 mA			0.5			0.5			0.5	mA
e_n	Output Noise Voltage	T_J = 25°C, 10 Hz ≤ f ≤ 100 kHz		500			550			600		μV
$\frac{\Delta V_{IN}}{\Delta V_O}$	Ripple Rejection	T_J = 25°C, 3 V ≤ $V_{IN}-V_O$ ≤ 13 V (V_{IN} Max = 39 V), f = 120 Hz	46	54		46	54		46	54		dB
$V_{IN} - V_O$	Dropout Voltage	T_J = 25°C, Note 3			2.5			2.5			2.5	V
I_{SC}	Short Circuit Current	T_J = 25°C, V_{IN} = 35 V, Note 2		400			400			400		mA
I_OMax	Peak Output Current	T_J = 25°C, $V_{IN} - V_O$ = 8 V		1.0			1.0			1.0		A
$\frac{\Delta V_O}{\Delta T}$	Avg. Temp. Coefficient of Output Voltage			-5.3			-6.0			-6.4		mV/°C

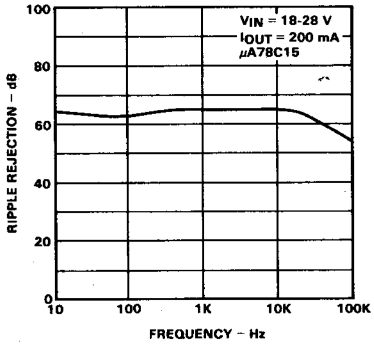
NOTES:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_W ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.
2. Refer to peak output current vs $\Delta(V_{IN} - V_{OUT})$ curves for temperature relationships.
3. Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.

ELECTRICAL PERFORMANCE CURVES

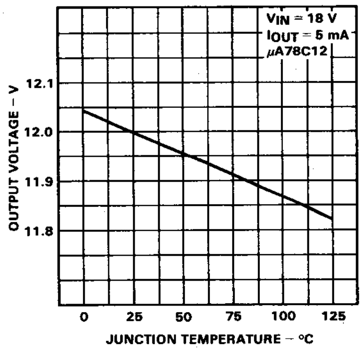
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



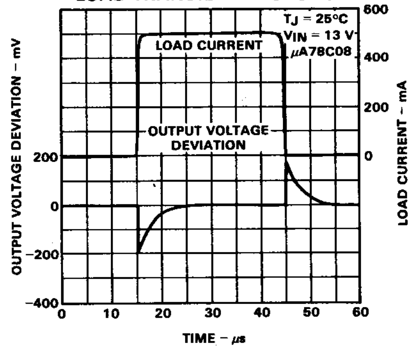
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



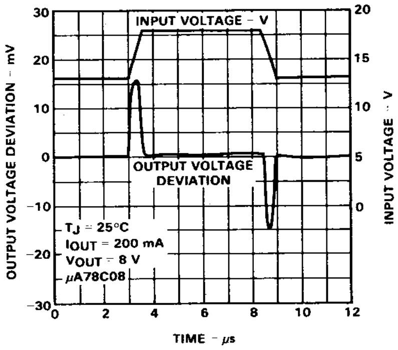
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



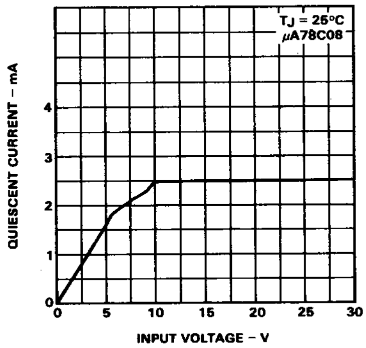
LOAD TRANSIENT RESPONSE



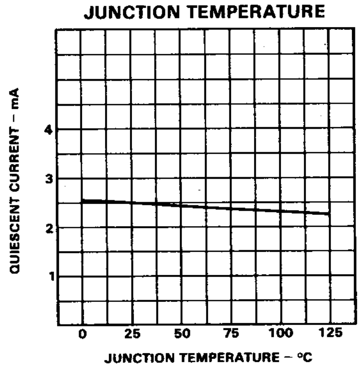
LINE TRANSIENT RESPONSE



QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



QUIESCENT CURRENT AS A FUNCTION OF JUNCTION TEMPERATURE



μA78C00 FIXED VOLTAGE VOLTAGE REGULATOR

Figure 1 shows the equivalent circuit of the μA78C00 regulator. The reference is derived from Zener diode D1 and compensated by the base-emitter voltage of the error amplifier Q4. Additional gain is provided by Q7 and Q8 to the Darlington-connected emitter-follower output stage of Q10 and Q11. The output stage is compensated by capacitor C1. A positive start-up condition is ensured by FET transistor Q1 to provide base current to transistors Q2 and Q5. Q2, Q5 and Q6 then form a positive feedback loop which raises the base voltage of Q2 until the reference Zener D1 conducts. Thermal overload protection is achieved by transistor Q3. The bias to the base-emitter voltage of Q3 is derived from D1 via Q2 and the divider network of R1 and R2. At high junction temperatures, Q3 turns on and removes the drive to the output stage. Current-limit transistor Q9 protects the device against accidental shorts by sensing the voltage drop across R7 while Zener diode D2 along with Q9 and resistors R5, R6 and R7 limit the power dissipation to a safe value.

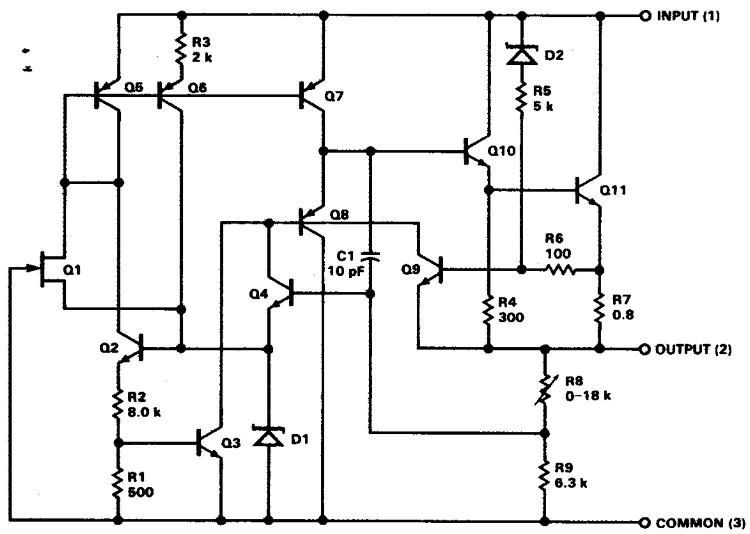
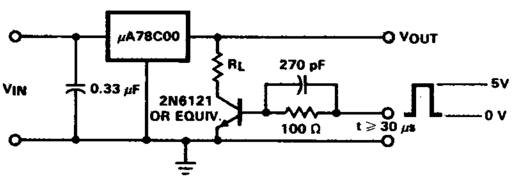
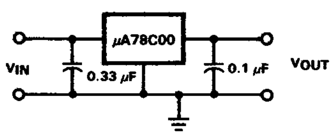


Fig. 1
SCHEMATIC DIAGRAM
FIXED VOLTAGE 3-TERMINAL VOLTAGE REGULATOR

TEST CIRCUITS



LOAD REGULATION TEST CIRCUIT



DC PARAMETER TEST CIRCUIT

DESIGN CONSIDERATIONS

The μA78C00 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation for reducing the output short circuit current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (125°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP θ_{JC}	MAX θ_{JC}	TYP θ_{JA}	MAX θ_{JA}
Power Watt	6.0	8.0	75	80

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_{J(MAX)} - T_A}{\theta_{JA}} \text{ (Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

Solving for T_J: $T_J = T_A + P_D (\theta_{JC} + \theta_{CA})$ or $T_A + P_D\, \theta_{JA}$ (Without heat sink)

Where:

T_J = Junction Temperature

T_A = Ambient Temperature

P_D = Power Dissipation

θ_{JA} = Junction to ambient thermal resistance

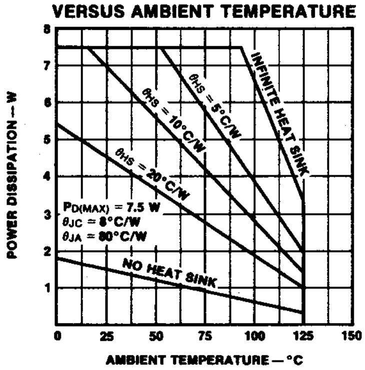
θ_{JC} = Junction to case thermal resistance

θ_{CA} = Case to ambient thermal resistance

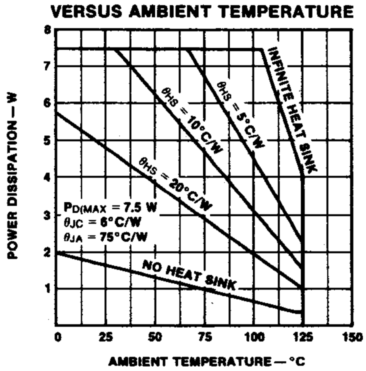
θ_{CS} = Case to heat sink thermal resistance

θ_{SA} = Heat sink to ambient thermal resistance

WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE



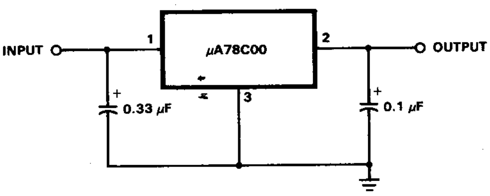
TYPICAL POWER DISSIPATION VERSUS AMBIENT TEMPERATURE



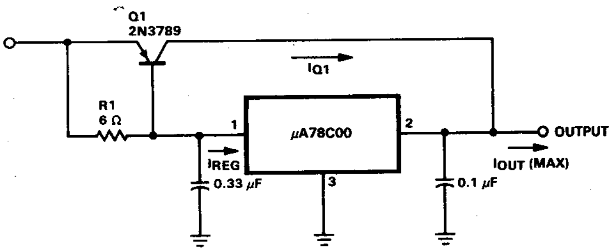
TYPICAL APPLICATIONS

In many μA78C00 applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33 μF and 0.1 μF, respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

FIXED OUTPUT REGULATOR



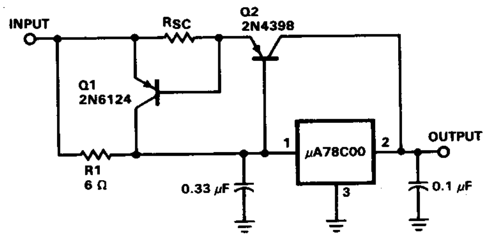
HIGH CURRENT VOLTAGE REGULATOR



$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\ (\beta + 1) - I_{OUT(MAX)}}$$

$$\beta_{Q1} \geqslant \frac{I_{OUT}}{I_{REG}}$$

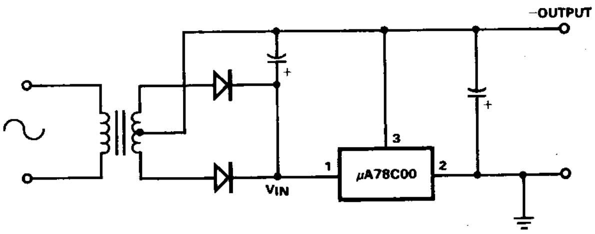
HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



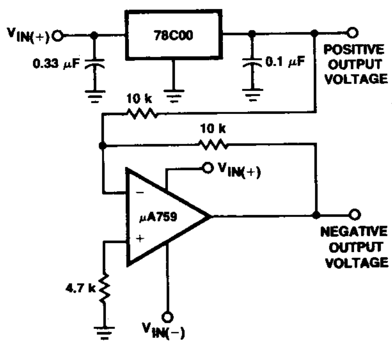
$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\ (\beta + 1) - I_{OUT(MAX)}}$$

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{OUT(MAX)}}$$

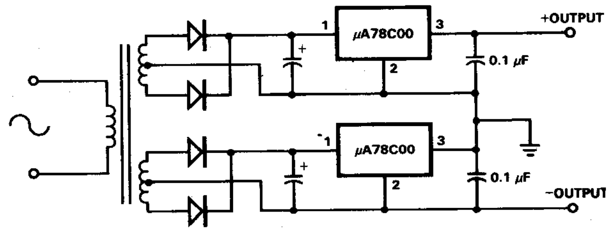
NEGATIVE OUTPUT VOLTAGE CIRCUIT



± TRACKING VOLTAGE REGULATOR

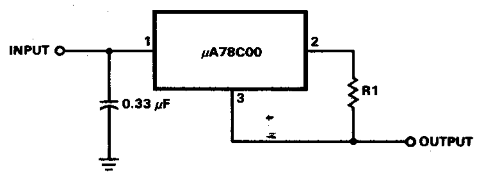


POSITIVE AND NEGATIVE REGULATOR



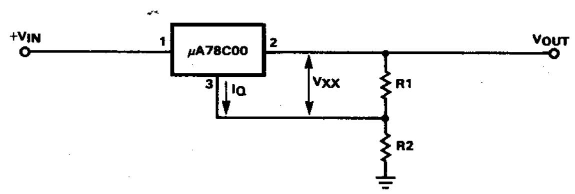
TYPICAL APPLICATIONS (Cont'd)

CURRENT REGULATOR



$$\text{Output Current} = \frac{V_{OUT}}{R1}$$

CIRCUIT FOR INCREASING OUTPUT VOLTAGE



$$V_{OUT} = V_{XX}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

μA78M00 SERIES

3-TERMINAL POSITIVE VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

GENERAL DESCRIPTION — The μA78M00 series of 3-Terminal Medium Current Positive Voltage Regulators is constructed using the Fairchild Planar* epitaxial process. These regulators employ internal current limiting, thermal shutdown and safe area compensation making them essentially indestructible. If adequate heat sinking is provided, they can deliver in excess of 500 mA output current. They are intended as fixed voltage regulators in a wide range of applications including local or on-card regulation for elimination of noise and distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

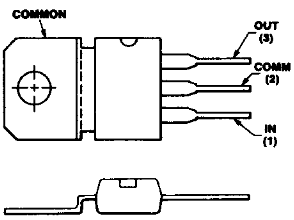
- **OUTPUT CURRENT IN EXCESS OF 0.5 A**
- **NO EXTERNAL COMPONENTS**
- **INTERNAL THERMAL OVERLOAD PROTECTION**
- **INTERNAL SHORT CIRCUIT CURRENT LIMITING**
- **OUTPUT TRANSISTOR SAFE AREA COMPENSATION**
- **AVAILABLE IN JEDEC TO-220 AND TO-39 PACKAGES**
- **OUTPUT VOLTAGES OF 5 V, 6 V, 8 V, 12 V, 15 V, 20 V and 24 V**
- **MILITARY AND COMMERCIAL TEMPERATURE RANGE**

ABSOLUTE MAXIMUM RATINGS

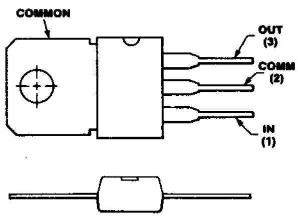
Input Voltage	
(5 V through 15 V)	35 V
(20 V, 24 V)	40 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	
TO-39	-65°C to + 150°C
TO-220 and Power Tap	-55°C to +150°C
Operating Junction Temperature Range	
μA78M00	-55°C to +150°C
μA78M00C	0°C to +150°C
Lead Temperatures (Soldering, 60 s time limit) TO-39	300°C
(Soldering, 10 s time limit) TO-220 and Power Tab	230°C

CONNECTION DIAGRAMS
POWER TAB PACKAGES
(TO-202 EQUIVALENT)

U1



U2

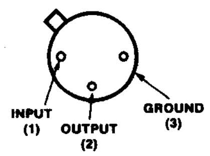


ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA78M05	μA78M05U1C
6 V	μA78M06	μA78M06U1C
8 V	μA78M08	μA78M08U1C
12 V	μA78M12	μA78M12U1C
15 V	μA78M15	μA78M15U1C
20 V	μA78M20	μA78M20U1C
24 V	μA78M24	μA78M24U1C

*or U2C for straight heatsink

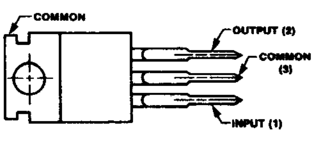
CONNECTION DIAGRAM
TO-39 PACKAGE
(TOP VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA78M05	μA78M05HM
6 V	μA78M06	μA78M06HM
8 V	μA78M08	μA78M08HM
12 V	μA78M12	μA78M12HM
15 V	μA78M15	μA78M15HM
20 V	μA78M20	μA78M20HM
24 V	μA78M24	μA78M24HM
5 V	μA78M05C	μA78M05HC
6 V	μA78M06C	μA78M06HC
8 V	μA78M08C	μA78M08HC
12 V	μA78M12C	μA78M12HC
15 V	μA78M15C	μA78M25HC
20 V	μA78M20C	μA78M20HC
24 V	μA78M24C	μA78M24HC

TO-220 PACKAGE



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA78M05C	μA78M05UC
6 V	μA78M06C	μA78M06UC
8 V	μA78M08C	μA78M08UC
12 V	μA78M12C	μA78M12UC
15 V	μA78M15C	μA78M15UC
20 V	μA78M20C	μA78M20UC
24 V	μA78M24C	μA78M24UC

μA78M05

ELECTRICAL CHARACTERISTICS: V_{IN} = 10 V, I_{OUT} = 350 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		4.8	5.0	5.2	V
Line Regulation		T_J = 25°C	7 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		3.0	50	mV
			8 V ≤ V_{IN} ≤ 20 V, I_{OUT} = 200 mA		1.0	25	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		20	50	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	25	mV
Output Voltage		8 V ≤ V_{IN} ≤ 20 V, 5 mA ≤ I_{OUT} ≤ 350 mA		4.7		5.3	V
Quiescent Current		T_J = 25°C			4.5	6.0	mA
Quiescent Current Change	with line	8 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 8 V ≤ V_{IN} ≤ 18 V	I_{OUT} = 100 mA	62			dB
			I_{OUT} = 300 mA, T_J = 25°C	62	80		dB
Dropout Voltage		T_A = 25°C, I_{OUT} = 350 mA			2.0	2.5	V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			300	600	mA
Peak Output Current		T_J = 25°C		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55°C ≤ T_J ≤ +25°C			0.4	mV/°C/
			+25°C ≤ T_J ≤ +150°C			0.3	V_{OUT}

μA78M05C

ELECTRICAL CHARACTERISTICS: V_{IN} = 10 V, I_{OUT} = 350 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		4.8	5.0	5.2	V
Line Regulation		T_J = 25°C	7 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		3.0	100	mV
			8 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		1.0	50	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		20	100	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	50	mV
Output Voltage		7 V ≤ V_{IN} ≤ 20 V, 5 mA ≤ I_{OUT} ≤ 350 mA		4.75		5.25	V
Quiescent Current		T_J = 25°C			4.5	6.0	mA
Quiescent Current Change	with line	8 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			40		μV
Ripple Rejection		f = 120 Hz, 8 V ≤ V_{IN} ≤ 18 V	I_{OUT} = 100 mA	62			dB
			I_{OUT} = 300 mA, T_J = 25°C	62	80		dB
Dropout Voltage		T_A = 25°C			2.0		V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			300		mA
Peak Output Current		T_J = 25°C			700		mA
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA			−1.0		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

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μA78M06

ELECTRICAL CHARACTERISTICS: V_{IN} = 11 V, I_{OUT} = 350 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		5.75	6.0	6.25	V
Line Regulation		T_J = 25°C	8 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		5.0	60	mV
			9 V ≤ V_{IN} ≤ 20 V, I_{OUT} = 200 mA		1.5	30	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		20	60	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	30	mV
Output Voltage		9 V ≤ V_{IN} ≤ 21 V, 5 mA ≤ I_{OUT} ≤ 350 mA		5.7		6.3	V
Quiescent Current		T_J = 25°C			4.5	6.0	mA
Quiescent Current Change	with line	9 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 9 V ≤ V_{IN} ≤ 19 V	I_{OUT} = 100 mA	59			dB
			I_{OUT} = 300 mA, T_J = 25°C	59	80		dB
Dropout Voltage		T_A = 25°C, I_{OUT} = 350 mA			2.0	2.5	V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			300	600	mA
Peak Output Current		T_J = 25°C		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55°C ≤ T_J ≤ +25°C		0.4	.4	mV/°C/V_{OUT}
			+25°C ≤ T_J ≤ 150°C		0.3	.3	

μA78M06C

ELECTRICAL CHARACTERISTICS: V_{IN} = 11 V, I_{OUT} = 350 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		5.75	6.0	6.25	V
Line Regulation		T_J = 25°C	8 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		5.0	100	mV
			9 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		1.5	50	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		20	120	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	60	mV
Output Voltage		8 V ≤ V_{IN} ≤ 21 V, 5 mA ≤ I_{OUT} ≤ 350 mA		5.7		6.3	V
Quiescent Current		T_J = 25°C			4.5	6.0	mA
Quiescent Current Change	with line	9 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			45		μV
Ripple Rejection		f = 120 Hz, 9 V ≤ V_{IN} ≤ 19 V	I_{OUT} = 100 mA	59			dB
			I_{OUT} = 300 mA, T_J = 25°C	59	80		dB
Dropout Voltage		T_A = 25°C			2.0		V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			270		mA
Peak Output Current		T_J = 25°C			700		mA
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA			−0.5		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

µA78M08

ELECTRICAL CHARACTERISTICS: V_{IN} = 14 V, I_{OUT} = 350 mA, –55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 µF, C_{OUT} = 0.1 µF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		7.7	8.0	8.3	V
Line Regulation		T_J = 25°C	10.5 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		6.0	60	mV
			11 V ≤ V_{IN} ≤ 20 V, I_{OUT} = 200 mA		2.0	30	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		25	80	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	40	mV
Output Voltage		11.5 V ≤ V_{IN} ≤ 23 V, 5 mA ≤ I_{OUT} ≤ 350 mA		7.6		8.4	V
Quiescent Current		T_J = 25°C			4.6	6.0	mA
Quiescent Current Change	with line	11.5 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	µV/V_{OUT}
Ripple Rejection		f = 120 Hz, 11.5 V ≤ V_{IN} ≤ 21.5 V	I_{OUT} = 100 mA	56			dB
			I_{OUT} = 300 mA, T_J = 25°C	56	80		dB
Dropout Voltage		T_A = 25°C, I_{OUT} = 350 mA			2.0	2.5	V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			300	600	mA
Peak Output Current		T_J = 25°C		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	–55°C ≤ T_J ≤ +25°C			0.4	mV/°C
			+25°C ≤ T_J ≤ 150°C			0.3	mV/°C

µA78M08C

ELECTRICAL CHARACTERISTICS: V_{IN} = 14 V, I_{OUT} = 350 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 µF, C_{OUT} = 0.1 µF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		7.7	8.0	8.3	V
Line Regulation		T_J = 25°C	10.5 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		6.0	100	mV
			11 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA		2.0	50	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		25	160	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	80	mV
Output Voltage		10.5 V ≤ V_{IN} ≤ 23 V, 5 mA ≤ I_{OUT} ≤ 350 mA		7.6		8.4	V
Quiescent Current		T_J = 25°C			4.6	6.0	mA
Quiescent Current Change	with line	10.5 V ≤ V_{IN} ≤ 25 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			52		µV
Ripple Rejection		f = 120 Hz, 11.5 V ≤ V_{IN} ≤ 21.5 V	I_{OUT} = 100 mA	56			dB
			I_{OUT} = 300 mA, T_J = 25°C	56	80		dB
Dropout Voltage		T_A = 25°C			2.0		V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			250		mA
Peak Output Current		T_J = 25°C			700		mA
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA			–0.5		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

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μA78M12

ELECTRICAL CHARACTERISTICS: $V_{IN} = 19$ V, $I_{OUT} = 350$ mA, $-55°C \leq T_J \leq 150°C$, $C_{IN} = 0.33$ μF, $C_{OUT} = 0.1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		11.5	12	12.5	V
Line Regulation		$T_J = 25°C$	$14.5\ V \leq V_{IN} \leq 30\ V$, $I_{OUT} = 200$ mA		8.0	60	mV
			$16\ V \leq V_{IN} \leq 25\ V$, $I_{OUT} = 200$ mA		2.0	30	mV
Load Regulation		$T_J = 25°C$	$5\ mA \leq I_{OUT} \leq 500$ mA		25	120	mV
			$5\ mA \leq I_{OUT} \leq 200$ mA		10	60	mV
Output Voltage		$15.5\ V \leq V_{IN} \leq 27\ V$, $5\ mA \leq I_{OUT} \leq 350$ mA		11.4		12.6	V
Quiescent Current		$T_J = 25°C$			4.8	6.0	mA
Quiescent Current Change	with line	$15\ V \leq V_{IN} \leq 30\ V$, $I_{OUT} = 200$ mA				0.8	mA
	with load	$5\ mA \leq I_{OUT} \leq 350$ mA				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100$ kHz			8	40	$\mu V/V_{OUT}$
Ripple Rejection		f = 120 Hz, $15\ V \leq V_{IN} \leq 25\ V$	$I_{OUT} = 100$ mA	55			dB
			$I_{OUT} = 300$ mA, $T_J = 25°C$	55	80		dB
Dropout Voltage		$T_A = 25°C$, $I_{OUT} = 350$ mA			2.0	2.5	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = 35$ V			300	600	mA
Peak Output Current		$T_J = 25°C$		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA	$-55°C \leq T_J \leq +25°C$			0.4	$mV/°C/V_{OUT}$
			$+25°C \leq T_J \leq +150°C$			0.3	

μA78M12C

ELECTRICAL CHARACTERISTICS: $V_{IN} = 19$ V, $I_{OUT} = 350$ mA, $0°C \leq T_J \leq 125°C$, $C_{IN} = 0.33$ μF, $C_{OUT} = 0.1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		11.5	12	12.5	V
Line Regulation		$T_J = 25°C$	$14.5\ V \leq V_{IN} \leq 30\ V$, $I_{OUT} = 200$ mA		8.0	100	mV
			$16\ V \leq V_{IN} \leq 30\ V$, $I_{OUT} = 200$ mA		2.0	50	mV
Load Regulation		$T_J = 25°C$	$5\ mA \leq I_{OUT} \leq 500$ mA		25	240	mV
			$5\ mA \leq I_{OUT} \leq 200$ mA		10	120	mV
Output Voltage		$14.5\ V \leq V_{IN} \leq 27\ V$, $5\ mA \leq I_{OUT} \leq 350$ mA		11.4		12.6	V
Quiescent Current		$T_J = 25°C$			4.8	6.0	mA
Quiescent Current Change	with line	$14.5\ V \leq V_{IN} \leq 30\ V$, $I_{OUT} = 200$ mA				0.8	mA
	with load	$5\ mA \leq I_{OUT} \leq 350$ mA				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100$ kHz			75		μV
Ripple Rejection		f = 120 Hz, $15\ V \leq V_{IN} \leq 25\ V$	$I_{OUT} = 100$ mA	55			dB
			$I_{OUT} = 300$ mA, $T_J = 25°C$	55	80		dB
Dropout Voltage		$T_A = 25°C$			2.0		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = 35$ V			240		mA
Peak Output Current		$T_J = 25°C$			700		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA			−1.0		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA78M15

ELECTRICAL CHARACTERISTICS: $V_{IN} = 23$ V, $I_{OUT} = 350$ mA, $-55°C \leq T_J \leq 150°C$, $C_{IN} = 0.33$ μF, $C_{OUT} = 0.1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		14.4	15	15.6	V
Line Regulation		$T_J = 25°C$	$17.5\text{ V} \leq V_{IN} \leq 30\text{ V}$, $I_{OUT} = 200$ mA		10	60	mV
			$20\text{ V} \leq V_{IN} \leq 30\text{ V}$, $I_{OUT} = 200$ mA		3.0	30	mV
Load Regulation		$T_J = 25°C$	$5\text{ mA} \leq I_{OUT} \leq 500$ mA		25	150	mV
			$5\text{ mA} \leq I_{OUT} \leq 200$ mA		10	75	mV
Output Voltage		$18.5\text{ V} \leq V_{IN} \leq 30$ V, $5\text{ mA} \leq I_{OUT} \leq 350$ mA		14.25		15.75	V
Quiescent Current		$T_J = 25°C$			4.8	6.0	mA
Quiescent Current Change	with line	$18.5\text{ V} \leq V_{IN} \leq 30$ V, $I_{OUT} = 200$ mA				0.8	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 350$ mA				0.5	mA
Output Noise Voltage		$T_A = 25°C$, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, $18.5\text{ V} \leq V_{IN} \leq 28.5$ V	$I_{OUT} = 100$ mA	54			dB
			$I_{OUT} = 300$ mA, $T_J = 25°C$	54	70		dB
Dropout Voltage		$T_A = 25°C$			2.0	2.5	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = 35$ V			300	600	mA
Peak Output Current		$T_J = 25°C$		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA	$-55°C \leq T_J \leq +25°C$			0.4	mV/°C/V_{OUT}
			$+25°C \leq T_J \leq +150°C$			0.3	

μA78M15C

ELECTRICAL CHARACTERISTICS: $V_{IN} = 23$ V, $I_{OUT} = 350$ mA, $0°C \leq T_J \leq 125°C$, $C_{IN} = 0.33$ μF, $C_{OUT} = 0.1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		14.4	15	15.6	V
Line Regulation		$T_J = 25°C$	$17.5\text{ V} \leq V_{IN} \leq 30\text{ V}$, $I_{OUT} = 200$ mA		10	100	mV
			$20\text{ V} \leq V_{IN} \leq 30\text{ V}$, $I_{OUT} = 200$ mA		3.0	50	mV
Load Regulation		$T_J = 25°C$	$5\text{ mA} \leq I_{OUT} \leq 500$ mA		25	300	mV
			$5\text{ mA} \leq I_{OUT} \leq 200$ mA		10	150	mV
Output Voltage		$17.5\text{ V} \leq V_{IN} \leq 30$ V, $5\text{ mA} \leq I_{OUT} \leq 350$ mA		14.25		15.75	V
Quiescent Current		$T_J = 25°C$			4.8	6.0	mA
Quiescent Current Change	with line	$17.5\text{ V} \leq V_{IN} \leq 30$ V, $I_{OUT} = 200$ mA				0.8	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 350$ mA				0.5	mA
Output Noise Voltage		$T_A = 25°C$, 10 Hz ≤ f ≤ 100 kHz			90		μV
Ripple Rejection		f = 120 Hz, $18.5\text{ V} \leq V_{IN} \leq 28.5$ V	$I_{OUT} = 100$ mA	54			dB
			$I_{OUT} = 300$ mA, $T_J = 25°C$	54	70		dB
Dropout Voltage		$T_A = 25°C$			2.0		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = 35$ V			240		mA
Peak Output Current		$T_J = 25°C$			700		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA			−1.0		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_W \leq 10$ ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA78M20

ELECTRICAL CHARACTERISTICS: V_{IN} = 29 V, I_{OUT} = 350 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		19.2	20	20.8	V
Line Regulation		T_J = 25°C	23 V ≤ V_{IN} ≤ 35 V, I_{OUT} = 200 mA		10	60	mV
			24 V ≤ V_{IN} ≤ 35 V, I_{OUT} = 200 mA		5.0	30	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		30	200	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	100	mV
Output Voltage		24 V ≤ V_{IN} ≤ 35 V, 5 mA ≤ I_{OUT} ≤ 350 mA		19		21	V
Quiescent Current		T_J = 25°C			4.9	6.0	mA
Quiescent Current Change	with line	24 V ≤ V_{IN} ≤ 35 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 24 V ≤ V_{IN} ≤ 34 V	I_{OUT} = 100 mA	53			dB
			I_{OUT} = 300 mA, T_J = 25°C	53	70		dB
Dropout Voltage		T_A = 25°C, I_{OUT} = 350 mA			2.0	2.5	V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			300	600	mA
Peak Output Current		T_J = 25°C		0.4	0.7	1.4	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55°C ≤ T_J ≤ +25°C			0.4	mV/°C/V_{OUT}
			+25°C ≤ T_J ≤ 150°C			0.3	

μA78M20C

ELECTRICAL CHARACTERISTICS: V_{IN} = 29 V, I_{OUT} = 350 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		19.2	20	20.8	V
Line Regulation		T_J = 25°C	23 V ≤ V_{IN} ≤ 35 V, I_{OUT} = 200 mA		10	100	mV
			24 V ≤ V_{IN} ≤ 35 V, I_{OUT} = 200 mA		5.0	50	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		30	400	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	200	mV
Output Voltage		23 V ≤ V_{IN} ≤ 35 V, 5 mA ≤ I_{OUT} ≤ 350 mA		19		21	V
Quiescent Current		T_J = 25°C			4.9	6.0	mA
Quiescent Current Change	with line	23 V ≤ V_{IN} ≤ 35 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			110		μV
Ripple Rejection		f = 120 Hz, 24 V ≤ V_{IN} ≤ 34 V	I_{OUT} = 100 mA	53			dB
			I_{OUT} = 300 mA, T_J = 25°C	53	70		dB
Dropout Voltage		T_A = 25°C			2.0		V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			240		mA
Peak Output Current		T_J = 25°C			700		mA
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA			−1.1		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA78M24

ELECTRICAL CHARACTERISTICS: V_{IN} = 33 V, I_{OUT} = 350 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		23	24	25	V
Line Regulation		T_J = 25°C	27 V ≤ V_{IN} ≤ 38 V, I_{OUT} = 200 mA		10	60	mV
			30 V ≤ V_{IN} ≤ 36 V, I_{OUT} = 200 mA		5.0	30	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		30	240	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	120	mV
Output Voltage		28 V ≤ V_{IN} ≤ 38 V, 5 mA ≤ I_{OUT} ≤ 350 mA		22.8		25.2	V
Quiescent Current		T_J = 25°C			5.0	6.0	mA
Quiescent Current Change	with line	28 V ≤ V_{IN} ≤ 38 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 28 V ≤ V_{IN} ≤ 38 V	I_{OUT} = 100 mA	50			dB
			I_{OUT} = 300 mA, T_J = 25°C	50	70		dB
Dropout Voltage		T_A = 25°C, I_{OUT} = 350 mA			2.0	2.5	V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			300	600	mA
Peak Output Current		T_J = 25°C		0.4	0.7	1.4	mA
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55°C ≤ T_J ≤ +25°C			0.4	mV/°C/ V_{OUT}
			+25°C ≤ T_J ≤ 150°C			0.3	

μA78M24C

ELECTRICAL CHARACTERISTICS: V_{IN} = 33 V, I_{OUT} = 350 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		23	24	25	V
Line Regulation		T_J = 25°C	27 V ≤ V_{IN} ≤ 38 V, I_{OUT} = 200 mA		10	100	mV
			28 V ≤ V_{IN} ≤ 38 V, I_{OUT} = 200 mA		5.0	50	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 500 mA		30	480	mV
			5 mA ≤ I_{OUT} ≤ 200 mA		10	240	mV
Output Voltage		27 V ≤ V_{IN} ≤ 38 V, 5 mA ≤ I_{OUT} ≤ 350 mA		22.8		25.2	V
Quiescent Current		T_J = 25°C			5.0	6.0	mA
Quiescent Current Change	with line	27 V ≤ V_{IN} ≤ 38 V, I_{OUT} = 200 mA				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 350 mA				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			170		μV
Ripple Rejection		f = 120 Hz, 28 V ≤ V_{IN} ≤ 38 V	I_{OUT} = 100 mA	50			dB
			I_{OUT} = 300 mA, T_J = 25°C	50	70		dB
Dropout Voltage		T_A = 25°C			2.0		V
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			240		mA
Peak Output Current		T_J = 25°C			700		mA
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA			−1.2		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_W ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

DESIGN CONSIDERATIONS

The μA78M00 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation for reducing the output short circuit current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (150°C for 78M00, 125°C for 78M00C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	TYP θ_{JC}	MAX θ_{JC}	TYP θ_{JA}	MAX θ_{JA}
TO-39	18	25	120	185
TO-220	3	5	62	70
POWER TAB (TO-202 EQUIVALENT)	6	8	75	80

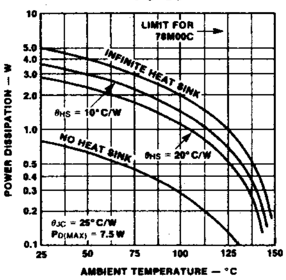
$$P_{D\,(MAX)} = \frac{T_{J\,(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_{J\,(MAX)} - T_A}{\theta_{JA}} \text{ (Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

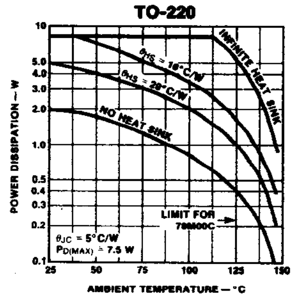
Solving for T_J: $T_J = T_A + P_D(\theta_{JC}+\theta_{CA})$ or $T_A + P_D\,\theta_{JA}$ (Without a heat sink)

Where T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation
θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to Ambient thermal resistance
θ_{CS} = Case to heat sink to resistance
θ_{SA} = Heat sink to ambient thermal resistance
θ_{JA} = Junction to Ambient thermal resistance

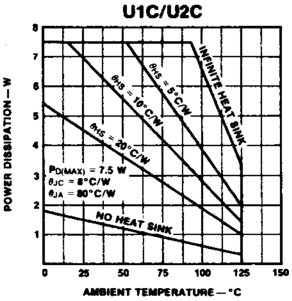
WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE TO-39



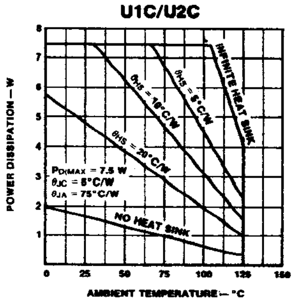
WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE TO-220



WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE U1C/U2C

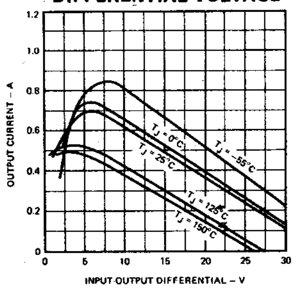


TYPICAL POWER DISSIPATION VERSUS AMBIENT TEMPERATURE U1C/U2C

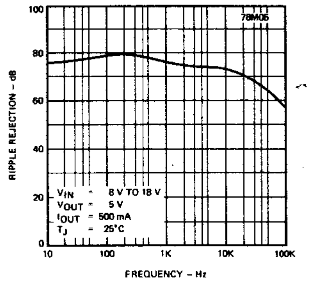


ELECTRICAL PERFORMANCE CURVES

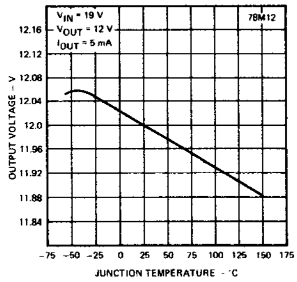
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



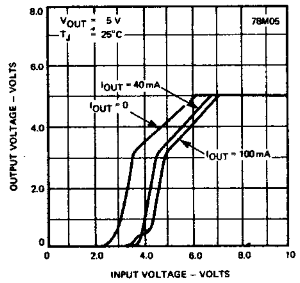
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



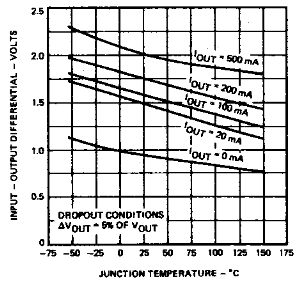
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



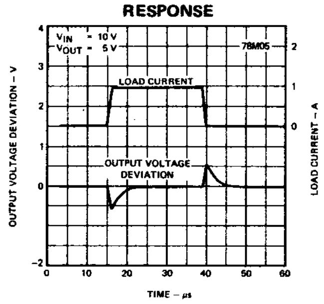
DROPOUT CHARACTERISTICS



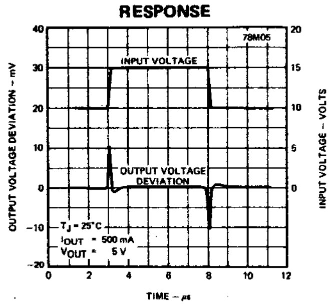
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



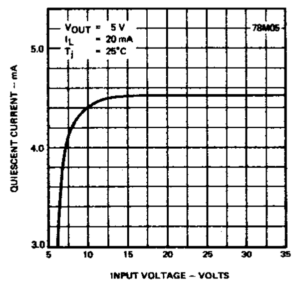
LOAD TRANSIENT RESPONSE



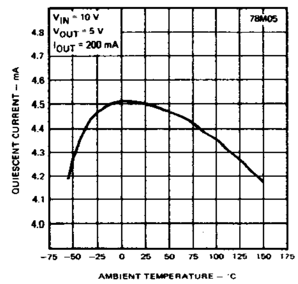
LINE TRANSIENT RESPONSE



QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE

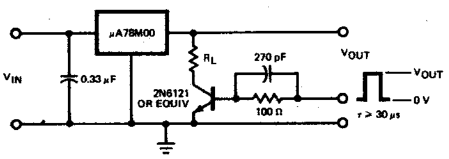


QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE

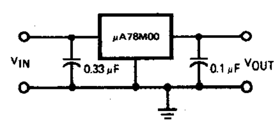


NOTE: Other μA78M00 Series devices have similar curves.

TEST CIRCUITS

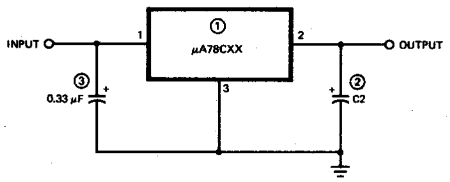


LOAD REGULATION TEST CIRCUIT



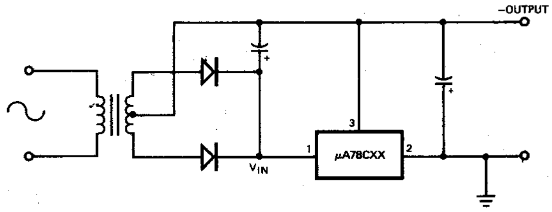
DC PARAMETER TEST CIRCUIT

APPLICATIONS

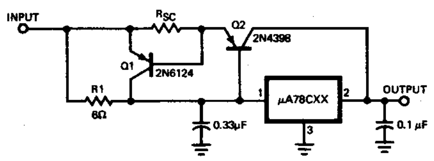


NOTES:
① To specify an output voltage, substitute voltage value for "XX".
② Although no output capacitor is needed for stability, it does improve transient response.
③ Required if regulator is located an appreciable distance from power supply filter.

FIXED OUTPUT REGULATOR



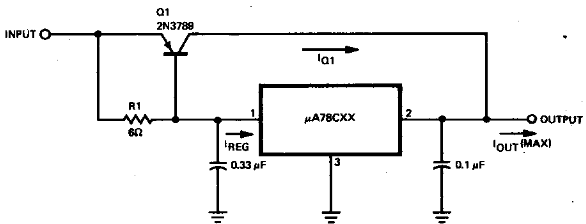
NEGATIVE OUTPUT VOLTAGE CIRCUIT



$$R1 = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\ (\beta + 1) - I_{OUT}(MAX)}$$

$$R_{SC} = \frac{V_{BE}(Q1)}{I_{OUT}}$$

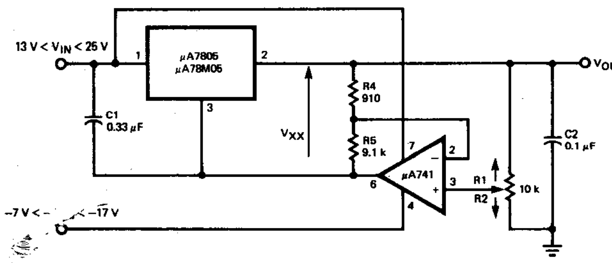
HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



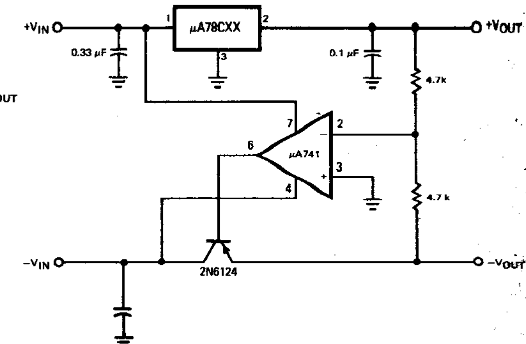
$$R1 = \frac{V_{BE}(Q1)}{I_{REG}} = \frac{\beta V_{BE}(Q1)}{I_{REQ(MAX)}\ (\beta + 1) - I_{OUT}(MAX)}$$

$$\beta_{Q1} \geq \frac{I_{OUT}}{I_{REG}}$$

HIGH CURRENT VOLTAGE REGULATOR

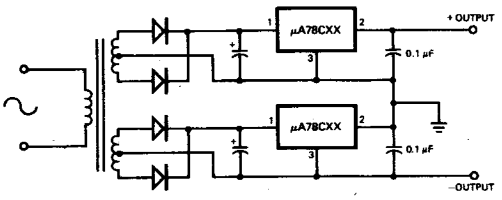


VARIABLE OUTPUT VOLTAGE, 0.5 TO 10 V

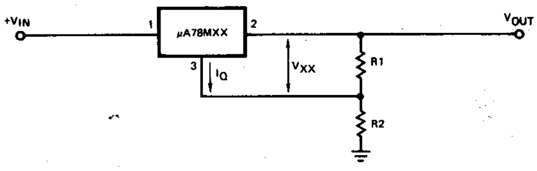


± TRACKING VOLTAGE REGULATOR

APPLICATIONS (Cont'd)

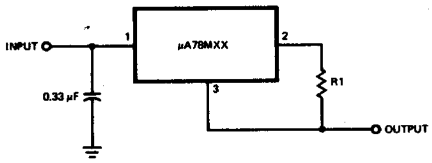


POSITIVE AND NEGATIVE REGULATOR



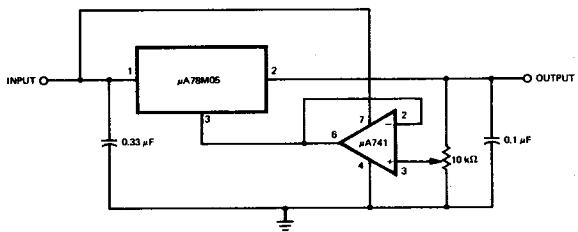
$$V_{OUT} = V_{XX}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

CIRCUIT FOR INCREASING OUTPUT VOLTAGE



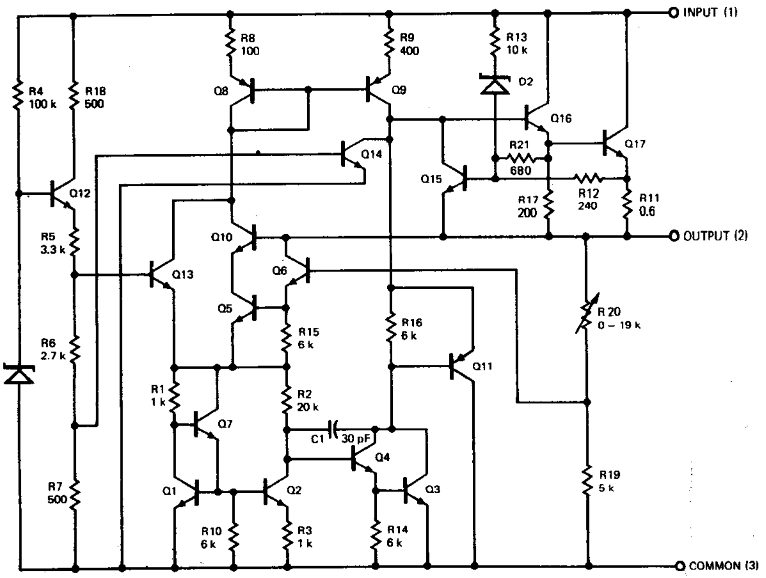
$$\text{Output Current} = \frac{V_{OUT}}{R1}$$

CURRENT REGULATOR



ADJUSTABLE OUTPUT REGULATOR, 7 V TO 30 V

EQUIVALENT CIRCUIT



μA7800 SERIES
3-TERMINAL POSITIVE VOLTAGE REGULATORS
FAIRCHILD LINEAR INTEGRATED CIRCUITS

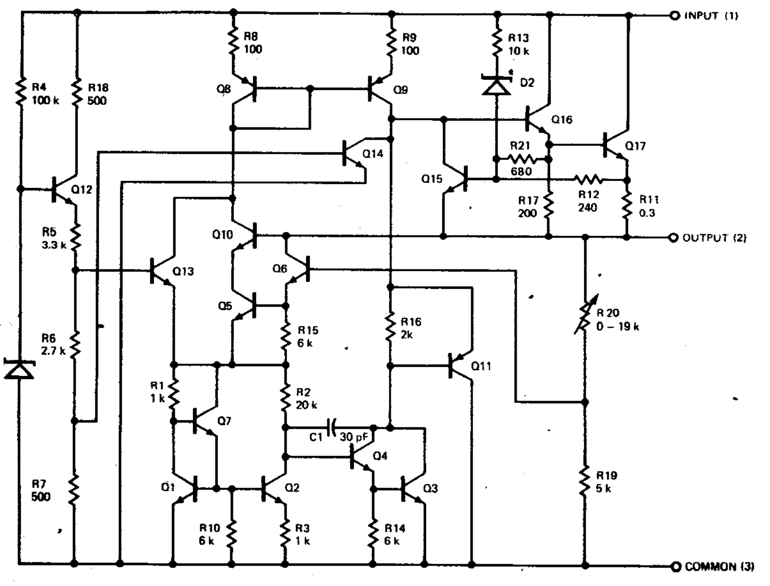
GENERAL DESCRIPTION – The μA7800 series of monolithic 3-Terminal Positive Voltage Regulators is constructed using the Fairchild Planar* epitaxial process. These regulators employ internal current limiting, thermal shutdown and safe area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1 A output current. They are intended as fixed voltage regulators in a wide range of applications including local (on card) regulation for elimination of distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

- **OUTPUT CURRENT IN EXCESS OF 1 A**
- **NO EXTERNAL COMPONENTS**
- **INTERNAL THERMAL OVERLOAD PROTECTION**
- **INTERNAL SHORT CIRCUIT CURRENT LIMITING**
- **OUTPUT TRANSISTOR SAFE AREA COMPENSATION**
- **AVAILABLE IN THE TO-220 AND THE TO-3 PACKAGE**
- **OUTPUT VOLTAGES OF 5, 6, 8, 8.5, 12, 15, 18, AND 24 V**

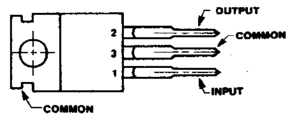
ABSOLUTE MAXIMUM RATINGS

Input Voltage (5 V through 18 V)		35 V
(24 V)		40 V
Internal Power Dissipation		Internally Limited
Storage Temperature Range		−65°C to +150°C
Operating Junction Temperature Range	μA7800	−55°C to +150°C
	μA7800C	0°C to +150°C
Lead Temperature (Soldering, 60 s time limit) TO-3 Package		300°C
(Soldering, 10 s time limit) TO-220 Package		230°C

EQUIVALENT CIRCUIT



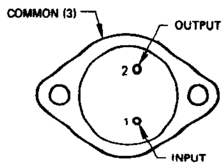
CONNECTION DIAGRAMS
TO-220 PACKAGE
(SIDE VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA7805C	μA7805UC
6 V	μA7806C	μA7806UC
8 V	μA7808C	μA7808UC
8.5 V	μA7885C	μA7885UC
12 V	μA7812C	μA7812UC
15 V	μA7815C	μA7815UC
18 V	μA7818C	μA7818UC
24 V	μA7824C	μA7824UC

TO-3 PACKAGE
(TOP VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5 V	μA7805	μA7805KM
6 V	μA7806	μA7806KM
8 V	μA7808	μA7808KM
8.5 V	μA7885	μA7885KM
12 V	μA7812	μA7812KM
15 V	μA7815	μA7815KM
18 V	μA7818	μA7818KM
24 V	μA7824	μA7824KM
5 V	μA7805C	μA7805KC
6 V	μA7806C	μA7806KC
8 V	μA7808C	μA7808KC
8.5 V	μA7885C	μA7885KC
12 V	μA7812C	μA7812KC
15 V	μA7815C	μA7815KC
18 V	μA7818C	μA7818KC
24 V	μA7824C	μA7824KC

*Planar is a patented Fairchild process.

μA7805

Electrical Characteristics V_{IN} = 10 V, I_{OUT} = 500 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

Characteristic		Condition (Note)		Min	Typ	Max	Unit
Output Voltage		T_J = 25°C		4.8	5.0	5.2	V
Line Regulation		T_J = 25°C	7 V ≤ V_{IN} ≤ 25 V		3	50	mV
			8 V ≤ V_{IN} ≤ 12 V		1	25	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		15	100	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		5	25	mV
Output Voltage		8.0 V ≤ V_{IN} ≤ 20 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		4.65		5.35	V
Quiescent Current		T_J = 25°C			4.2	6.0	mA
Quiescent Current Change	with line	8 V ≤ V_{IN} ≤ 25 V				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 8 V ≤ V_{IN} ≤ 18 V		68	78		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0	2.5	V
Output Resistance		f = 1 kHz			17		mΩ
Short-Circuit Current		T_J = 25°C, V_{IN} = 35 V			0.75	1.2	A
Peak Output Current		T_J = 25°C		1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55° C ≤ T_J ≤ +25°C			0.4	mV/°C/
			+25°C ≤ T_J ≤ +150°C			0.3	V_{OUT}

μA7805C

Electrical Characteristics V_{IN} = 10 V, I_{OUT} = 500 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

Characteristic		Condition (Note)		Min	Typ	Max	Unit
Output Voltage		T_J = 25°C		4.8	5.0	5.2	V
Line Regulation		T_J = 25°C	7 V ≤ V_{IN} ≤ 25 V		3	100	mV
			8 V ≤ V_{IN} ≤ 12 V		1	50	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		15	100	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		5	50	mV
Output Voltage		7 V ≤ V_{IN} ≤ 20 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		4.75		5.25	V
Quiescent Current		T_J = 25°C			4.2	8.0	mA
Quiescent Current Change	with line	7 V ≤ V_{IN} ≤ 25 V				1.3	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			40		μV
Ripple Rejection		f = 120 Hz, 8 V ≤ V_{IN} ≤ 18 V		62	78		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			17		mΩ
Short-Circuit Current		T_J = 25°C, V_{IN} = 35 V			750		mA
Peak Output Current		T_J = 25°C			2.2		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			1.1		mV/°C

μA7806C

Electrical Characteristics V_{IN} = 11 V, I_{OUT} = 500 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

Characteristic		Condition (Note)		Min	Typ	Max	Unit
Output Voltage		T_J = 25°C		5.75	6.0	6.25	V
Line Regulation		T_J = 25°C	8 V ≤ V_{IN} ≤ 25 V		5	120	mV
			9 V ≤ V_{IN} ≤ 13 V		1.5	60	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		14	120	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4	60	mV
Output Voltage		8 V ≤ V_{IN} ≤ 21 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		5.7		6.3	V
Quiescent Current		T_J = 25°C			4.3	8.0	mA
Quiescent Current Change	with line	8 V ≤ V_{IN} ≤ 25 V				1.3	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			45		μV
Ripple Rejection		f = 120 Hz, 9 V ≤ V_{IN} ≤ 19 V		59	75		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			19		mΩ
Short-Circuit Current		T_J = 25°C, V_{IN} = 35 V			550		mA
Peak Output Current		T_J = 25°C			2.2		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			0.8		mV/°C

2

Note

1. For all tables, all characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_W ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7808

ELECTRICAL CHARACTERISTICS: V_{IN} = 14 V, I_{OUT} = 500 mA, –55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		7.7	8.0	8.3	V
Line Regulation		T_J = 25°C	10.5 V ≤ V_{IN} ≤ 25 V		6.0	80	mV
			11 V ≤ V_{IN} ≤ 17 V		2.0	40	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	100	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	40	mV
Output Voltage		11.5 V ≤ V_{IN} ≤ 23 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		7.6		8.4	V
Quiescent Current		T_J = 25°C			4.3	6.0	mA
Quiescent Current Change	with line	11.5 V ≤ V_{IN} ≤ 25 V				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 11.5 V ≤ V_{IN} ≤ 21.5 V		62	72		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0	2.5	V
Output Resistance		f = 1 kHz			16		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			0.75	1.2	A
Peak Output Current		T_J = 25°C		1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	–55°C ≤ T_J ≤ +25°C			0.4	mV/°C/
			+25°C ≤ T_J ≤ 150°C			0.3	V_{OUT}

μA7808C

ELECTRICAL CHARACTERISTICS: V_{IN} = 14 V, I_{OUT} = 500 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		7.7	8.0	8.3	V
Line Regulation		T_J = 25°C	10.5 V ≤ V_{IN} ≤ 25 V		6.0	160	mV
			11 V ≤ V_{IN} ≤ 17 V		2.0	80	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	160	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	80	mV
Output Voltage		10.5 V ≤ V_{IN} ≤ 23 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		7.6		8.4	V
Quiescent Current		T_J = 25°C			4.3	8.0	mA
Quiescent Current Change	with line	10.5 V ≤ V_{IN} ≤ 25 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz, ≤ f ≤ 100 kHz			52		μV
Ripple Rejection		f = 120 Hz, 11.5 V ≤ V_{IN} ≤ 21.5 V		56	72		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			16		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			450		mA
Peak Output Current		T_J = 25°C			2.2		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			–0.8		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7885

ELECTRICAL CHARACTERISTICS: V_{IN} = 15 V, I_{OUT} = 500 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		8.15	8.5	8.85	V
Line Regulation		T_J = 25°C	10.5 V ≤ V_{IN} ≤ 25 V		6.0	85	mV
			11 V ≤ V_{IN} ≤ 17 V		2.0	40	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	85	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	40	mV
Output Voltage		12 V ≤ V_{IN} ≤ 23.5 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		8.1		8.9	V
Quiescent Current		T_J = 25°C			4.3	6.0	mA
Quiescent Current Change	with line	11.5 V ≤ V_{IN} ≤ 25 V				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 11.5 V ≤ V_{IN} ≤ 21.5 V		62	70		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0	2.5	V
Output Resistance		f = 1 kHz			16		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			0.75	1.2	A
Peak Output Current		T_J = 25°C		1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55°C ≤ T_J ≤ +25°C			0.4	mV/°C/V_{OUT}
			+25°C ≤ T_J ≤ +150°C			0.3	

μA7885C

ELECTRICAL CHARACTERISTICS: V_{IN} = 15 V, I_{OUT} = 500 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		8.15	8.5	8.85	V
Line Regulation		T_J = 25°C	10.5 V ≤ V_{IN} ≤ 25 V		6.0	170	mV
			11 V ≤ V_{IN} ≤ 17 V		2.0	85	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	170	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	85	mV
Output Voltage		11 V ≤ V_{IN} ≤ 23.5 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		8.1		8.9	V
Quiescent Current		T_J = 25°C			4.3	8.0	mA
Quiescent Current Change	with line	10.5 V ≤ V_{IN} ≤ 25 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz, ≤ f ≤ 100 kHz			55		μV
Ripple Rejection		f = 120 Hz, 11.5 V ≤ V_{IN} ≤ 21.5 V		56	70		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			16		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			450		mA
Peak Output Current		T_J = 25°C			2.2		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			−0.8		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7812

ELECTRICAL CHARACTERISTICS: V_{IN} = 19 V, I_{OUT} = 500 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		11.5	12.0	12.5	V
Line Regulation		T_J = 25°C	14.5 V ≤ V_{IN} ≤ 30 V		10	120	mV
			16 V ≤ V_{IN} ≤ 22 V		3.0	60	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	120	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	60	mV
Output Voltage		15.5 V ≤ V_{IN} ≤ 27 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		11.4		12.6	V
Quiescent Current		T_J = 25°C			4.3	6.0	mA
Quiescent Current Change	with line	15 V ≤ V_{IN} ≤ 30 V				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 15 V ≤ V_{IN} ≤ 25 V		61	71		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0	2.5	V
Output Resistance		f = 1 kHz			18		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			0.75	1.2	A
Peak Output Current		T_J = 25°C		1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55°C ≤ T_J ≤ +25°C			0.4	mV/°C/
			+25°C ≤ T_J ≤ +150°C			0.3	V_{OUT}

μA7812C

ELECTRICAL CHARACTERISTICS: V_{IN} = 19 V, I_{OUT} = 500 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		11.5	12.0	12.5	V
Line Regulation		T_J = 25°C	14.5 V ≤ V_{IN} ≤ 30 V		10	240	mV
			16 V ≤ V_{IN} ≤ 22 V		3.0	120	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	240	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	120	mV
Output Voltage		14.5 V ≤ V_{IN} ≤ 27 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		11.4		12.6	V
Quiescent Current		T_J = 25°C			4.3	8.0	mA
Quiescent Current Change	with line	14.5 V ≤ V_{IN} ≤ 30 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			75		μV
Ripple Rejection		f = 120 Hz, 15 ≤ V_{IN} ≤ 25 V		55	71		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			18		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			350		mA
Peak Output Current		T_J = 25°C			2.2		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			−1.0		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7815

ELECTRICAL CHARACTERISTICS: V_{IN} = 23 V, I_{OUT} = 500 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		14.4	15.0	15.6	V
Line Regulation		T_J = 25°C	17.5 V ≤ V_{IN} ≤ 30 V		11	150	mV
			20 V ≤ V_{IN} ≤ 26 V		3	75	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	150	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4	75	mV
Output Voltage		18.5 V ≤ V_{IN} ≤ 30 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		14.25		15.75	V
Quiescent Current		T_J = 25°C			4.4	6.0	mA
Quiescent Current Change	with line	18.5 V ≤ V_{IN} ≤ 30 V				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 18.5 V ≤ V_{IN} ≤ 28.5 V		60	70		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0	2.5	V
Output Resistance		f = 1 kHz			19		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			0.75		A
Peak Output Current		T_J = 25°C		1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55°C ≤ T_J ≤ +25°C			0.4	mV/°C/
			+25°C ≤ T_J ≤ +150°C			0.3	V_{OUT}

μA7815C

ELECTRICAL CHARACTERISTICS: V_{IN} = 23 V, I_{OUT} = 500 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		14.4	15.0	15.6	V
Line Regulation		T_J = 25°C	17.5 V ≤ V_{IN} ≤ 30 V		11	300	mV
			20 V ≤ V_{IN} ≤ 26 V		3	150	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	300	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4	150	mV
Output Voltage		17.5 V ≤ V_{IN} ≤ 30 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		14.25		15.75	V
Quiescent Current		T_J = 25°C			4.4	8.0	mA
Quiescent Current Change	with line	17.5 V ≤ V_{IN} ≤ 30 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			90		μV
Ripple Rejection		f = 120 Hz, 18.5 V ≤ V_{IN} ≤ 28.5 V		54	70		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			19		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			230		mA
Peak Output Current		T_J = 25°C			2.1		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			−1.0		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7818

ELECTRICAL CHARACTERISTICS: V_{IN} = 27 V, I_{OUT} = 500 mA, $-55°C \leq T_J \leq 150°C$, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		17.3	18.0	18.7	V
Line Regulation		T_J = 25°C	21 V ≤ V_{IN} ≤ 33 V		15	180	mV
			24 V ≤ V_{IN} ≤ 30 V		5.0	90	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	180	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	90	mV
Output Voltage		22 V ≤ V_{IN} ≤ 33 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		17.1		18.9	V
Quiescent Current		T_J = 25°C			4.5	6.0	mA
Quiescent Current Change	with line	22 V ≤ V_{IN} ≤ 33 V				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 22 V ≤ V_{IN} ≤ 32 V		59	69		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			22	2.5	mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			0.75	1.2	A
Peak Output Current		T_J = 25°C		1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	+25°C ≤ T_J ≤ +150°C			0.4	mV/°C/V_{OUT}
			−55°C ≤ T_J ≤ +25°C			0.3	

μA7818C

ELECTRICAL CHARACTERISTICS: V_{IN} = 27 V, I_{OUT} = 500 mA, $0°C \leq T_J \leq 125°C$, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		17.3	18.0	18.7	V
Line Regulation		T_J = 25°C	21 V ≤ V_{IN} ≤ 33 V		15	360	mV
			24 V ≤ V_{IN} ≤ 30 V		5.0	180	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	360	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	180	mV
Output Voltage		21 V ≤ V_{IN} ≤ 33 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		17.1		18.9	V
Quiescent Current		T_J = 25°C			4.5	8.0	mA
Quiescent Current Change	with line	21 V ≤ V_{IN} ≤ 33 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			110		μV
Ripple Rejection		f = 120 Hz, 22 ≤ V_{IN} ≤ 32 V		53	69		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			22		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			200		mA
Peak Output Current		T_J = 25°C			2.1		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			−1.0		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7824

ELECTRICAL CHARACTERISTICS: V_{IN} = 33 V, I_{OUT} = 500 mA, −55°C ≤ T_J ≤ 150°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		23.0	24.0	25.0	V
Line Regulation		T_J = 25°C	27 V ≤ V_{IN} ≤ 38 V		18	240	mV
			30 V ≤ V_{IN} ≤ 36 V		6	120	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	240	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4	120	mV
Output Voltage		28 V ≤ V_{IN} ≤ 38 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		22.8		25.2	V
Quiescent Current		T_J = 25°C			4.6	6.0	mA
Quiescent Current Change	with line	28 V ≤ V_{IN} ≤ 38 V				0.8	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			8	40	μV/V_{OUT}
Ripple Rejection		f = 120 Hz, 28 V ≤ V_{IN} ≤ 38 V		56	66		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0	2.5	V
Output Resistance		f = 1 kHz			28		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			0.75	1.2	A
Peak Output Current		T_J = 25°C		1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA	−55°C ≤ T_J ≤ +25°C			0.4	mV/°C/
			+25°C ≤ T_J ≤ +150°C			0.3	V_{OUT}

μA7824C

ELECTRICAL CHARACTERISTICS: V_{IN} = 33 V, I_{OUT} = 500 mA, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		23.0	24.0	25.0	V
Line Regulation		T_J = 25°C	27 V ≤ V_{IN} ≤ 38 V		18	480	mV
			30 V ≤ V_{IN} ≤ 36 V		6	240	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	480	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4	240	mV
Output Voltage		27 V ≤ V_{IN} ≤ 38 V 5 mA ≤ I_{OUT} ≤ 1.0 A P ≤ 15 W		22.8		25.2	V
Quiescent Current		T_J = 25°C			4.6	8.0	mA
Quiescent Current Change	with line	27 V ≤ V_{IN} ≤ 38 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			170		μV
Ripple Rejection		f = 120 Hz, 28 V ≤ V_{IN} ≤ 38 V		50	66		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			2.0		V
Output Resistance		f = 1 kHz			28		mΩ
Short Circuit Current		T_J = 25°C, V_{IN} = 35 V			150		mA
Peak Output Current		T_J = 25°C			2.1		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			−1.5		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

DESIGN CONSIDERATIONS

The μA7800 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the regulator's maximum current, and output transistor safe area compensation for reducing the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (150°C for 7800, 125°C for 7800C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	Typ θ_{JC}	Max θ_{JC}	Typ θ_{JA}	Max θ_{JA}
TO-3	3.5	5.5	40	45
TO-220	3.0	5.0	60	65

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_{J(MAX)} - T_A}{\theta_{JA}} \text{ (Without a heat sink)}$$

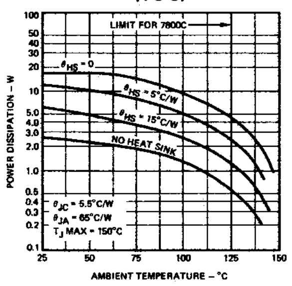
$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

solving for T_J: $T_J = T_A + P_D\,(\theta_{JC} + \theta_{CA})$ or $T_A + P_D\theta_{JA}$ (without a heat sink)

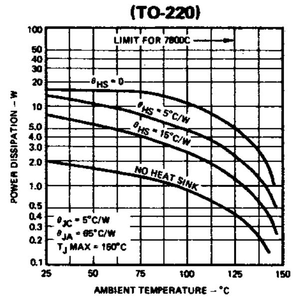
where T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation

θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to ambient thermal resistance
θ_{CS} = Case to heat sink to resistance
θ_{SA} = Heat sink to ambient thermal resistance
θ_{JA} = Junction to ambient thermal resistance

WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE (TO-3)

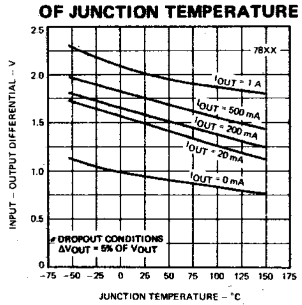


WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE (TO-220)

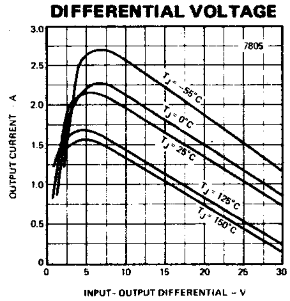


TYPICAL PERFORMANCE CURVES

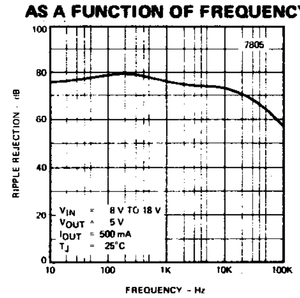
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT/OUTPUT DIFFERENTIAL VOLTAGE

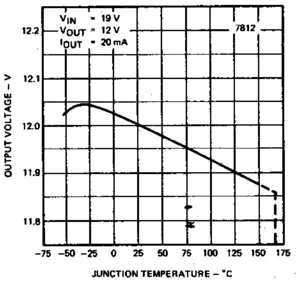


RIPPLE REJECTION AS A FUNCTION OF FREQUENCY

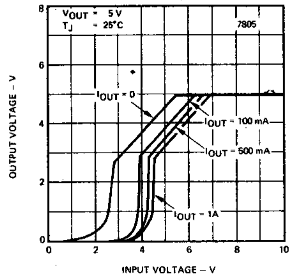


TYPICAL PERFORMANCE CURVES (Cont'd)

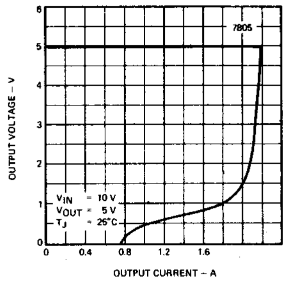
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



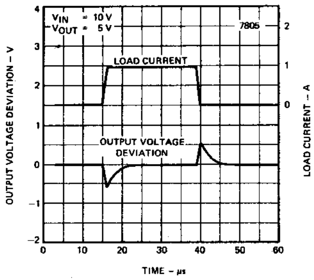
DROPOUT CHARACTERISTICS



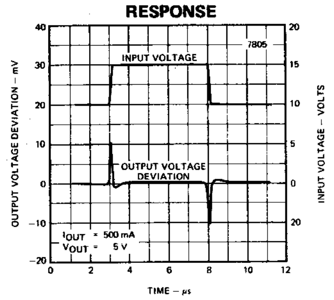
CURRENT LIMITING CHARACTERISTICS



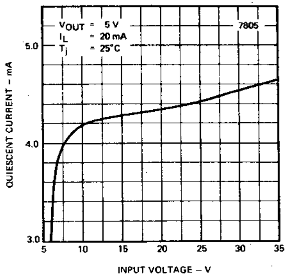
LOAD TRANSIENT RESPONSE



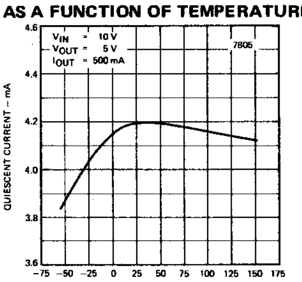
LINE TRANSIENT RESPONSE



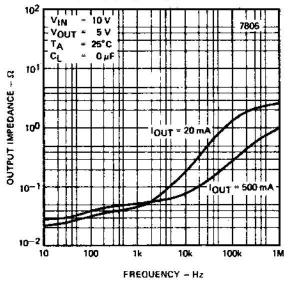
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTACE



QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE

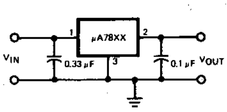


OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY

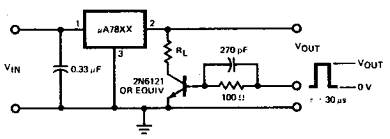


Note: The other μA7800 series devices have similar curves.

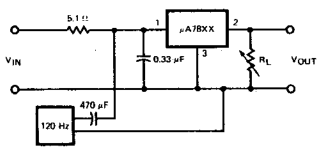
EQUIVALENT TEST CIRCUITS



DC PARAMETER TEST CIRCUIT

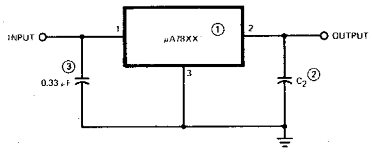


LOAD REGULATION TEST CIRCUIT



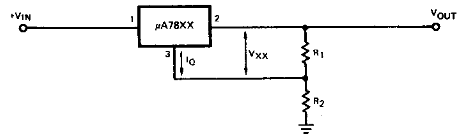
RIPPLE REJECTION TEST CIRCUIT

TYPICAL APPLICATIONS



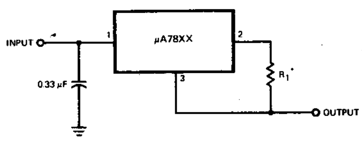
NOTES:
①To specify an output voltage, substitute voltage value for "XX".
②Although no output capacitor is needed for stability, it does improve transient response.
③Required if regulator is located an appreciable distance from power supply filter.

FIXED OUTPUT REGULATOR



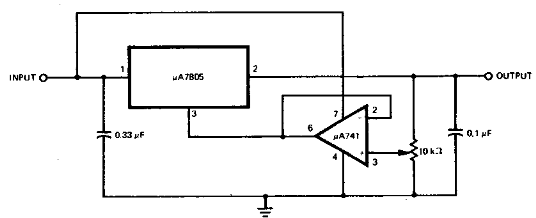
$$V_{OUT} = V_{XX}\left(1 + \frac{R_2}{R_1}\right) + I_Q R_2$$

CIRCUIT FOR INCREASING OUTPUT VOLTAGE

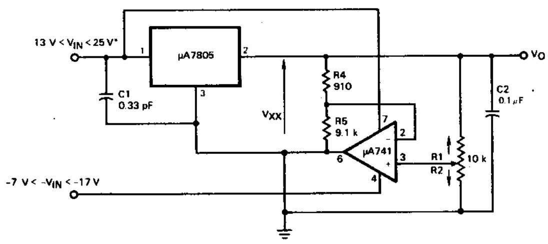


$$\text{Output Current} = \frac{V_{OUT}}{R_1}$$

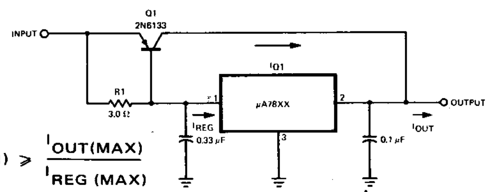
CURRENT REGULATOR



ADJUSTABLE OUTPUT REGULATOR, 7 to 30 VOLTS



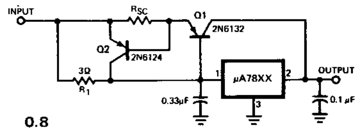
0.5 TO 10 V REGULATOR



$$\beta(Q1) \geq \frac{I_{OUT(MAX)}}{I_{REG\,(MAX)}}$$

$$R1 = \frac{0.9}{I_{REG}} = \frac{\beta(Q1)\,V_{BE(Q1)}}{I_{REG(MAX)}\,(\beta+1) - I_{OUT(MAX)}}$$

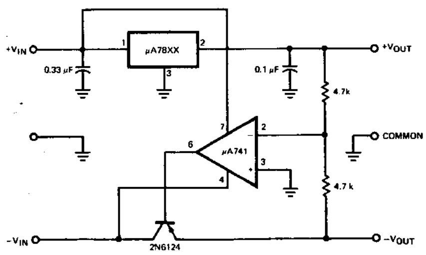
HIGH CURRENT VOLTAGE REGULATOR



$$R_{SC} = \frac{0.8}{I_{SC}}$$

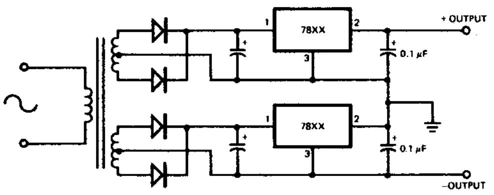
$$R1 = \frac{\beta V_{BE\,(Q1)}}{I_{REG(MAX)}\,(\beta+1) - I_{OUT(MAX)}}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED

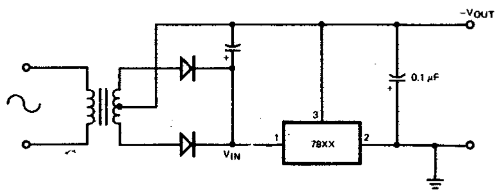


± TRACKING VOLTAGE REGULATOR

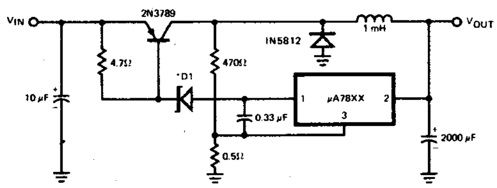
TYPICAL APPLICATIONS (Cont'd)



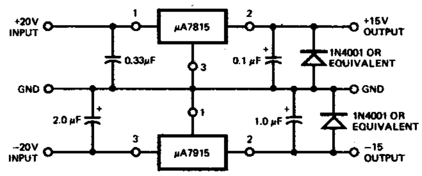
POSITIVE AND NEGATIVE REGULATOR



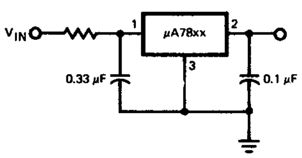
NEGATIVE OUTPUT VOLTAGE CIRCUIT

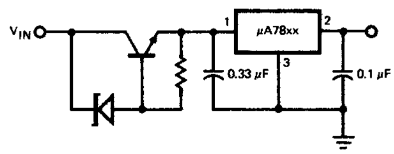


SWITCHING REGULATOR



DUAL SUPPLY
OPERATIONAL AMPLIFIER SUPPLY (±15 V @ 1.0 A)





HIGH INPUT VOLTAGE CIRCUITS

μA109 • μA209

5 VOLT REGULATOR

FAIRCHILD LINEAR INTEGRATED CIRCUITS

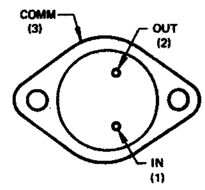
GENERAL DESCRIPTION – The 109 and 209 are complete Five Volt Regulators constructed using the Fairchild Planar* epitaxial process. These regulators employ internal current limiting, thermal shutdown and safe-area compensation making them essentially indestructible. They are intended for use as local regulators, eliminating noise and distribution problems associated with single point regulation. If adequate heat sinking is provided, they can provide over 1A output current. The 109 and 209 are intended primarily for use with TTL and DTL logic and are completely specified under worst case conditions to match the power supply requirements of these logic families. In addition to use as a fixed 5 V regulator, these devices can be used with external components to obtain adjustable output voltages and currents and as the power pass element in precision regulators.

- **OUTPUT CURRENT IN EXCESS OF 1 A**
- **SPECIFIED TO MATCH WORST CASE TTL AND DTL REQUIREMENTS**
- **NO EXTERNAL COMPONENTS**
- **INTERNAL THERMAL OVERLOAD PROTECTION**
- **OUTPUT TRANSISTOR SAFE-AREA COMPENSATION**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	35 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	−65°C to +150°C
Operating Junction Temperature Range	
Military Grade (μA109)	−55°C to +150°C
Industrial Grade (μA209)	−25°C to +150°C
Lead Temperature (Soldering, 60 seconds)	300°C

CONNECTION DIAGRAM
TO-3 PACKAGE
(TOP VIEW)



Case is connected to ground.

ORDER INFORMATION

TYPE	PART NO.
μA109	μA109KM
μA209	μA209KM

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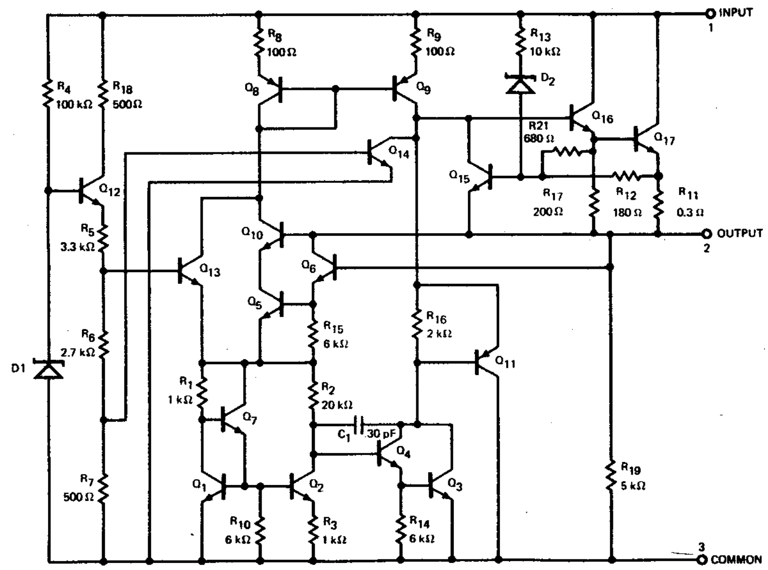
EQUIVALENT CIRCUIT



*Planar is a patented Fairchild process.

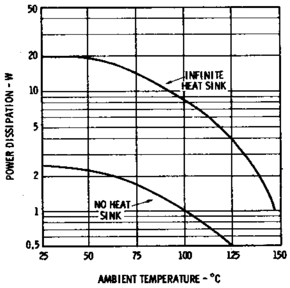
ELECTRICAL CHARACTERISTICS: T_J = −55°C to +150°C for 109, −25°C to +150°C for 209, V_{IN} = 10 V, I_{OUT} = 0.5 A, unless otherwise specified

CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		4.7	5.05	5.3	V
Line Regulation		T_J = 25°C, 7 V ≤ V_{IN} ≤ 25 V			4	50	mV
Load Regulation		T_J = 25°C, 5 mA ≤ I_{OUT} ≤ 1.5 A			15	100	mV
Output Voltage		8 V ≤ V_{IN} ≤ 20 V, 5 mA ≤ I_{OUT} ≤ 1 A, P ≤ 15 W		4.6		5.4	V
Quiescent Current		7 V ≤ V_{IN} ≤ 25 V				10	mA
			T_J = 25°C		4.2		mA
Quiescent Current Change	with Line	8V ≤ V_{IN} ≤ 25 V				0.8	mA
	with Load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			40		μV
Long Term Stability						10	mV
Thermal Resistance Junction to Case (Note 1)					3.0		°C/W

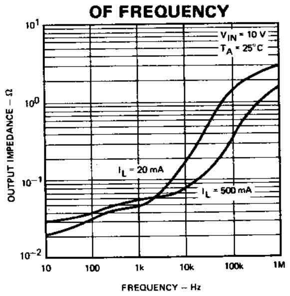
NOTE 1: Without a heat sink, the thermal resistance is $\theta_{JA(max)}$ 45°C/W. With a heat sink, the effective thermal resistance can only approach the values specified, depending on the efficiency of the sink.

TYPICAL PERFORMANCE CURVES FOR μA109 AND μA209

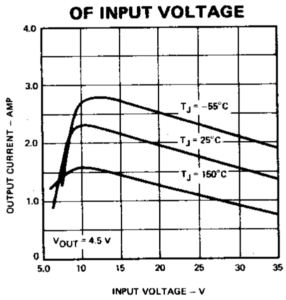
MAXIMUM AVERAGE POWER DISSIPATION AS A FUNCTION OF AMBIENT TEMPERATURE



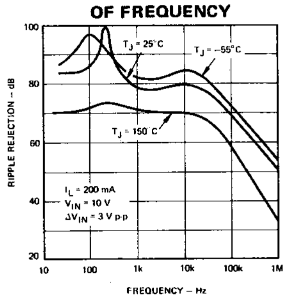
OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



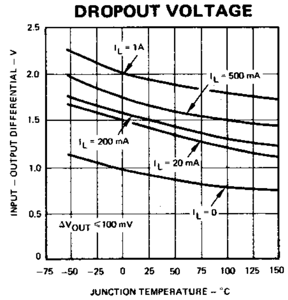
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT VOLTAGE



RIPPLE REJECTION AS A FUNCTION OF FREQUENCY

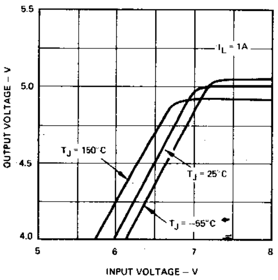


DROPOUT VOLTAGE

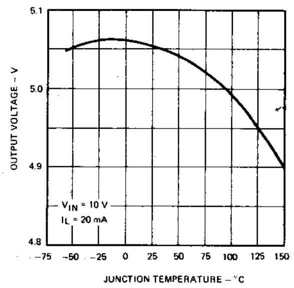


TYPICAL PERFORMANCE CURVES FOR μA109 AND μA209 (Cont'd)

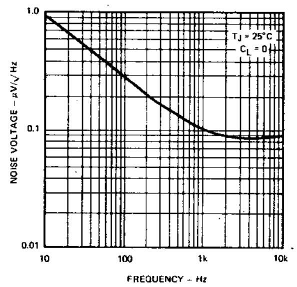
DROPOUT CHARACTERISTIC



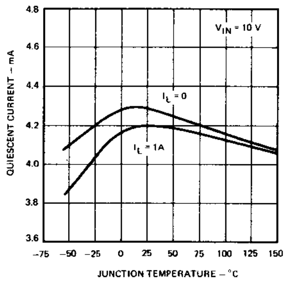
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



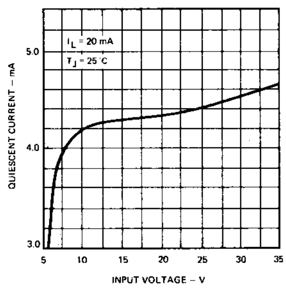
OUTPUT NOISE VOLTAGE AS A FUNCTION OF FREQUENCY



QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE

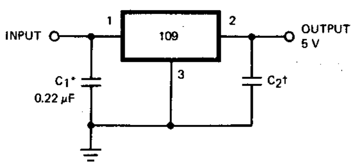


QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



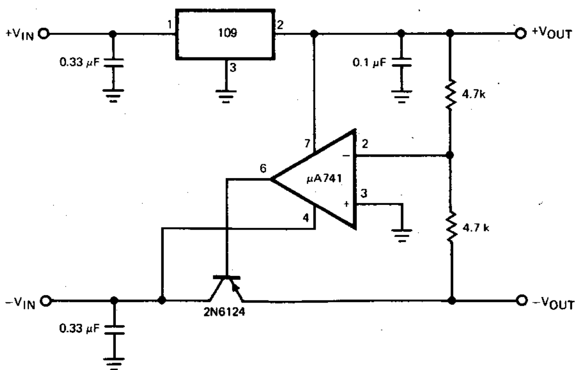
APPLICATIONS

FIXED 5 V REGULATOR



NOTES:
*Required if regulator is located an appreciable distance from power supply filter.
†Although no output capacitor is needed for stability, it does improve transient response.

TRACKING VOLTAGE REGULATOR



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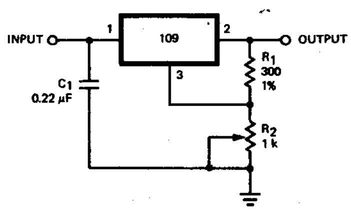
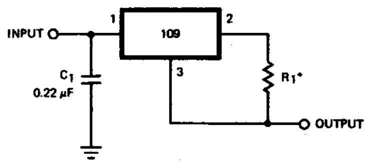
APPLICATIONS (Cont'd)

ADJUSTABLE OUTPUT REGULATOR

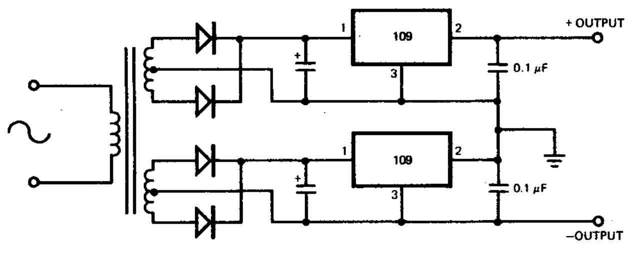


CURRENT REGULATOR



NOTE: *Determines output current.

POSITIVE AND NEGATIVE REGULATOR



μA309

5 VOLT REGULATOR

FAIRCHILD LINEAR INTEGRATED CIRCUIT

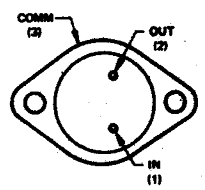
GENERAL DESCRIPTION – The 309 is a monolithic 5 Volt Regulator constructed using the Fairchild Planar* epitaxial process. This regulator employs internal current limiting, thermal shutdown and safe-area compensation making it essentially indestructable. The 309 is intended for use as a local regulator, eliminating noise and distribution problems associated with single point regulation. If adequate heat sinking is provided, it can provide over 1A output current. The 309 is intended primarily for use with TTL and DTL logic and is completely specified under worst case conditions to match the power supply requirements of these logic families. In addition to use as a fixed 5 volt regulator, this device can be used with external components to obtain adjustable output voltages and currents and as the power pass element in precision regulators.

- **OUTPUT CURRENT IN EXCESS OF 1 AMP**
- **SPECIFIED TO MATCH WORST CASE TTL AND DTL REQUIREMENTS**
- **NO EXTERNAL COMPONENTS**
- **INTERNAL THERMAL OVERLOAD PROTECTION**
- **OUTPUT TRANSISTOR SAFE-AREA COMPENSATION**
- **INTERNAL SHORT CIRCUIT LIMITING**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	35 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	−65°C to +150°C
Operating Junction Temperature Range	0°C to +125°C
Lead Temperature (Soldering, 60 s time limit)	300°C

CONNECTION DIAGRAM
TO-3 PACKAGE
(TOP VIEW)

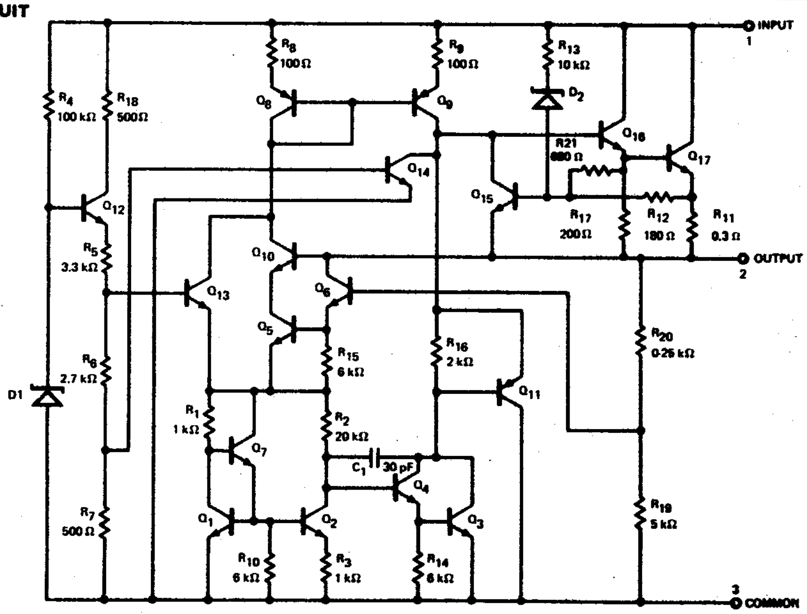


Case is connected to ground.

ORDER INFORMATION

TYPE	PART NO.
μA309	μA309KC

EQUIVALENT CIRCUIT



*Planar is a patented Fairchild process.

ELECTRICAL CHARACTERISTICS: Note 1

CHARACTERISTICS		CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$	4.8	5.05	5.2	V
Line Regulation		$T_J = 25°C$ $7.0\ V \leq V_{IN} \leq 25\ V$		4.0	50	mV
Load Regulation		$T_J = 25°C$ $5.0\ mA \leq I_{OUT} \leq 1.5\ A$		50	100	mV
Output Voltage		$7.0\ V \leq V_{IN} \leq 25\ V$ $5.0\ mA \leq I_{OUT} \leq 1.0\ A$ $P \leq 20\ W$	4.75		5.25	V
Quiescent Current		$7.0\ V \leq V_{IN} \leq 25\ V$		5.2	10	mA
Quiescent Current Change	with line	$7.0\ V \leq V_{IN} \leq 25\ V$			0.5	mA
	with load	$5.0\ mA \leq I_{OUT} \leq 1.0\ A$			0.8	mA
Output Noise Voltage		$T_A = 25°C$ $10\ Hz \leq f \leq 100\ kHz$		40		μV
Long Term Stability					20	mV

NOTE:
1. Unless otherwise specified, these specifications apply for $0°C \leq T_J \leq 125°C$, $V_{IN} = 10\ V$ and $I_{OUT} = 0.5\ A$.

DESIGN CONSIDERATIONS

μA309 regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across each pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (125°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP θ_{JC}	MAX θ_{JC}	TYP θ_{JA}	MAX θ_{JA}
TO-3	3.5°C/W	5.5°C/W	40°C/W	45°C/W

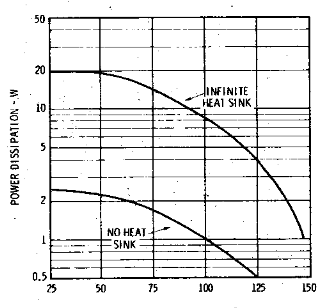
$$P_{D\,(MAX)} = \frac{T_{J\,(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_{J\,(MAX)} - T_A}{\theta_{JA}} \quad \text{(Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

Solving for T_J: $T_J = T_A + P_D\,(\theta_{JC} + \theta_{CA})$ or $T_A + P_D\theta_{JA}$ (Without heat sink)

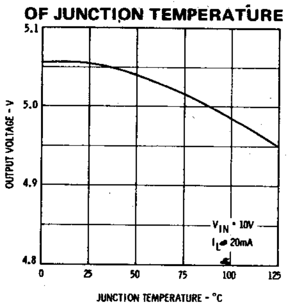
Where
T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation
θ_{JA} = Junction to ambient thermal resistance
θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to ambient thermal resistance
θ_{CS} = Case to ambient thermal resistance
θ_{SA} = Heat sink to ambient thermal resistance

TO-3 PACKAGE
MAXIMUM AVERAGE
POWER DISSIPATION

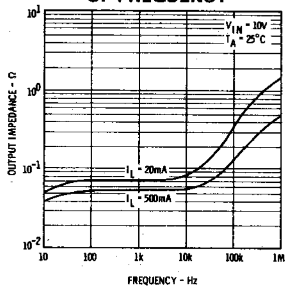


TYPICAL PERFORMANCE CURVES

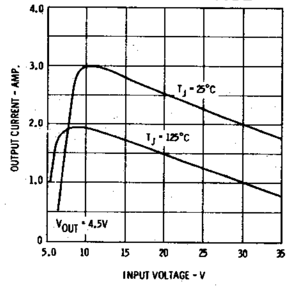
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



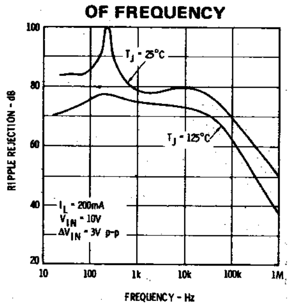
OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



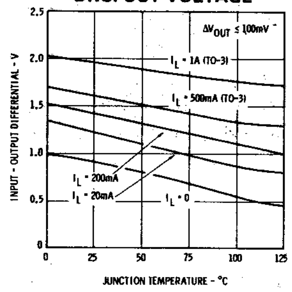
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT VOLTAGE



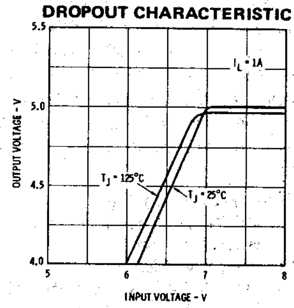
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



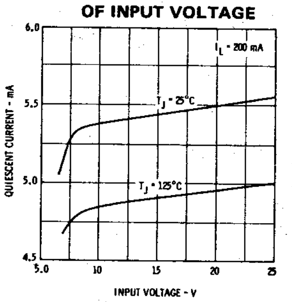
DROPOUT VOLTAGE



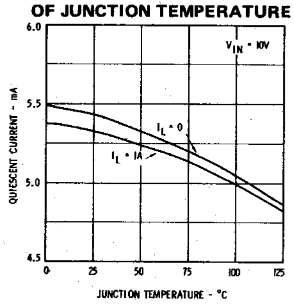
DROPOUT CHARACTERISTIC



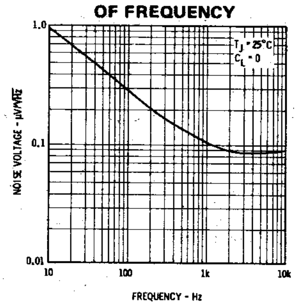
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



QUIESCENT CURRENT AS A FUNCTION OF JUNCTION TEMPERATURE



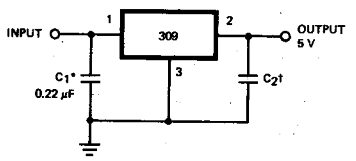
OUTPUT NOISE VOLTAGE AS A FUNCTION OF FREQUENCY



7

APPLICATIONS

FIXED 5 V REGULATOR

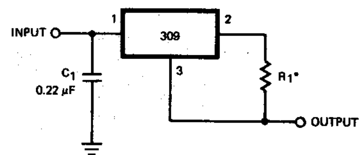


NOTES:

*Required if regulator is located an appreciable distance from power supply filter.

†Although no output capacitor is needed for stability, it does improve transient response.

CURRENT REGULATOR



NOTES:

*Determines output current.

μA78CB

POSITIVE 13.8 V, 2 AMP VOLTAGE REGULATOR

FAIRCHILD LINEAR INTEGRATED CIRCUITS

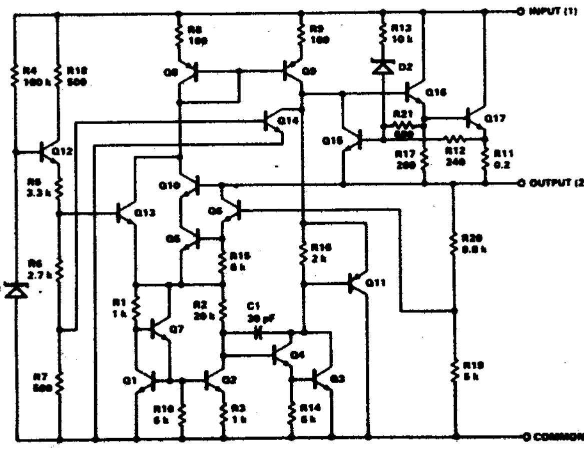
GENERAL DESCRIPTION – The μA78CB is a monolithic 3-Terminal Positive Regulator with a 13.8 V nominal output voltage. With adequate heat sinking, it can deliver output current in excess of 2.0 A. Just like its predecessors, the industry standard μA7800 series of regulators, the μA78CB employs current limiting, thermal shutdown and safe area protection and is essentially indestructible. The device is intended as a fixed voltage regulator for home base CB stations, and power supplies for driving automotive accessories directly from the AC line through a transformer, a fullwave rectifier and a filter capacitor. In addition to use as a fixed voltage regulator, the μA78CB can be used with external components to obtain adjustable output voltages and/or increased output currents.

- **OUTPUT VOLTAGE OF 13.8 V**
- **OUTPUT CURRENT IN EXCESS OF 2 A**
- **20 W POWER DISSIPATION**
- **NO EXTERNAL COMPONENTS**
- **INTERNAL THERMAL OVERLOAD PROTECTION**
- **INTERNAL SHORT CIRCUIT CURRENT LIMITING**
- **OUTPUT TRANSISTOR SAFE AREA COMPENSATION**
- **AVAILABLE IN THE TO-220 AND THE TO-3 PACKAGE**

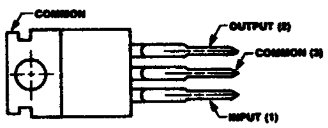
ABSOLUTE MAXIMUM RATINGS

Input Voltage	35 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	−65°C to +150°C
Operating Junction Temperature Range	0°C to +150°C
Lead Temperature	
(Soldering, 60 s time limit) TO-3 Package	300°C
(Soldering, 10 s time limit) TO-220 Package	230°C

EQUIVALENT CIRCUIT



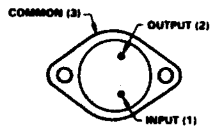
CONNECTION DIAGRAMS
TO-220 PACKAGE
(SIDE VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
13.8 V	μA78CB	μA78CBUC

TO-3 PACKAGE
(TOP VIEW)



ORDER INFORMATION

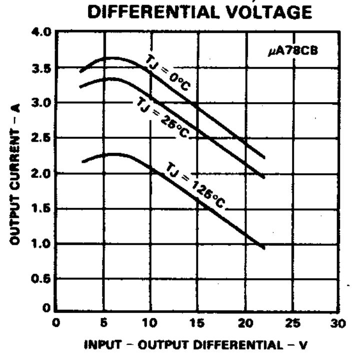
OUTPUT VOLTAGE	TYPE	PART NO.
13.8 V	μA78CB	μA78CBKC

ELECTRICAL CHARACTERISTICS: V_{IN} = 19 V, I_{OUT} = 1.0 A, 0°C ≤ T_J ≤ 125°C, C_{IN} = 0.33 μF, C_{OUT} = 0.1 μF, unless otherwise specified

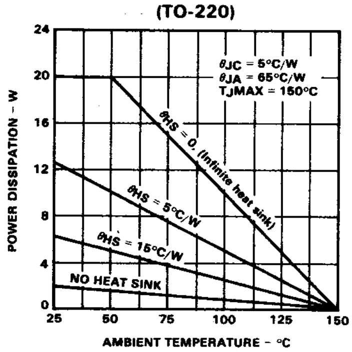
CHARACTERISTICS		CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		13.25	13.8	14.35	V
Line Regulation		T_J = 25°C, 17 V ≤ V_{IN} ≤ 25 V			8	150	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 2.0 A		50	150	mV
			0.5 A ≤ I_{OUT} 1.5 A		25	100	mV
Output Voltage		17 V ≤ V_{IN} ≤ 23 V 5 mA ≤ I_{OUT} ≤ 2.0 A		13.1		14.5	V
Quiescent Current		T_J = 25°C			4.3	8.0	mA
Quiescent Current Change	with line	17 V ≤ V_{IN} ≤ 25 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 2.0 A				1.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			75		μV
Ripple Rejection		f = 120 Hz, 17 ≤ V_{IN} ≤ 22 V		50	71		dB
Dropout Voltage		I_{OUT} = 2.0 A, T_J = 25°C			2.5		V
Short Circuit Current		T_J = 25°C			2.2		A
Peak Output Current		T_J = 25°C			3.3		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			−1.0		mV/°C

TYPICAL PERFORMANCE CURVES

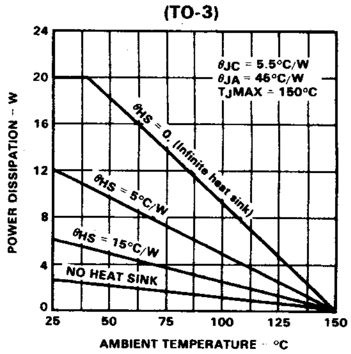
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT/OUTPUT DIFFERENTIAL VOLTAGE



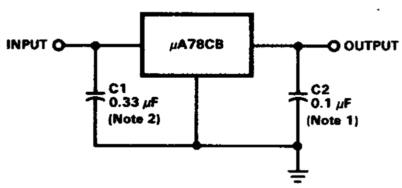
WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE (TO-220)



WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE (TO-3)



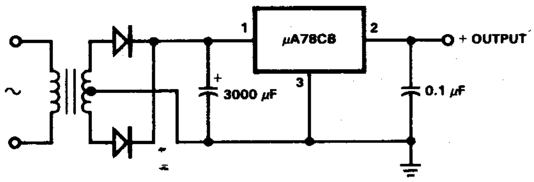
TYPICAL APPLICATIONS



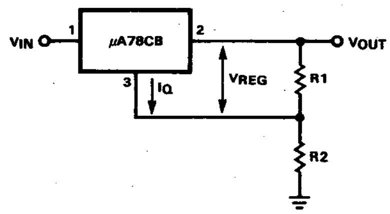
NOTES:
1. Although no output capacitor is needed for stability, it does improve transient response.
2. C_1 required if regulator is located an appreciable distance from power supply filter.

FIXED OUTPUT REGULATOR

TYPICAL APPLICATIONS (Cont'd)

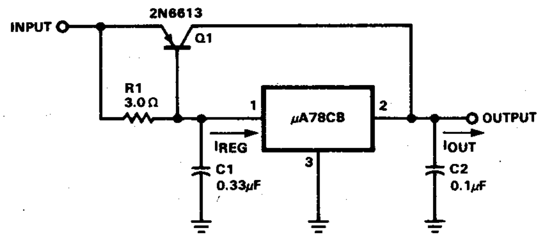


BASIC REGULATED POWER SUPPLY FOR CB HOME BASE STATIONS



$$V_{OUT} = V_{REG}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

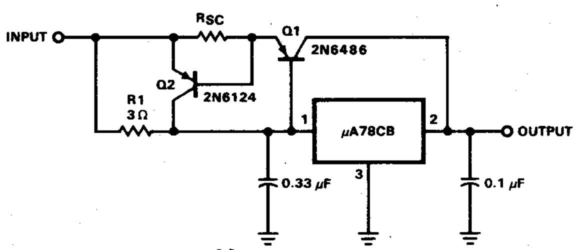
CIRCUIT FOR INCREASING OUTPUT VOLTAGE



$$I_{OUT(MAX)} > \beta(Q1) \times 2$$

$$R1 = \frac{0.9}{I_{REG}} = \frac{\beta(Q1)\, V_{BE(Q1)}}{I_{REG(MAX)}\,(\beta + 1) - I_{OUT(MAX)}}$$

HIGH CURRENT VOLTAGE REGULATOR



$$R_{SC} = \frac{0.9}{I_{SC}}$$

$$R1 = \frac{\beta V_{BE(Q1)}}{I_{REG(MAX)}\,(\beta + 1) - I_{OUT(MAX)}}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED

DESIGN CONSIDERATIONS – The μA78CB voltage regulator has thermal overload protection from excessive power, internal short circuit protection which limits the regulator's maximum current, and output transistor safe area compensation for reducting the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature of 125°C in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP θ_{JC}	MAX θ_{JC}	TYP θ_{JA}	MAX θ_{JA}
TO-3	3.5	5.5	40	45
TO-220	3.0	5.0	60	65

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_{J(MAX)} - T_{A(\text{Without a heat sink})}}{\theta_{JA}}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

solving for T_J: $T_J = T_A + P_D\,(\theta_{JC} + \theta_{CA})$ or $T_A + P_D\theta_{JA}$ (without a heat sink)

where T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation

θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to ambient thermal resistance
θ_{CS} = Case to heat sink thermal resistance
θ_{SA} = Heat sink to ambient thermal resistance
θ_{JA} = Junction to ambient thermal resistance

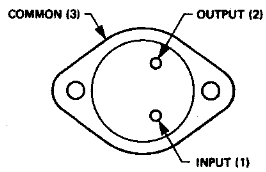
7

SH123 • SH223 • SH323
3-TERMINAL VOLTAGE REGULATORS
FAIRCHILD HYBRID PRODUCTS

GENERAL DESCRIPTION — The SH123/SH223/SH323 are hybrid integrated circuit positive voltage regulators. The output voltage is 5 V ±200 mV and the output current capability exceeds 3.0 A. Internal current limiting and thermal shutdown circuitry make the device essentially indestructible. The SH123/SH223/SH323 are intended for a wide range of systems where a regulated 5 V supply is required and can be used for a variety of on-card regulation and circuit isolation applications.

- 3 A OUTPUT CURRENT
- NO EXTERNAL COMPONENTS
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- STANDARD TO-3 PACKAGE

CONNECTION DIAGRAM
TO-3 PACKAGE
(TOP VIEW)



ORDER INFORMATION

OPERATING TEMPERATURE RANGE (JUNCTION)	PART NO.
-55°C to 150°C	SH123KM
0°C to 150°C	SH323KC
-25°C to 150°C	SH223KV

ABSOLUTE MAXIMUM RATINGS (SH323)

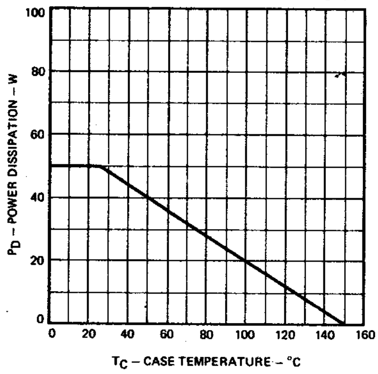
Input Voltage	25 V
Internal Power Dissipation	50 W @ 25°C Case
Operating Junction Temperature Range	0°C to +150°C
Storage Temperature	−55°C to +150°C

ELECTRICAL CHARACTERISTICS: V_{IN} = 10 V, I_{OUT} = 2.0 A, T_C = 25°C, unless otherwise specified

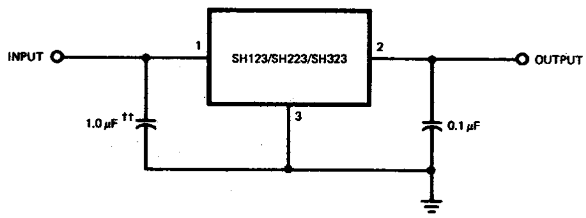
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	V_{IN} = 10 V, I_{OUT} = 2.0 A, T_C = 25°C	4.8	5.0	5.2	V
Line Regulation	8.5 V < V_{IN} < 20 V		10	50	mV
Load Regulation	10 mA < I_{OUT} < 3.0 A			50	mV
Quiescent Current	I_{OUT} = 0 A			10	mA
Input Voltage	10 mA < I_{OUT} < 3.0 A*	8.5		25	V
Ripple Rejection	f = 120 Hz, I_{OUT} = 1.0 A	60			dB

*Maximum power dissipation must be observed. (See Maximum Power Dissipation graph.)

MAXIMUM POWER DISSIPATION



TYPICAL APPLICATION



††Required if regulator is located an appreciable distance from power supply filter.

7

µA78H00/µA78HG SERIES

5 AMP VOLTAGE REGULATOR

FAIRCHILD LINEAR INTEGRATED CIRCUITS

GENERAL DESCRIPTION

Fixed Output – The µA78H00 series hybrids are regulators with fixed output voltages and 5 A output current capability with all the inherent characteristics of the monolithic 3-terminal regulators, i.e., full thermal overload, short-circuit and safe-area protection. The µA78H00 is packaged in a hermetically sealed TO-3 providing 50 W power dissipation. The regulator consists of a monolithic chip driving a discrete series-pass element and two short-circuit detection transistors. A beryllium-oxide substrate is used in conjunction with an isothermal layout to optimize the thermal characteristics of the device and still maintain electrical isolation between the various chips. This unique circuit design limits the maximum junction temperature of the power output transistor to provide full automatic thermal overload protection. If the safe operating area is ever exceeded, the device simply shuts down, rather than failing or damaging other system components. This feature eliminates the need to design costly output circuitry and overly conservative heat sinking arrangements typical of high-current regulators built from discrete components.

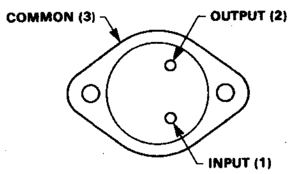
Adjustable Regulators – The µA78HG is an adjustable 4-terminal positive voltage regulator capable of supplying in excess of 5 A over a 5.0 V to 24 V output range. The same features and construction details of the µA78H00 series have been incorporated into the µA78HG. Only two (2) external resistors are required to set the output voltage. Input and output capacitors should be used to improve input filtering and transient response.

- **5 A OUTPUT CURRENT**
- **INTERNAL CURRENT AND THERMAL LIMITING**
- **INTERNAL SHORT-CIRCUIT CURRENT LIMIT**
- **LOW DROP-OUT VOLTAGE**
- **50 W POWER DISSIPATION**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	
µA78H05, 12, 15	25 V
µA78HG	40 V
Internal Power Dissipation	50 W @ 25°C Case
Maximum Input-to-Output Voltage Differential	25 V
Operating Junction Temperature Range	
µA78H00C (fixed voltage series)	–0°C to 150°C
µA78HGC (adjustable voltage series)	–0°C to 150°C
Military Temperature Range (consult factory)	–55°C to 150°C
Storage Temperature Range	–55°C to 150°C
Lead Temperature (Soldering, 60 s)	300°C

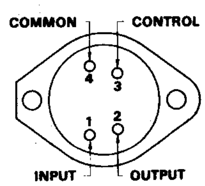
CONNECTION DIAGRAMS
TO-3 PACKAGE
(TOP VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5.0 V	78H05C	µA78H05KC
12 V	78H12C	µA78H12KC
15 V	78H15C	µA78H15KC

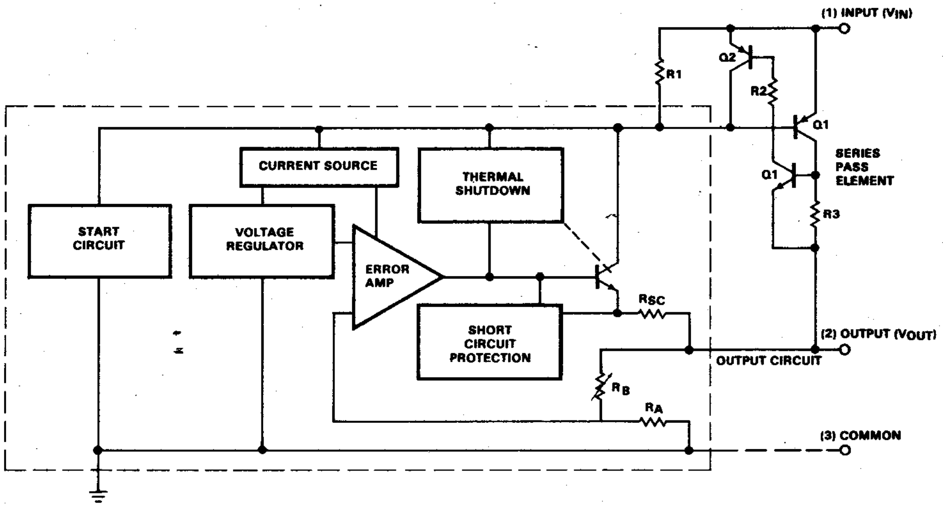
TO-3 PACKAGE
(TOP VIEW)



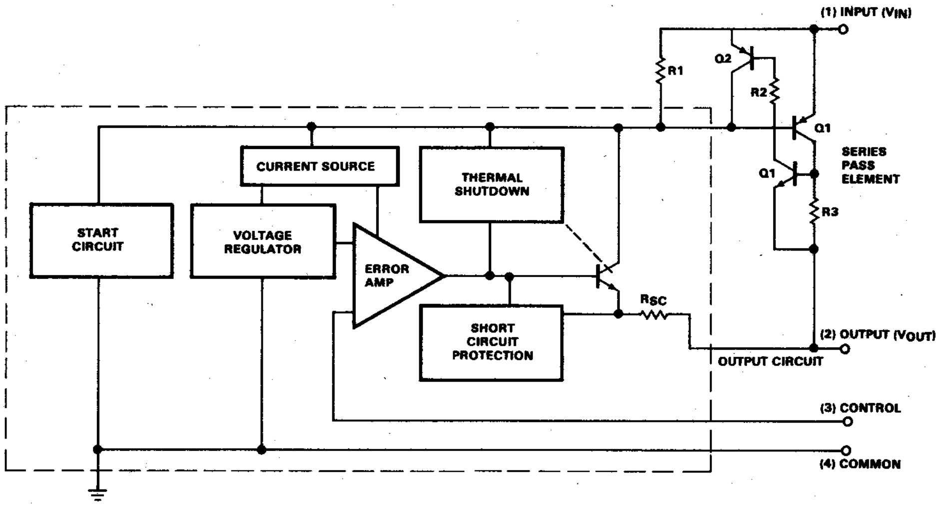
ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
5–24 V Adjustable	78HGC	µA78HGKC

BLOCK DIAGRAM – FIXED OUTPUT 78H00 SERIES



BLOCK DIAGRAM – ADJUSTABLE OUTPUT 78HG



ELECTRICAL CHARACTERISTICS: $T_J = 25°C$, $I_{OUT} = 2.0$ A unless otherwise specified.

CHARACTERISTICS	CONDITIONS	μA78H05C			UNITS
		MIN	TYP	MAX	
Output Voltage	$I_{OUT} = 2.0$ A, $V_{IN} = 10$ V	4.8	5.0	5.2	V
Line Regulation (Note 1)	$V_{IN} = 8.5$ to 25 V		10	50	mV
Load Regulation (Note 1)	10 mA $\leq I_{OUT} \leq$ 5.0 A, $V_{IN} = 10$ V		10	50	mV
Quiescent Current	$I_{OUT} = 0$, $V_{IN} = V_{OUT} + 5.0$ V			10	mA
Ripple Rejection	$I_{OUT} = 1.0$ A, f = 210 Hz, 5.0 V P-P	60			dB
Output Noise	10 Hz $\leq$ f $\leq$ 100 kHz, $V_{IN} = V_{OUT} + 5.0$ V		40		μV_{RMS}
Dropout Voltage	$I_O = 5.0$ A		3.0		V
	$I_O = 3.0$ A		2.6		V
Short Circuit Current Limit	$V_{IN} = 10$ V		7.0		A_{pk}

7

ELECTRICAL CHARACTERISTICS: $T_J = 25°C$, $I_{OUT} = 2.0$ A unless otherwise specified.

CHARACTERISTICS	CONDITIONS	μA78H12C			UNITS
		MIN	TYP	MAX	
Output Voltage	$I_{OUT} = 2.0$ A, $V_{IN} = 19$ V	11.5	12	12.5	V
Line Regulation (Note 1)	$V_{IN} = 16$ to 25 V		20	120	mV
Load Regulation (Note 1)	10 mA $\leq I_{OUT} \leq$ 5.0 A, $V_{IN} = 19$ V		20	120	mV
Quiescent Current	$I_{OUT} = 0$, $V_{IN} = V_{OUT} + 5.0$ V			10	mA
Ripple Rejection	$I_{OUT} = 1.0$ A, f = 210 Hz, 5.0 V P-P	60			dB
Output Noise	10 Hz $\leq$ f $\leq$ 100 kHz, $V_{IN} = V_{OUT} + 5.0$ V		75		μV_{RMS}
Dropout Voltage	$I_O = 5.0$ A		3.0		V
	$I_O = 3.0$ A		2.6		V
Short Circuit Current Limit	$V_{IN} = 19$ V		7.0		A_{pk}

ELECTRICAL CHARACTERISTICS: $T_J = 25°C$, $I_{OUT} = 2.0$ A unless otherwise specified.

CHARACTERISTICS	CONDITIONS	μA78H15C			UNITS
		MIN	TYP	MAX	
Output Voltage	$I_{OUT} = 2.0$ A, $V_{IN} = 20$ V	14.4	15	15.6	V
Line Regulation (Note 1)	$V_{IN} = 19$ to 25 V		30	150	mV
Load Regulation (Note 1)	10 mA $\leq I_{OUT} \leq$ 5.0 A, $V_{IN} = 20$ V		30	150	mV
Quiescent Current	$I_{OUT} = 0$, $V_{IN} = V_{OUT} + 5.0$ V			10	mA
Ripple Rejection	$I_{OUT} = 1.0$ A, f = 210 Hz, 5.0 V P-P	60			dB
Output Noise	10 Hz $\leq$ f $\leq$ 100 kHz, $V_{IN} = V_{OUT} + 5.0$ V		75		μV_{RMS}
Dropout Voltage	$I_O = 5.0$ A		3.0		V
	$I_O = 3.0$ A		2.6		V
Short Circuit Current Limit	$V_{IN} = 20$ V		7.0		A_{pk}

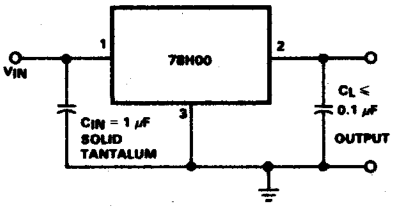
ELECTRICAL CHARACTERISTICS: $T_J = 25°C$, $I_{OUT} = 2.0$ A unless otherwise specified.

CHARACTERISTICS	CONDITIONS	μA78HGC (Adjustable)			UNITS (Note 2)
		MIN	TYP	MAX	
Output Voltage	$I_{OUT} = 2.0$ A, $V_{IN} = V_{OUT} + 3.5$ V	5.0	Note 3	24	V
Line Regulation (Note 1)	$V_{IN} = 8.5$ to 25 V			1%	V_{OUT}
Load Regulation (Note 1)	10 mA $\leq I_{OUT} \leq$ 5.0 A, $V_{IN} = 10$ V			1%	V_{OUT}
Quiescent Current	$I_{OUT} = 0$, $V_{IN} = V_{OUT} + 5.0$ V			10	mA
Ripple Rejection	$I_{OUT} = 1.0$ A, f = 210 Hz, 5.0 V P-P	60			dB
Output Noise	10 Hz $\leq$ f $\leq$ 100 kHz, $V_{IN} = V_{OUT} + 5.0$ V		50		μV_{RMS}
Dropout Voltage	$I_O = 5.0$ A		3.0		V
	$I_O = 3.0$ A		2.6		V
Short Circuit Current Limit	$V_{IN} = 10$ V		7.0		A_{pk}
Control Pin Voltage	$V_{IN} = 10$ V	4.8	5.0	5.2	V

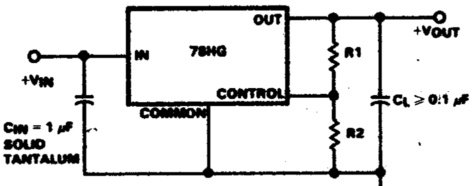
NOTES:
1. Load and line regulation are specified at constant junction temperature. Pulse testing is required with a pulse width $\leq$ 1 ms and a duty cycle $\leq$ 5%. Full Kelvin connection methods must be used to measure these parameters.
2. The performance characteristics of the adjustable series (μA78HG) is specified for $V_{OUT} = 5.0$ V.
3. V_{OUT} for (μA78HG) is defined as $V_{OUT} = \frac{R1 + R2}{R2} (V_{CONT})$

BASIC TEST CIRCUITS

μA78H00 SERIES
FIXED OUTPUT VOLTAGE



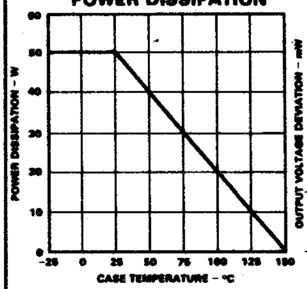
μA78HG
ADJUSTABLE OUTPUT VOLTAGE



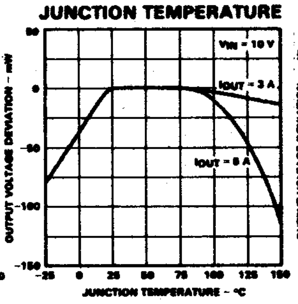
$V_{OUT} = V_{CONT}\left(\frac{R1 + R2}{R2}\right)$

TYPICAL PERFORMANCE CHARACTERISTICS

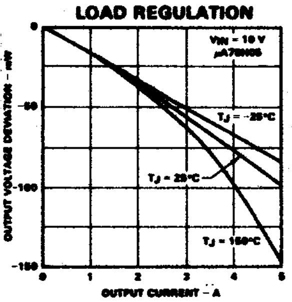
MAXIMUM POWER DISSIPATION



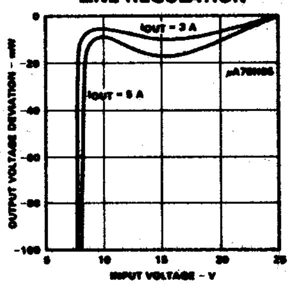
OUTPUT VOLTAGE DEVIATION AS A FUNCTION OF JUNCTION TEMPERATURE



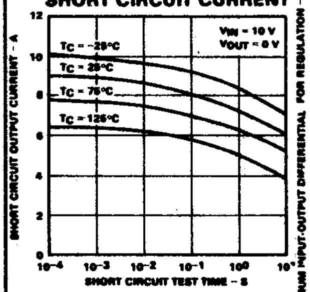
LOAD REGULATION



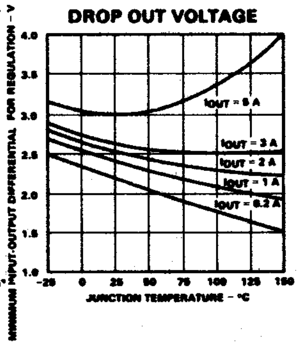
LINE REGULATION



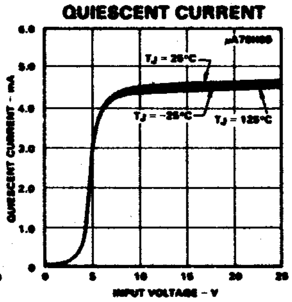
SHORT CIRCUIT CURRENT



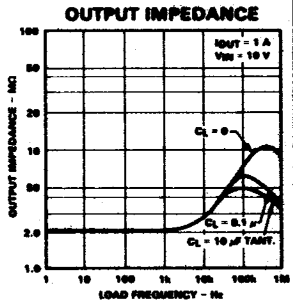
DROP OUT VOLTAGE



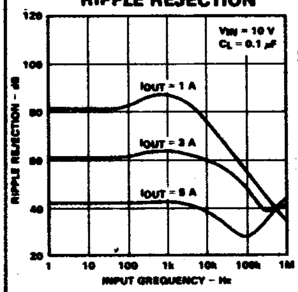
QUIESCENT CURRENT



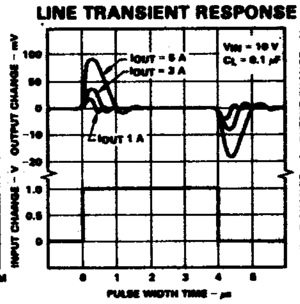
OUTPUT IMPEDANCE



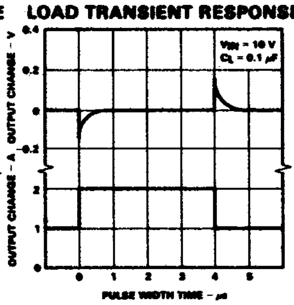
RIPPLE REJECTION



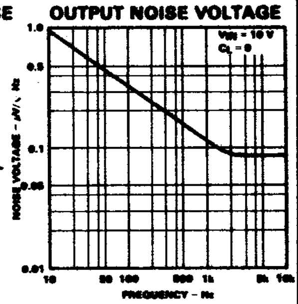
LINE TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE



OUTPUT NOISE VOLTAGE



DESIGN CONSIDERATIONS

78H00 Series – The μA78H00 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation to prevent excessive instantaneous power appearing across the pass transistor as the voltage across it increases. Thus, the device is fully protected from all overload abnormalities.

78HG Series – The μA78HG variable voltage regulator has an output voltage which varies from $V_{CONTROL}$ to typically $V_{IN} - 3.0$ V by $V_{OUT} = V_{CONTROL}$ (R1 + R2)/R2. The nominal reference in the μA78HG is 5.0 V. If we allow 1.0 mA to flow in the control string to eliminate bias current effects, we can make R2 = 5 kΩ in the μA78HG. The output voltage is then: V_{OUT} = (R1 + R2) V, where R1 and R2 are in kΩs.

Example: If R2 = 5 kΩ and R1 = 10 kΩ then V_{OUT} = 15 V nominal, for the μA78HG.

By proper wiring of the feedback resistors, load regulation of the devices can be improved significantly.

The regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection to prevent excessive instantaneous power appearing across the pass transistor as the voltage across it increases. Thus the device is fully protected from all overload abnormalities.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (125°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYP θ_{JC}	MAX θ_{JC}	TYP θ_{JA}	MAX θ_{JA}
TO-3	2.0	2.5	32	38

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

Solving for T_J: $T_J = T_A + P_D (\theta_{JC} + \theta_{CA})$ or $T_A + P_D\theta_{JA}$ (Without heat sink)

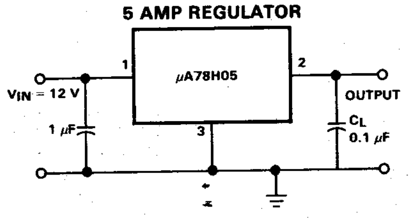
Where:

T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation
θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to ambient thermal resistance
θ_{CS} = Case to heat sink thermal resistance
θ_{SA} = Heat sink to ambient thermal resistance
θ_{JA} = Junction to ambient thermal resistance

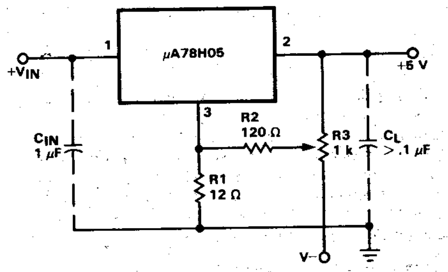
TYPICAL APPLICATIONS FOR μA78H00/78HG SERIES

In many applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (1.0 μF solid tantalum and 0.1 μF respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

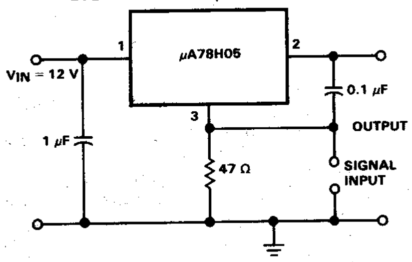
5 AMP REGULATOR



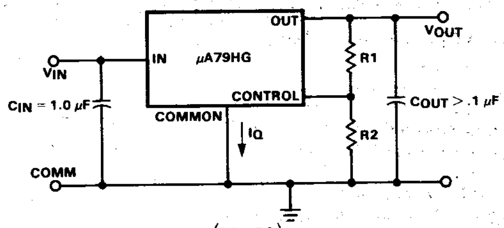
TRIMMING OUTPUT TO 5 V



SIGNAL DRIVER/MODULATOR



ADJUSTABLE VOLTAGE OUTPUT 5–20 VOLTS



$$V_{OUT} = \left(\frac{R1 + R2}{R2}\right) V_{CONTROL}$$

$V_{CONTROL}$ NOMINAL = 5 V

R2 CURRENT ≈ 1 mA

7

µA79M00 SERIES

3-TERMINAL NEGATIVE VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

GENERAL DESCRIPTION – The µA79M00 series of 3-Terminal Medium Current Negative Voltage Regulators are constructed using the Fairchild Planar* epitaxial process. These regulators employ internal current limiting, thermal shutdown and safe area compensation making them essentially indestructible. If adequate heat sinking is provided, they can deliver up to 500 mA output current. They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

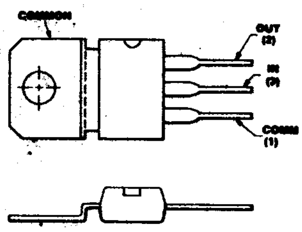
- OUTPUT CURRENT IN EXCESS OF 0.5 A
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT LIMITING
- OUTPUT TRANSISTOR SAFE AREA COMPENSATION
- AVAILABLE IN JEDEC TO-220 AND TO-39 PACKAGES
- OUTPUT VOLTAGES OF –5 V, –6 V, –8 V, –12 V, –15 V, –20 V AND –24 V

ABSOLUTE MAXIMUM RATINGS

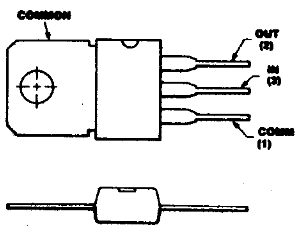
Input Voltage	
(–5 V through –15 V)	–35 V
(–20 V, –24 V)	–40 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	
TO-39	–65°C to +150°C
TO-220 and Power Tab	–55°C to +125°C
Operating Junction Temperature Range	
TO-39 Military (µA79M00)	–55°C to +150°C
Commercial (µA79M00C)	0°C to +150°C
TO-220 Commercial (µA79M00C)	0°C to +150°C
Lead Temperature (Soldering, 60 s) TO-39	300°C
(Soldering, 10 s) TO-220 and Power Tab	230°C

CONNECTION DIAGRAMS
POWER TAB PACKAGES
(TO-202 EQUIVALENT)

U1



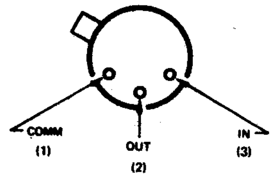
U2



OUTPUT VOLTAGE	TYPE	PART NO.*
–5 V	µA79M05	µA79M05U1C
–6 V	µA79M06	µA79M06U1C
–8 V	µA79M08	µA79M08U1C
–12 V	µA79M12	µA79M12U1C
–15 V	µA79M15	µA79M15U1C
–20 V	µA79M20	µA79M20U1C
–24 V	µA79M24	µA79M24U1C

* or U2C for straight heatsink.

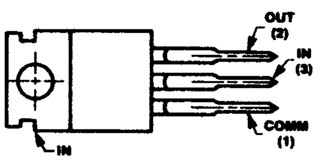
CONNECTION DIAGRAMS
TO-39 PACKAGE
(TOP VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	PART NO.	PART NO.
–5 V	µA 79M05HM	µA79M05AHC
–6 V	µA 79M06HM	µA79M06AHC
–8 V	µA 79M08HM	µA79M08AHC
–12 V	µA 79M12HM	µA79M12AHC
–15 V	µA 79M15HM	µA79M15AHC
–20 V	µA 79M20HM	µA79M20AHC
–24 V	µA 79M24HM	µA79M24AHC

TO-220 PACKAGE



ORDER INFORMATION

OUTPUT VOLTAGE	PART NO.
–5 V	µA 79M05AUC
–6 V	µA 79M06AUC
–8 V	µA 79M08AUC
–12 V	µA 79M12AUC
–15 V	µA 79M15AUC
–20 V	µA 79M20AUC
–24 V	µA 79M24AUC

*Planar is a patented Fairchild process.

μA79M05HM

ELECTRICAL CHARACTERISTICS: $V_{IN} = -10$ V, $I_{OUT} = 350$ mA, $-55°C \leq T_J \leq 150°C$, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$, unless otherwise specified. Notes 1 and 2

CHARACTERISTICS		CONDITIONS (Note 3)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−5.2	−5.0	−4.8	V
Line Regulation		$T_J = 25°C$	$-25\ V \leq V_{IN} \leq -7\ V$		7.0	50	mV
			$-18\ V \leq V_{IN} \leq -8\ V$		3.0	30	mV
Load Regulation		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 500\ mA$			75	100	mV
		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 350\ mA$			50		mV
Output Voltage		$-25\ V \leq V_{IN} \leq -7\ V$, $5\ mA \leq I_{OUT} \leq 350\ mA$*		−5.25		−4.75	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-25\ V \leq V_{IN} \leq -8\ V$				0.4	mA
	with load	$5\ mA \leq I_{OUT} \leq 350\ mA$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$-18\ V \leq V_{IN} \leq -8\ V$,	$I_{OUT} = 100\ mA$	50			dB
		f = 120 Hz	$I_{OUT} = 300\ mA$, $T_J = 25°C$	54	60		dB
Dropout Voltage		$T_J = 25°C$			1.1	2.3	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -35\ V$				0.6	A
Peak Output Current				0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\ mA$ $-55°C \leq T_J \leq +150°C$				0.3	$mV/°C/V_{OUT}$

μA79M05AHC AND μA79M05AUC

ELECTRICAL CHARACTERISTICS: $V_{IN} = -10$ V, $I_{OUT} = 350$ mA, $0°C \leq T_J \leq 125°C$, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 3)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−5.2	−5.0	−4.8	V
Line Regulation		$T_J = 25°C$	$-25\ V \leq V_{IN} \leq -7\ V$		7.0	50	mV
			$-18\ V \leq V_{IN} \leq -8\ V$		3.0	30	mV
Load Regulation		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 500\ mA$			75	100	mV
		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 350\ mA$			50		mV
Output Voltage		$-25\ V \leq V_{IN} \leq -7\ V$, $5\ mA \leq I_{OUT} \leq 350\ mA$*		−5.25		−4.75	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-25\ V \leq V_{IN} \leq -8\ V$				0.4	mA
	with load	$5\ mA \leq I_{OUT} \leq 350\ mA$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			125		μV
Ripple Rejection		$-18\ V \leq V_{IN} \leq -8\ V$,	$I_{OUT} = 100\ mA$	50			dB
		f = 120 Hz	$I_{OUT} = 300\ mA$, $T_J = 25°C$	54	60		dB
Dropout Voltage		$T_J = 25°C$			1.1		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -30\ V$			140		mA
Peak Output Current					650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\ mA$			−0.4		mV/°C

*$P_D \leq 4$ W

NOTES:

1. See Test Circuit.
2. The convention for negative regulators is the algebraic valves, thus −15 V is less than −10 V.
3. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes due to changes in internal temperature must be taken into account separately.

7

μA79M06HM

ELECTRICAL CHARACTERISTICS: $V_{IN} = -11$ V, $I_{OUT} = 350$ mA, $-55°C \leq T_J \leq 150°C$, $C_{IN} = 2$ μF, $C_{OUT} = 1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−6.25	−6.0	−5.75	V
Line Regulation		$T_J = 25°C$	$-25\text{ V} \leq V_{IN} \leq -8\text{ V}$		7.0	60	mV
			$-19\text{ V} \leq V_{IN} \leq -9\text{ V}$		3.0	40	mV
Load Regulation		$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 500\text{ mA}$			80	120	mV
		$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$*			55		mV
Output Voltage		$-25\text{ V} \leq V_{IN} \leq -8\text{ V}$, $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$*		−6.3		−5.7	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-25\text{ V} \leq V_{IN} \leq -9\text{ V}$				0.4	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$-19\text{ V} \leq V_{IN} \leq -9\text{ V}$,	$I_{OUT} = 100$ mA	50			dB
		f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	54	60		dB
Dropout Voltage		$T_J = 25°C$			1.1	2.3	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -35$ V				0.6	A
Peak Output Current				0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $-55°C \leq T_J \leq +150°C$				0.3	$mV/°C/V_{OUT}$

μA79M06AHC AND μA79M06AUC

ELECTRICAL CHARACTERISTICS: $V_{IN} = -11$ V, $I_{OUT} = 350$ mA, $0°C \leq T_J \leq 125°C$, $C_{IN} = 2$ μF, $C_{OUT} = 1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−6.25	−6.0	−5.75	V
Line Regulation		$T_J = 25°C$	$-25\text{ V} \leq V_{IN} \leq -8\text{ V}$		7.0	60	mV
			$-19\text{ V} \leq V_{IN} \leq -9\text{ V}$		3.0	40	mV
Load Regulation		$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 500\text{ mA}$			80	120	mV
		$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$			55		mV
Output Voltage		$-25\text{ V} \leq V_{IN} \leq -8\text{ V}$, $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$		−6.3		−5.7	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-25\text{ V} \leq V_{IN} \leq -9\text{ V}$				0.4	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$			150		μV
Ripple Rejection		$-19\text{ V} \leq V_{IN} \leq -9\text{ V}$,	$I_{OUT} = 100$ mA	50			dB
		f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	54	60		dB
Dropout Voltage		$T_J = 25°C$			1.1		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -30$ V			140		mA
Peak Output Current					650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA			−0.4		mV/°C

*$P_D \leq 4$ W

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA79M08HM

ELECTRICAL CHARACTERISTICS: $V_{IN} = -14$ V, $I_{OUT} = 350$ mA, $-55°C \leq T_J \leq 150°C$, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−8.3	−8.0	−7.7	V
Line Regulation		$T_J = 25°C$	$-25\ V \leq V_{IN} \leq -10.5\ V$		8.0	80	mV
			$-21\ V \leq V_{IN} \leq -11\ V$		4.0	50	mV
Load Regulation		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 500\ mA$			90	160	mV
		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 350\ mA$			60		mV
Output Voltage		$-25\ V \leq V_{IN} \leq -10.5\ V$, $5\ mA \leq I_{OUT} \leq 350\ mA$*		−8.4		−7.6	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-25\ V \leq V_{IN} \leq -10.5\ V$				0.4	mA
	with load	$5\ mA \leq I_{OUT} \leq 350\ mA$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$-21.5\ V \leq V_{IN} \leq -11.5\ V$,	$I_{OUT} = 100$ mA	50			dB
		f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	54	59		dB
Dropout Voltage		$T_J = 25°C$			1.1	2.3	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -35$ V				0.6	A
Peak Output Current				0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $-55°C \leq T_J \leq +150°C$				0.3	$mV/°C/V_{OUT}$

μA79M08AHC AND μA79M08AUC

ELECTRICAL CHARACTERISTICS: $V_{IN} = -14$ V, $I_{OUT} = 350$ mA, $0°C \leq T_J \leq 125°C$, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−8.3	−8.0	−7.7	V
Line Regulation		$T_J = 25°C$	$-25\ V \leq V_{IN} \leq -10.5\ V$		8.0	80	mV
			$-21\ V \leq V_{IN} \leq -11\ V$		4.0	50	mV
Load Regulation		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 500\ mA$			90	160	mV
		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 350\ mA$			60		mV
Output Voltage		$-25\ V \leq V_{IN} \leq -10.5\ V$, $5\ mA \leq I_{OUT} \leq 350\ mA$		−8.4		−7.6	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-25\ V \leq V_{IN} \leq -10.5\ V$				0.4	mA
	with load	$5\ mA \leq I_{OUT} \leq 350\ mA$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			200		μV
Ripple Rejection		$-21.5\ V \leq V_{IN} \leq -11.5\ V$,	$I_{OUT} = 100$ mA	50			dB
		f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	54	59		dB
Dropout Voltage		$T_J = 25°C$			1.1		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -30$ V			140		mA
Peak Output Current					650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA			−0.6		mV/°C

*$P_D \leq 4$ W

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA79M12HM

ELECTRICAL CHARACTERISTICS: $V_{IN} = -11$ V, $I_{OUT} = 350$ mA, $-55°C < T_J < 150°C$, $C_{IN} = 2$ μF, $C_{OUT} = 1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−12.5	−12	−11.5	V
Line Regulation		$T_J = 25°C$	$-30\text{ V} < V_{IN} < -14.5\text{ V}$		9.0	80	mV
			$-25\text{ V} < V_{IN} < -15\text{ V}$		5.0	50	mV
Load Regulation		$T_J = 25°C$, $5\text{ mA} < I_{OUT} < 500\text{ mA}$			65	240	mV
		$T_J = 25°C$, $5\text{ mA} < I_{OUT} < 350\text{ mA}$			45		mV
Output Voltage		$-30\text{ V} < V_{IN} < -14.5\text{ V}$, $5\text{ mA} < I_{OUT} < 350\text{ mA}$*		−12.6		−11.4	V
Quiescent Current		$T_J = 25°C$			1.5	3.0	mA
Quiescent Current Change	with line	$-30\text{ V} < V_{IN} < -14.5\text{ V}$				0.4	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} < f < 100\text{ kHz}$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$-25\text{ V} < V_{IN} < -15\text{ V}$,	$I_{OUT} = 100$ mA	50			dB
		f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	54	60		dB
Dropout Voltage		$T_J = 25°C$			1.1	2.3	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -35$ V				0.6	A
Peak Output Current				0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $-55°C < T_J < +150°C$				0.3	$mV/°C/V_{OUT}$

μA79M12AHC AND μA79M12AUC

ELECTRICAL CHARACTERISTICS: $V_{IN} = -19$ V, $I_{OUT} = 350$ mA, $0°C < T_J < 125°C$, $C_{IN} = 2$ μF, $C_{OUT} = 1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−12.5	−12	−11.5	V
Line Regulation		$T_J = 25°C$	$-30\text{ V} < V_{IN} < -14.5\text{ V}$		9.0	80	mV
			$-25\text{ V} < V_{IN} < -15\text{ V}$		5.0	50	mV
Load Regulation		$T_J = 25°C$, $5\text{ mA} < I_{OUT} < 500\text{ mA}$			65	240	mV
		$T_J = 25°C$, $5\text{ mA} < I_{OUT} < 350\text{ mA}$			45		mV
Output Voltage		$-30\text{ V} < V_{IN} < -14.5\text{ V}$, $5\text{ mA} < I_{OUT} < 350\text{ mA}$		−12.6		−11.4	V
Quiescent Current		$T_J = 25°C$			1.5	3.0	mA
Quiescent Current Change	with line	$-30\text{ V} < V_{IN} < -14.5\text{ V}$				0.4	mA
	with load	$5\text{ mA} < I_{OUT} < 350\text{ mA}$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} < f < 100\text{ kHz}$			300		μV
Ripple Rejection		$-25\text{ V} < V_{IN} < -15\text{ V}$,	$I_{OUT} = 100$ mA	50			dB
		f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	54	60		dB
Dropout Voltage		$T_J = 25°C$			1.1		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -30$ V			140		mA
Peak Output Current					650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA			−0.8		mV/°C

$^*P_D < 4$ W

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w < 10$ ms, duty cycle < 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA79M15HM

ELECTRICAL CHARACTERISTICS: $V_{IN} = -23$ V, $I_{OUT} = 350$ mA, $0°C \leq T_J \leq 125°C$, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		–15.6	–15	–14.4	V
Line Regulation		$T_J = 25°C$	$-30\ V \leq V_{IN} \leq -17.5\ V$		9.0	80	mV
			$-28\ V \leq V_{IN} \leq -18\ V$		7.0	50	mV
Load Regulation		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 500\ mA$			65	240	mV
		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 350\ mA$			45		mV
Output Voltage		$-30\ V \leq V_{IN} \leq -17.5\ V$, $5\ mA \leq I_{OUT} \leq 350\ mA$*		–15.75		–14.25	V
Quiescent Current		$T_J = 25°C$			1.5	3.0	mA
Quiescent Current Change	with line	$-30\ V \leq V_{IN} \leq -17.5\ V$				0.4	mA
	with load	$5\ mA \leq I_{OUT} \leq 350\ mA$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$-28.5\ V \leq V_{IN} \leq -18.5\ V$,	$I_{OUT} = 100\ mA$	50			dB
		f = 120 Hz	$I_{OUT} = 300\ mA$, $T_J = 25°C$	54	59		dB
Dropout Voltage		$T_J = 25°C$			1.1	2.3	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -35\ V$				0.6	A
Peak Output Current				0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\ mA$, $-55°C \leq T_J \leq +150°C$				0.3	$mV/°C/V_{OUT}$

μA79M15AHC AND μA79M15AUC

ELECTRICAL CHARACTERISTICS: $V_{IN} = -23$ V, $I_{OUT} = 350$ mA, $-55°C \leq T_J \leq 150°C$, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		–15.6	–15	–14.4	V
Line Regulation		$T_J = 25°C$	$-30\ V \leq V_{IN} \leq -17.5\ V$		9.0	80	mV
			$-28\ V \leq V_{IN} \leq -18\ V$		7.0	50	mV
Load Regulation		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 500\ mA$			65	240	mV
		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 350\ mA$			45		mV
Output Voltage		$-30\ V \leq V_{IN} \leq -17.5\ V$, $5\ mA \leq I_{OUT} \leq 350\ mA$		–15.75		–14.25	V
Quiescent Current		$T_J = 25°C$			1.5	3.0	mA
Quiescent Current Change	with line	$-30\ V \leq V_{IN} \leq -17.5\ V$				0.4	mA
	with load	$5\ mA \leq I_{OUT} \leq 350\ mA$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			375		μV
Ripple Rejection		$-28.5\ V \leq V_{IN} \leq -18.5\ V$,	$I_{OUT} = 100\ mA$	50			dB
		f = 120 Hz	$I_{OUT} = 300\ mA$, $T_J = 25°C$	54	59		dB
Dropout Voltage		$T_J = 25°C$			1.1		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -30\ V$			140		mA
Peak Output Current					650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\ mA$			–1.0		mV/°C

*$P_D \leq 4$ W

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

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μA79M20HM

ELECTRICAL CHARACTERISTICS: $V_{IN} = -29$ V, $I_{OUT} = 350$ mA, $-55°C \leq T_J \leq 150°C$, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$ unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−20.8	−20	−19.2	V
Line Regulation		$T_J = 25°C$	$-35\ V \leq V_{IN} \leq -23\ V$		12	80	mV
			$-34\ V \leq V_{IN} \leq -24\ V$		10	70	mV
Load Regulation		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 500\ mA$			75	300	mV
		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 350\ mA$			50		mV
Output Voltage		$-35\ V \leq V_{IN} \leq -23\ V$, $5\ mA \leq I_{OUT} \leq 350\ mA$*		−21		−19	V
Quiescent Current		$T_J = 25°C$			1.5	3.5	mA
Quiescent Current Change	with line	$-35\ V \leq V_{IN} \leq -23\ V$				0.4	mA
	with load	$5\ mA \leq I_{OUT} \leq 350\ mA$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$-34\ V \leq V_{IN} \leq -24\ V$,	$I_{OUT} = 100\ mA$	50			dB
		f = 120 Hz	$I_{OUT} = 300\ mA$, $T_J = 25°C$	54	58		dB
Dropout Voltage		$T_J = 25°C$			1.1	2.3	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -35$ V				0.6	A
Peak Output Current				0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $-55°C \leq T_J \leq +150°C$				0.3	$mV/°C/V_{OUT}$

μA79M20AHC AND μA79M20AUC

ELECTRICAL CHARACTERISTICS: $V_{IN} = -29$ V, $I_{OUT} = 350$ mA, $0°C \leq T_J \leq 125°C$, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−20.8	−20	−19.2	V
Line Regulation		$T_J = 25°C$	$-35\ V \leq V_{IN} \leq -23\ V$		12	80	mV
			$-34\ V \leq V_{IN} \leq -24\ V$		10	70	mV
Load Regulation		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 500\ mA$			75	300	mV
		$T_J = 25°C$, $5\ mA \leq I_{OUT} \leq 350\ mA$			50		mV
Output Voltage		$-35\ V \leq V_{IN} \leq -23\ V$, $5\ mA \leq I_{OUT} \leq 350\ mA$		−21		−19	V
Quiescent Current		$T_J = 25°C$			1.5	3.5	mA
Quiescent Current Change	with line	$-35\ V \leq V_{IN} \leq -23\ V$				0.4	mA
	with load	$5\ mA \leq I_{OUT} \leq 350\ mA$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			500		μV
Ripple Rejection		$-34\ V \leq V_{IN} \leq -24\ V$,	$I_{OUT} = 100\ mA$	50			dB
		f = 120 Hz	$I_{OUT} = 300\ mA$, $T_J = 25°C$	54	58		dB
Dropout Voltage		$T_J = 25°C$			1.1		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -30$			140		mA
Peak Output Current					650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA			−1.0		mV/°C

*$P_D \leq 4$ W

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA79M24HM

ELECTRICAL CHARACTERISTICS: $V_{IN} = -33$ V, $I_{OUT} = 350$ mA, $-55°C \leq T_J \leq 150°C$, $C_{IN} = 2$ μF, $C_{OUT} = 1$ μF, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−25	−24	−23	V
Line Regulation		$T_J = 25°C$	$-38\text{ V} \leq V_{IN} \leq -27\text{ V}$		12	80	mV
			$-38\text{ V} \leq V_{IN} \leq -28\text{ V}$		12	70	mV
Load Regulation		$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 500\text{ mA}$			75	300	mV
		$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$			50		mV
Output Voltage		$-38\text{ V} \leq V_{IN} \leq -27\text{ V}$, $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$*		−25.2		−22.8	V
Quiescent Current		$T_J = 25°C$			1.5	3.5	mA
Quiescent Current Change	with line	$-38\text{ V} \leq V_{IN} \leq -27\text{ V}$				0.4	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$-38\text{ V} \leq V_{IN} \leq -28\text{ V}$,	$I_{OUT} = 100$ mA	50			dB
		f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	54	58		dB
Dropout Voltage		$T_J = 25°C$			1.1	2.3	V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -35$ V				0.6	A
Peak Output Current				0.4	0.65	1.4	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA, $-55°C \leq T_J \leq +150°C$				0.3	$mV/°C/V_{OUT}$

μA79M24AHC AND μA79M24AUC

ELECTRICAL CHARACTERISTICS: $V_{IN} = -33$ V, $I_{OUT} = 350$ mA, $0°C \leq T_J \leq 125°C$, $C_{IN} = 2$ μF, $C_{OUT} = 1$ μF, unless otherwise specified.

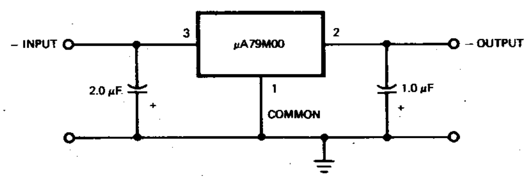
CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−25	−24	−23	V
Line Regulation		$T_J = 25°C$	$-38\text{ V} \leq V_{IN} \leq -27\text{ V}$		12	80	mV
			$-38\text{ V} \leq V_{IN} \leq -28\text{ V}$		12	70	mV
Load Regulation		$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 500\text{ mA}$			75	300	mV
		$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$			50		mV
Output Voltage		$-38\text{ V} \leq V_{IN} \leq -27\text{ V}$, $5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$		−25.2		−22.8	V
Quiescent Current		$T_J = 25°C$			1.5	3.5	mA
Quiescent Current Change	with line	$-38\text{ V} \leq V_{IN} \leq -27\text{ V}$				0.4	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 350\text{ mA}$				0.4	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$			600		μV
Ripple Rejection		$-38\text{ V} \leq V_{IN} \leq -28\text{ V}$,	$I_{OUT} = 100$ mA	50			dB
		f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	54	58		dB
Dropout Voltage		$T_J = 25°C$			1.1		V
Short Circuit Current		$T_J = 25°C$, $V_{IN} = -30$ V			140		mA
Peak Output Current					650		mA
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5$ mA			−1.0		mV/°C

*$P_D \leq 4$ W

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

DC PARAMETER TEST CIRCUIT



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DESIGN CONSIDERATIONS

The µA79M00 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation for reducing the output current as the voltage across the pass transistor is increased.

The safe area protection network may cause the device to latch-up if the output is shorted and the regulator is operating with high input voltages. This mode of operation will not damage the device. However, power (input voltage or the load) must be interrupted momentarily for the device to recover from the latched condition.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (150°C for 79M00, 125°C for 79M00AC and 79M00C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

	TYP	MAX	TYP	MAX
PACKAGE	θJC	θJC	θJA	θJA
TO-39	18.0	25	120	185
TO-220	3.0	5.0	62	70
Power Tab (TO-202 Equiv.)	6.0	8.0	75	80

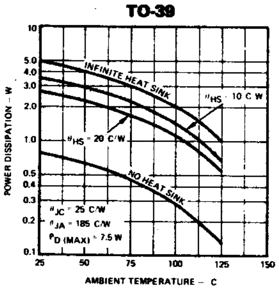
$$P_{D\,(MAX)} = \frac{T_{J\,(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_{J\,(MAX)} - T_A}{\theta_{JA}} \quad \text{(Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

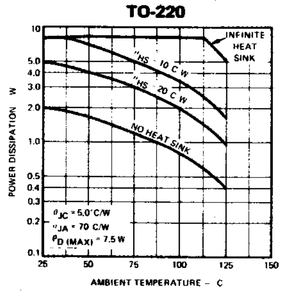
Solving for T_J: $T_J = T_A + P_D(\theta_{JC} + \theta_{CA})$ or $T_A + P_D\,\theta_{JA}$ (Without a heat sink)

Where T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation
θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to ambient thermal resistance
θ_{CS} = Case to heat sink thermal resistance
θ_{SA} = Heat sink to ambient thermal resistance
θ_{JA} = Junction to ambient thermal resistance

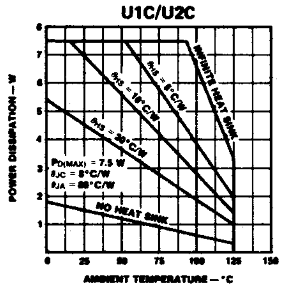
WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE TO-39



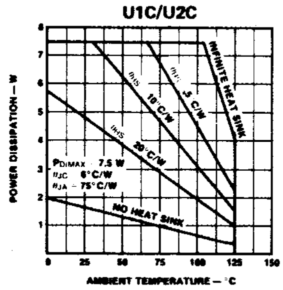
WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE TO-220



WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE U1C/U2C

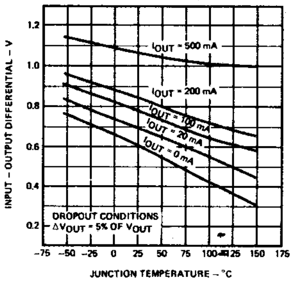


TYPICAL POWER DISSIPATION VERSUS AMBIENT TEMPERATURE U1C/U2C

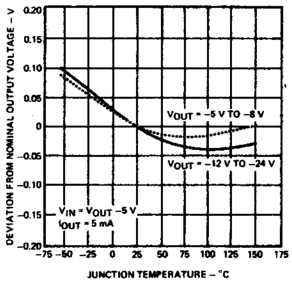


TYPICAL PERFORMANCE CURVES

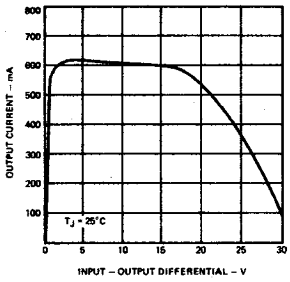
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



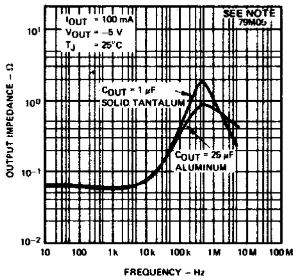
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



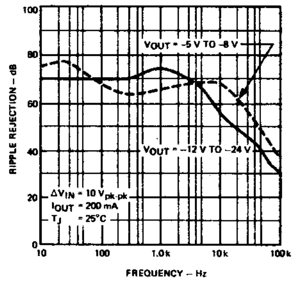
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



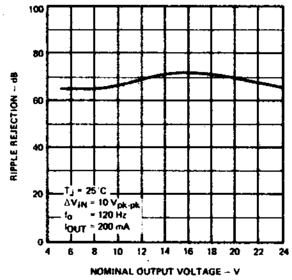
OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



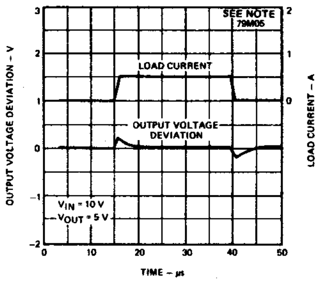
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



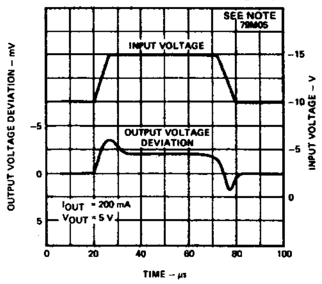
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGES



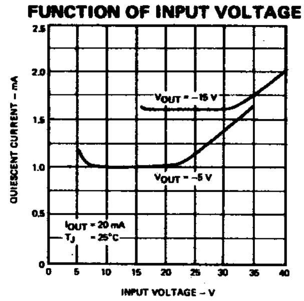
LOAD TRANSIENT RESPONSE



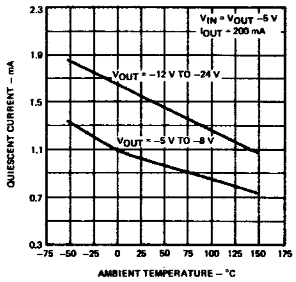
LINE TRANSIENT RESPONSE



QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE

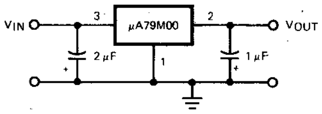


NOTE: The other μA79M00 voltage series devices have similar performance curves.

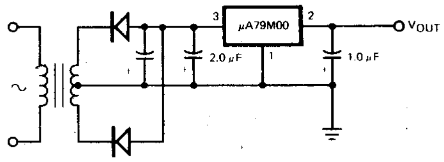
TYPICAL APPLICATIONS

Bypass capacitors are recommended for stable operation of the 79M00 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

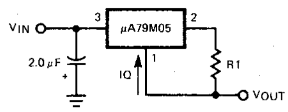
The bypass capacitors, (2 μF on the input, 1 μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10 μF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.



FIXED OUTPUT REGULATOR

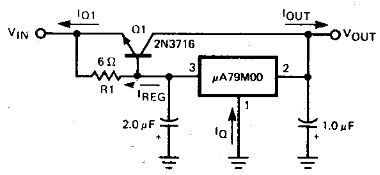


NEGATIVE OUTPUT VOLTAGE CIRCUIT



$$\text{OUTPUT CURRENT} = \frac{5.0\ \text{V}}{R1} + I_Q$$

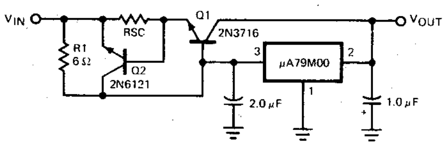
BASIC CURRENT REGULATOR



$$R1 = \frac{V_{BE(Q1)}}{I_{REG}} = \frac{\beta V_{BE(Q1)}}{I_{REQ(MAX)}(\beta+1) - I_{OUT(MAX)}}$$

$$I_{Q1} = \beta(Q1) I_{REG}$$

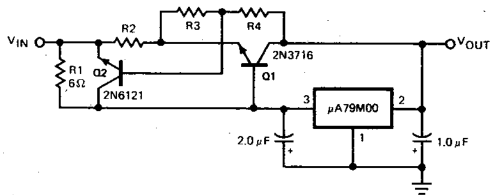
HIGH CURRENT VOLTAGE REGULATOR



$$R1 = \frac{\beta V_{BE(Q1)}}{I_{REQ(MAX)}(\beta+1) - I_{OUT(MAX)}}$$

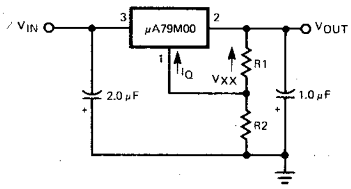
$$R_{SC} = \frac{V_{BE(Q2)}}{I_{SC}}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED



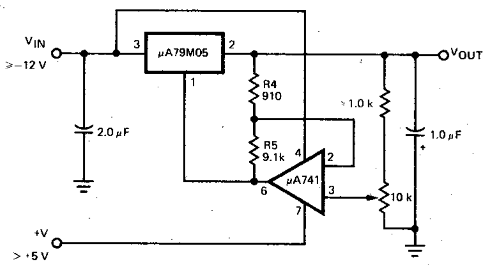
$$R1 = \frac{\beta V_{BE(Q1)}}{I_{REQ(MAX)}(\beta+1) - I_{OUT(MAX)}}$$

HIGH OUTPUT CURRENT, FOLDBACK CURRENT LIMITED



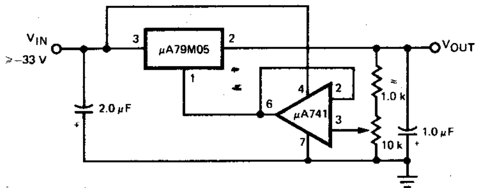
$$|V_{OUT}| = V_{XX}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

VARIABLE OUTPUT VOLTAGE REGULATOR

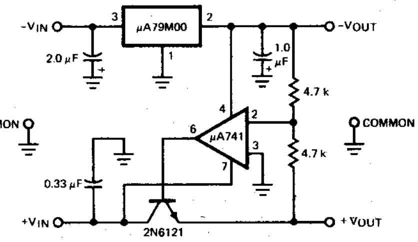


VARIABLE OUTPUT VOLTAGE, −0.5 V TO −10 V

TYPICAL APPLICATIONS (Cont'd)

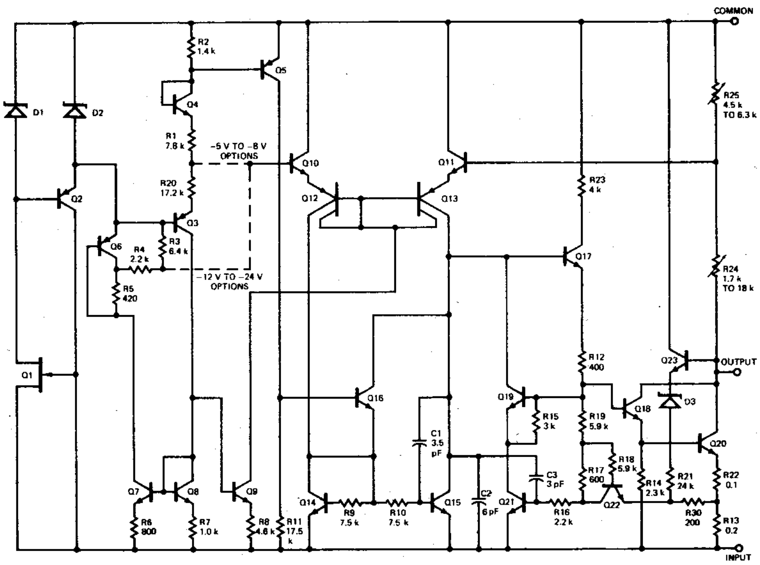


VARIABLE OUTPUT VOLTAGE, −30 V TO −7 V



POSITIVE AND NEGATIVE TRACKING VOLTAGE REGULATOR

EQUIVALENT CIRCUIT



µA7900 SERIES
3-TERMINAL NEGATIVE VOLTAGE REGULATORS
FAIRCHILD LINEAR INTEGRATED CIRCUITS

GENERAL DESCRIPTION – The µA7900 series of monolithic 3-Terminal Negative Regulators is manufactured using the Fairchild Planer* epitaxial process. These negative regulators are intended as complements to the popular µA7800 series of positive voltage regulators, and they are available in the same voltage options from –5 to –24 V. The 7900s employ internal current limiting, safe-area protection, and thermal shutdown, making them virtually indestructible.

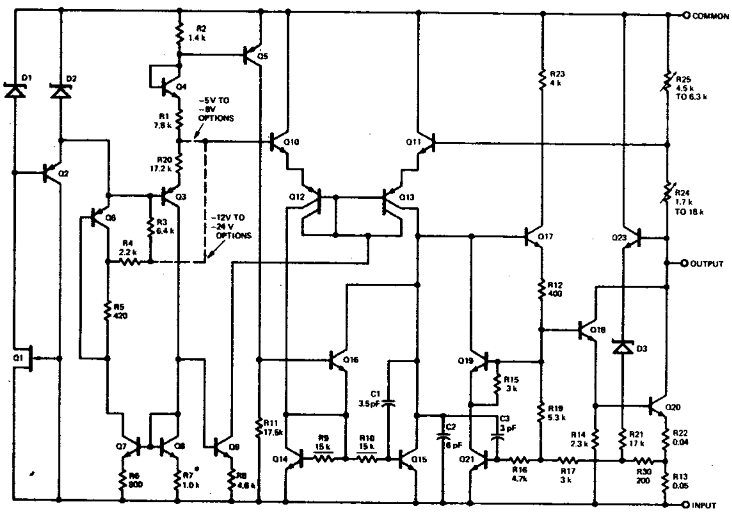
- **OUTPUT CURRENT IN EXCESS OF 1 A**
- **INTERNAL THERMAL OVERLOAD PROTECTION**
- **INTERNAL SHORT CIRCUIT CURRENT LIMITING**
- **OUTPUT TRANSISTOR SAFE AREA COMPENSATION**
- **AVAILABLE IN THE TO-220 AND THE TO-3 PACKAGE**
- **OUTPUT VOLTAGES ARE 5, 6, 8, 12, 15, 18 AND 24 V**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	
(5 V through 18 V)	–35 V
(24 V)	–40 V
Internal Power Dissipation	Internally Limited
Storage Temperature Range	
TO-3 (Al. or Steel)	–65°C to +150°C
TO-220	–55°C to +150°C
Operating Junction Temperature Range	
Military (µA7900)	–55°C to +150°C
Commercial (µA7900C)	0°C to +150°C
Lead Temperature	
TO-3 (Soldering, 60 s)	300°C
TO-220 (Soldering, 10 s)	230°C

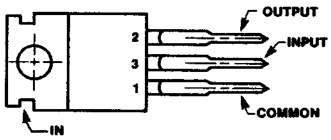
NOTE: The convention for Negative Regulators is the Algebraic value, thus –15 is less than –10 V.

EQUIVALENT CIRCUIT



*Planar is a patented Fairchild process.

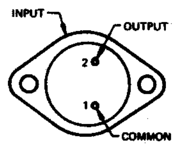
CONNECTION DIAGRAMS
TO-220 PACKAGE
(TOP VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
–5 V	µA7905C	µA7905UC
–6 V	µA7906C	µA7906UC
–8 V	µA7908C	µA7908UC
–12 V	µA7912C	µA7912UC
–15 V	µA7915C	µA7915UC
–18 V	µA7918C	µA7918UC
–24 V	µA7924C	µA7924UC

TO-3 PACKAGE
(TOP VIEW)



ORDER INFORMATION

OUTPUT VOLTAGE	TYPE	PART NO.
–5 V	µA7905	µA7905KM
–6 V	µA7906	µA7906KM
–8 V	µA7908	µA7908KM
–12 V	µA7912	µA7912KM
–15 V	µA7915	µA7915KM
–18 V	µA7918	µA7918KM
–24 V	µA7924	µA7924KM
–5 V	µA7905C	µA7905KC
–6 V	µA7906C	µA7906KC
–8 V	µA7908C	µA7908KC
–12 V	µA7912C	µA7912KC
–15 V	µA7915C	µA7915KC
–18 V	µA7918C	µA7918KC
–24 V	µA7924C	µA7924KC

µA7908

ELECTRICAL CHARACTERISTICS: $V_{IN} = -14$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $-55°C < T_J < 150°C$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−7.7	−8.0	−8.3	V
Line Regulation		$T_J = 25°C$	$-10.5\text{ V} < V_{IN} < -25\text{ V}$		6.0	80	mV
			$-11\text{ V} < V_{IN} < -17\text{ V}$		2.0	40	mV
Load Regulation		$T_J = 25°C$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	80	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	40	mV
Output Voltage		$-11.5\text{ V} < V_{IN} < -23\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $p < 15\text{ W}$		−7.6		−8.4	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-11.5\text{ V} < V_{IN} < -25\text{ V}$				1.0	mA
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} < f < 100\text{ kHz}$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$f = 120\text{ Hz}$, $-11.5\text{ V} < V_{IN} < -21.5\text{ V}$		54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$, $T_J = 25°C$			1.1	2.3	V
Peak Output Current		$T_J = 25°C$		1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$, $-55°C < T_J < 150°C$				0.3	$mV/°C/V_{OUT}$
Short Circuit Current		$V_{IN} = -35\text{ V}$, $T_J = 25°C$				1.2	A

µA7908C

ELECTRICAL CHARACTERISTICS: $V_{IN} = -14$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $0°C < T_J < 125°C$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−7.7	−8.0	−8.3	V
Line Regulation		$T_J = 25°C$	$-10.5\text{ V} < V_{IN} < -25\text{ V}$		6.0	160	mV
			$-11\text{ V} < V_{IN} < -17\text{ V}$		2.0	80	mV
Load Regulation		$T_J = 25°C$	$5\text{ mA} < I_{OUT} < 1.5\text{ A}$		12	160	mV
			$250\text{ mA} < I_{OUT} < 750\text{ mA}$		4.0	80	mV
Output Voltage		$-10.5\text{ V} < V_{IN} < -23\text{ V}$ $5\text{ mA} < I_{OUT} < 1.0\text{ A}$ $p < 15\text{ W}$		−7.6		−8.4	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-10.5\text{ V} < V_{IN} < -25\text{ V}$				1.0	mA
	with load	$5\text{ mA} < I_{OUT} < 1.0\text{ A}$				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz}, < f < 100\text{ kHz}$			200		µV
Ripple Rejection		$f = 120\text{ Hz}$, $-11.5\text{ V} < V_{IN} < -21.5\text{ V}$		54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$, $T_J = 25°C$			1.1		V
Peak Output Current		$T_J = 25°C$			2.1		A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$, $0°C < T_J < 125°C$			−0.6		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

7

μA7912

ELECTRICAL CHARACTERISTICS: $V_{IN} = -19$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $-55°C \leq T_J \leq 150°C$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−11.5	−12.0	−12.5	V
Line Regulation		$T_J = 25°C$	$-14.5\ V \leq V_{IN} \leq -30\ V$		10	120	mV
			$-16\ V \leq V_{IN} \leq -22\ V$		3.0	60	mV
Load Regulation		$T_J = 25°C$	$5\ mA \leq I_{OUT} \leq 1.5\ A$		12	120	mV
			$250\ mA \leq I_{OUT} \leq 750\ mA$		4.0	60	mV
Output Voltage		$-15.5\ V \leq V_{IN} \leq -27\ V$ $5\ mA \leq I_{OUT} \leq 1.0\ A$ $p \leq 15\ W$		−11.4		−12.6	V
Quiescent Current		$T_J = 25°C$			1.5	3.0	mA
Quiescent Current Change	with line	$-15\ V \leq V_{IN} \leq -30\ V$				1.0	mA
	with load	$5\ mA \leq I_{OUT} \leq 1.0\ A$				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$f = 120\ Hz$, $-15\ V \leq V_{IN} \leq -25\ V$		54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\ A$, $T_J = 25°C$			1.1	2.3	V
Peak Output Current		$T_J = 25°C$		1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\ mA$, $-55°C \leq T_J \leq 150°C$				0.3	$mV/°C/V_{OUT}$
Short Circuit Current		$V_{IN} = -35\ V$, $T_J = 25°C$				1.2	A

μA7912C

ELECTRICAL CHARACTERISTICS: $V_{IN} = -19$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $0°C \leq T_J \leq 125°C$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		−11.5	−12.0	−12.5	V
Line Regulation		$T_J = 25°C$	$-14.5\ V \leq V_{IN} \leq -30\ V$		10	240	mV
			$-16\ V \leq V_{IN} \leq -22\ V$		3.0	120	mV
Load Regulation		$T_J = 25°C$	$5\ mA \leq I_{OUT} \leq 1.5\ A$		12	240	mV
			$250\ mA \leq I_{OUT} \leq 750\ mA$		4.0	120	mV
Output Voltage		$-14.5\ V \leq V_{IN} \leq -27\ V$ $5\ mA \leq I_{OUT} \leq 1.0\ A$ $p \leq 15\ W$		−11.4		−12.6	V
Quiescent Current		$T_J = 25°C$			1.5	3.0	mA
Quiescent Current Change	with line	$-14.5\ V \leq V_{IN} \leq -30\ V$				1.0	mA
	with load	$5\ mA \leq I_{OUT} \leq 1.0\ A$				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			300		μV
Ripple Rejection		$f = 120\ Hz$, $-15\ V \leq V_{IN} \leq -25\ V$		54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\ A$, $T_J = 25°C$			1.1		V
Peak Output Current		$T_J = 25°C$			2.1		A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\ mA$, $0°C \leq T_J \leq 125°C$			−0.8		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7905

ELECTRICAL CHARACTERISTICS: $V_{IN} = -10$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $-55°C \leq T_J \leq 150°C$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		–4.8	–5.0	–5.2	V
Line Regulation		$T_J = 25°C$	$-7\text{ V} \leq V_{IN} \leq -25\text{ V}$		3	50	mV
			$-8\text{ V} \leq V_{IN} \leq -12\text{ V}$		1	25	mV
Load Regulation		$T_J = 25°C$	$5\text{ mA} \leq I_{OUT} \leq 1.5\text{ A}$		15	50	mV
			$250\text{ mA} \leq I_{OUT} \leq 750\text{ mA}$		5	25	mV
Output Voltage		$-8.0\text{ V} \leq V_{IN} \leq -20\text{ V}$ $5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$ $p \leq 15\text{ W}$		–4.70		–5.30	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-8\text{ V} \leq V_{IN} \leq -25\text{ V}$				1.3	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$f = 120\text{ Hz}$, $-8\text{ V} \leq V_{IN} \leq -18\text{ V}$		54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$, $T_J = 25°C$			1.1	2.3	V
Peak Output Current		$T_J = 25°C$		1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$, $-55°C \leq T_J \leq 150°C$				0.3	$mV/°C/V_{OUT}$
Short Circuit Current		$V_{IN} = -35\text{ V}$, $T_J = 25°C$				1.2	A

μA7905C

ELECTRICAL CHARACTERISTICS: $V_{IN} = -10$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $0°C \leq T_J \leq 125°C$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		–4.8	–5.0	–5.2	V
Line Regulation		$T_J = 25°C$	$-7\text{ V} \leq V_{IN} \leq -25\text{ V}$		3.0	100	mV
			$-8\text{ V} \leq V_{IN} \leq -12\text{ V}$		1.0	50	mV
Load Regulation		$T_J = 25°C$	$5\text{ mA} \leq I_{OUT} \leq 1.5\text{ A}$		15	100	mV
			$250\text{ mA} \leq I_{OUT} \leq 750\text{ mA}$		5.0	50	mV
Output Voltage		$-7\text{ V} \leq V_{IN} \leq -20\text{ V}$ $5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$ $p \leq 15\text{ W}$		–4.75		–5.25	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-7\text{ V} \leq V_{IN} \leq -25\text{ V}$				1.3	mA
	with load	$5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$			125		μV
Ripple Rejection		$f = 120\text{ Hz}$, $-8\text{ V} \leq V_{IN} \leq -18\text{ V}$		54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\text{ A}$, $T_J = 25°C$			1.1		V
Peak Output Current		$T_J = 25°C$			2.1		A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\text{ mA}$, $0°C \leq T_J \leq 125°C$			–0.4		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_W \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7906

ELECTRICAL CHARACTERISTICS: $V_{IN} = -11$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $-55°C \leq T_J \leq 150°C$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		–5.75	–6.0	–6.25	V
Line Regulation		$T_J = 25°C$	$-8\ V \leq V_{IN} \leq -25\ V$		5.0	60	mV
			$-9\ V \leq V_{IN} \leq -13\ V$		1.5	30	mV
Load Regulation		$T_J = 25°C$	$5\ mA \leq I_{OUT} \leq 1.5\ A$		14	60	mV
			$250\ mA \leq I_{OUT} \leq 750\ mA$		4.0	30	mV
Output Voltage		$-9\ V \leq V_{IN} \leq -21\ V$ $5\ mA \leq I_{OUT} \leq 1.0\ A$ $p \leq 15\ W$		–5.65		–6.35	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-9\ V \leq V_{IN} \leq -25\ V$				1.3	mA
	with load	$5\ mA \leq I_{OUT} \leq 1.0\ A$				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			25	80	$\mu V/V_{OUT}$
Ripple Rejection		$f = 120\ Hz$, $-9\ V \leq V_{IN} \leq -19\ V$		54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\ A$, $T_J = 25°C$			1.1	2.3	V
Peak Output Current		$T_J = 25°C$		1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\ mA$, $-55°C \leq T_J \leq +150°C$				0.3	$mV/°C/V_{OUT}$
Short Circuit Current		$V_{IN} = -35\ V$, $T_J = 25°C$				1.2	A

μA7906C

ELECTRICAL CHARACTERISTICS: $V_{IN} = -11$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $0°C \leq T_J \leq 125°C$, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		$T_J = 25°C$		–5.75	–6.0	–6.25	V
Line Regulation		$T_J = 25°C$	$-8\ V \leq V_{IN} \leq -25\ V$		5.0	120	mV
			$-9\ V \leq V_{IN} \leq -13\ V$		1.5	60	mV
Load Regulation		$T_J = 25°C$	$5\ mA \leq I_{OUT} \leq 1.5\ A$		14	120	mV
			$250\ mA \leq I_{OUT} \leq 750\ mA$		4.0	60	mV
Output Voltage		$-8\ V \leq V_{IN} \leq -21\ V$ $5\ mA \leq I_{OUT} \leq 1.0\ A$ $p \leq 15\ W$		–5.7		–6.3	V
Quiescent Current		$T_J = 25°C$			1.0	2.0	mA
Quiescent Current Change	with line	$-8\ V \leq V_{IN} \leq -25\ V$				1.3	mA
	with load	$5\ mA \leq I_{OUT} \leq 1.0\ A$				0.5	mA
Output Noise Voltage		$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$			150		μV
Ripple Rejection		$f = 120\ Hz$, $-9\ V \leq V_{IN} \leq -19\ V$		54	60		dB
Dropout Voltage		$I_{OUT} = 1.0\ A$, $T_J = 25°C$			1.1		V
Peak Output Current		$T_J = 25°C$			2.1		A
Average Temperature Coefficient of Output Voltage		$I_{OUT} = 5\ mA$, $0°C \leq V_{IN} \leq 125°C$			–0.4		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7915

ELECTRICAL CHARACTERISTICS: V_{IN} = −23 V, I_{OUT} = 500 mA, C_{IN} = 2 μF, C_{OUT} = 1 μF, −55°C ≤ T_J ≤ 150°C, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		−14.4	−15.0	−15.6	V
Line Regulation		T_J = 25°C	−17.5 V ≤ V_{IN} ≤ −30 V		11	150	mV
			−20 V ≤ V_{IN} ≤ −26 V		3.0	75	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	150	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	75	mV
Output Voltage		−18.5 V ≤ V_{IN} ≤ −30 V 5 mA ≤ I_{OUT} ≤ 1.0 A p ≤ 15 W		−14.25		−15.75	V
Quiescent Current		T_J = 25°C			1.5	3.0	mA
Quiescent Current Change	with line	−18.5 V ≤ V_{IN} ≤ −30 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			25	80	μA/V_{OUT}
Ripple Rejection		f = 120 Hz, −18.5 V ≤ V_{IN} ≤ −28.5 V		54	60		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			1.1	2.3	V
Peak Output Current		T_J = 25°C		1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, −55°C ≤ T_J ≤ 150°C			−1.0	1.3	mV/°C/V_{OUT}
Short Circuit Current		V_{IN} = −35 V, T_J = 25°C				1.2	A

μA7915C

ELECTRICAL CHARACTERISTICS: V_{IN} = −23 V, I_{OUT} = 500 mA, C_{IN} = 2 μF, C_{OUT} = 1 μF, 0°C ≤ T_J ≤ 125°C, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		−14.4	−15.0	−15.6	V
Line Regulation		T_J = 25°C	−17.5 V ≤ V_{IN} ≤ −30 V		11	300	mV
			−20 V ≤ V_{IN} ≤ −26 V		3.0	150	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	300	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	150	mV
Output Voltage		−17.5 V ≤ V_{IN} ≤ −30 V 5 mA ≤ I_{OUT} ≤ 1.0 A p ≤ 15 W		−14.25		−15.75	V
Quiescent Current		T_J = 25°C			1.5	3.0	mA
Quiescent Current Change	with line	−17.5 V ≤ V_{IN} ≤ −30 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			375		μV
Ripple Rejection		f = 120 Hz, −18.5 V ≤ V_{IN} ≤ −28.5 V		54	60		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			1.1		V
Peak Output Current		T_J = 25°C			2.1		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			−1.0		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_W ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

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µA7918

ELECTRICAL CHARACTERISTICS: $V_{IN} = -27$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $-55°C \leq T_J \leq 150°C$, unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25°C$	−17.3	−18.0	−18.7	V
Line Regulation	$T_J = 25°C$, $-21\text{ V} \leq V_{IN} \leq -33\text{ V}$		15	180	mV
Line Regulation	$T_J = 25°C$, $-24\text{ V} \leq V_{IN} \leq -30\text{ V}$		5.0	90	mV
Load Regulation	$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 1.5\text{ A}$		12	180	mV
Load Regulation	$T_J = 25°C$, $250\text{ mA} \leq I_{OUT} \leq 750\text{ mA}$		4.0	90	mV
Output Voltage	$-22\text{ V} \leq V_{IN} \leq -33\text{ V}$, $5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$, $p \leq 15\text{ W}$	−17.1		−18.9	V
Quiescent Current	$T_J = 25°C$		1.5	3.0	mA
Quiescent Current Change, with line	$-22\text{ V} \leq V_{IN} \leq -33\text{ V}$			1.0	mA
Quiescent Current Change, with load	$5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$			0.5	mA
Output Noise Voltage	$T_A = 25°C$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$		25	80	$\mu V/V_{OUT}$
Ripple Rejection	$f = 120\text{ Hz}$, $-22\text{ V} \leq V_{IN} \leq -32\text{ V}$	54	60		dB
Dropout Voltage	$I_{OUT} = 1.0\text{ A}$, $T_J = 25°C$		1.1	2.3	V
Peak Output Current	$T_J = 25°C$	1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$, $0°C \leq T_J \leq 150°C$			0.3	$mV/°C/V_{OUT}$
Short Circuit Current	$V_{IN} = -35\text{ V}$, $T_J = 25°C$			1.2	A

µA7918C

ELECTRICAL CHARACTERISTICS: $V_{IN} = -27$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\,\mu F$, $C_{OUT} = 1\,\mu F$, $0°C \leq T_J \leq 125°C$, unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)	MIN	TYP	MAX	UNITS
Output Voltage	$T_J = 25°C$	−17.3	−18.0	−18.7	V
Line Regulation	$T_J = 25°C$, $-21\text{ V} \leq V_{IN} \leq -33\text{ V}$		15	360	mV
Line Regulation	$T_J = 25°C$, $-24\text{ V} \leq V_{IN} \leq -30\text{ V}$		5.0	180	mV
Load Regulation	$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 1.5\text{ A}$		12	360	mV
Load Regulation	$T_J = 25°C$, $250\text{ mA} \leq I_{OUT} \leq 750\text{ mA}$		4.0	180	mV
Output Voltage	$-21\text{ V} \leq V_{IN} \leq -33\text{ V}$, $5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$, $p \leq 15\text{ W}$	−17.1		−18.9	V
Quiescent Current	$T_J = 25°C$		1.5	3.0	mA
Quiescent Current Change, with line	$-21\text{ V} \leq V_{IN} \leq -33\text{ V}$			1.0	mA
Quiescent Current Change, with load	$5\text{ mA} \leq I_{OUT} \leq 1.0\text{ A}$			0.5	mA
Output Noise Voltage	$T_A = 25°C$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$		450		µV
Ripple Rejection	$f = 120\text{ Hz}$, $-22\text{ V} \leq V_{IN} \leq -32\text{ V}$	54	60		dB
Dropout Voltage	$I_{OUT} = 1.0\text{ A}$, $T_J = 25°C$		1.1		V
Peak Output Current	$T_J = 25°C$		2.1		A
Average Temperature Coefficient of Output Voltage	$I_{OUT} = 5\text{ mA}$, $0°C \leq T_J \leq 125°C$		−1.0		mV/°C

NOTE:
1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

μA7924

ELECTRICAL CHARACTERISTICS: V_{IN} = −33 V, I_{OUT} = 500 mA, C_{IN} = 2 μF, C_{OUT} = 1 μF, −55°C ≤ T_J ≤ 150°C, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		−23.0	−24.0	−25.0	V
Line Regulation		T_J = 25°C	−27 V ≤ V_{IN} ≤ −38 V		18	240	mV
			−30 V ≤ V_{IN} ≤ −36 V		6.0	120	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	240	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	120	mV
Output Voltage		−28 V ≤ V_{IN} ≤ −38 V 5 mA ≤ I_{OUT} ≤ 1.0 A p ≤ 15 W		−22.8		−25.2	V
Quiescent Current		T_J = 25°C			1.5	3.0	mA
Quiescent Current Change	with line	−28 V ≤ V_{IN} ≤ −38 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			25	80	μV/V_{OUT}
Ripple Rejection		f = 120 Ha, −28 V ≤ V_{IN} ≤ −38 V		54	60		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			1.1	2.3	V
Peak Output Current		T_J = 25°C		1.3	2.1	2.3	A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 150°C				0.3	mV/°C/V_{OUT}
Short Circuit Current		V_{IN} = −35 V, T_J = 25°C				1.2	A

μA7924C

ELECTRICAL CHARACTERISTICS: V_{IN} = −33 V, I_{OUT} = 500 mA, C_{IN} = 2 μF, C_{OUT} = 1 μF, 0°C ≤ T_J ≤ 150°C, unless otherwise specified.

CHARACTERISTICS		CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Output Voltage		T_J = 25°C		−23.0	−24.0	−25.0	V
Line Regulation		T_J = 25°C	−27 V ≤ V_{IN} ≤ −38 V		18	480	mV
			−30 V ≤ V_{IN} ≤ −36 V		6.0	240	mV
Load Regulation		T_J = 25°C	5 mA ≤ I_{OUT} ≤ 1.5 A		12	480	mV
			250 mA ≤ I_{OUT} ≤ 750 mA		4.0	240	mV
Output Voltage		−27 V ≤ V_{IN} ≤ −38 V 5 mA ≤ I_{OUT} ≤ 1.0 A p ≤ 15 W		−22.8		−25.2	V
Quiescent Current		T_J = 25°C			1.5	3.0	mA
Quiescent Current Change	with line	−27 V ≤ V_{IN} ≤ −38 V				1.0	mA
	with load	5 mA ≤ I_{OUT} ≤ 1.0 A				0.5	mA
Output Noise Voltage		T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			600		μV
Ripple Rejection		f = 120 Hz, −28 V ≤ V_{IN} ≤ −38 V		54	60		dB
Dropout Voltage		I_{OUT} = 1.0 A, T_J = 25°C			1.1		V
Peak Output Current		T_J = 25°C			2.1		A
Average Temperature Coefficient of Output Voltage		I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 125°C			−1.0		mV/°C

NOTE:

1. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

7

DESIGN CONSIDERATIONS

The μA7900 fixed voltage regulator series has thermal overload protection from excessive power, internal short circuit protection which limits the circuit's maximum current, and output transistor safe area compensation for reducing the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (150°C for 7900, 125°C for 7900C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	TYP θ_{JC}	MAX θ_{JC}	TYP θ_{JC}	MAX θ_{JA}
TO-3	3.5°C/W	5.5°C/W	40°C/W	45°C/W
TO-220	3.0°C/W	5.0°C/W	60°C/W	65°C/W

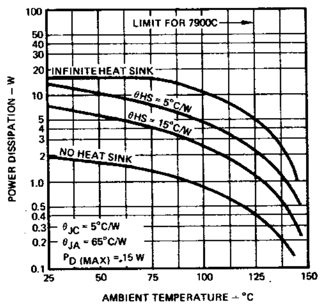
$$P_{D\,(MAX)} = \frac{T_{J\,(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_{J\,(MAX)}\ T_A}{\theta_{JA}} \quad \text{(Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

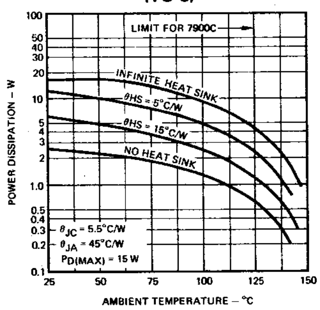
Solving for T_J: $T_J = T_A + P_D\,(\theta_{JC} + \theta_{CA})$ or $T_A + P_D\theta_{JA}$ (Without heat sink)

Where
T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation
θ_{JA} = Junction to Ambient Thermal Resistance
θ_{JC} = Junction to Case Thermal Resistance
θ_{CA} = Case to Ambient Thermal Resistance
θ_{CS} = Case to Heat Sink Thermal Resistance
θ_{SA} = Heat Sink to Ambient Thermal Resistance

WORST CASE POWER DISSIPATION AS A FUNCTION OF AMBIENT TEMPERATURE (TO-220)

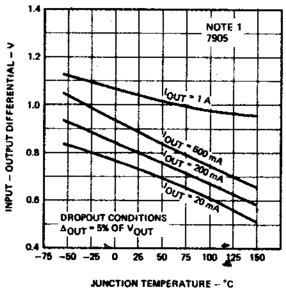


WORST CASE POWER DISSIPATION AS A FUNCTION OF AMBIENT TEMPERATURE (TO-3)

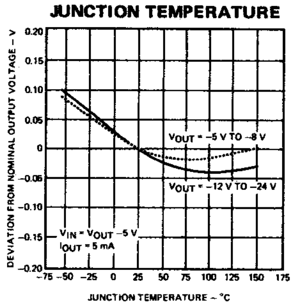


TYPICAL PERFORMANCE CURVES

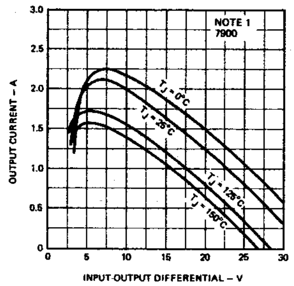
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



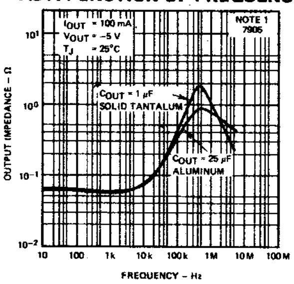
OUTPUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



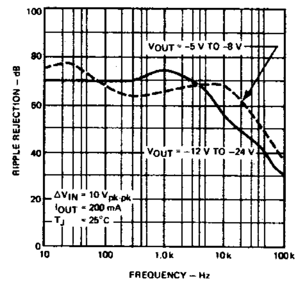
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



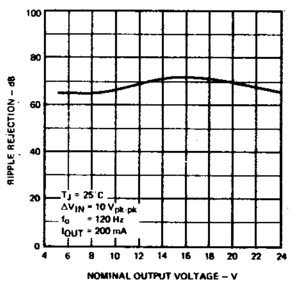
OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



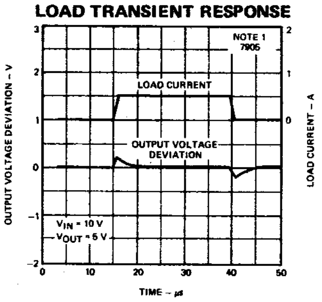
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



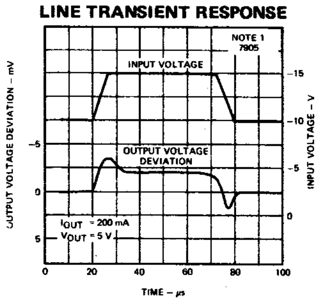
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGES



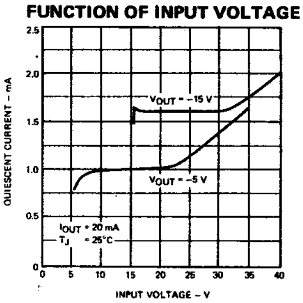
LOAD TRANSIENT RESPONSE



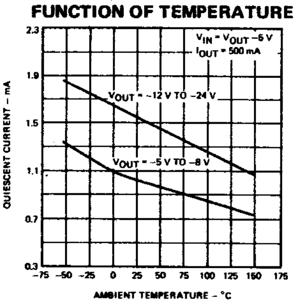
LINE TRANSIENT RESPONSE



QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



QUIESCENT CURRENT AS A FUNCTION OF TEMPERATURE



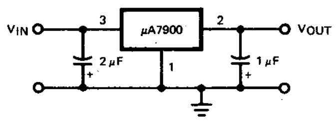
NOTE 1: The other μA7900 series devices have similar performance curves.

7

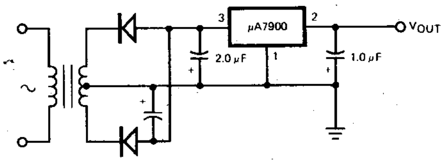
TYPICAL APPLICATIONS

Bypass capacitors are recommended for stable operation of the μA7900 series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

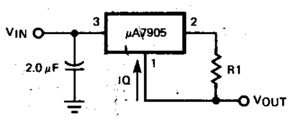
The bypass capacitors, (2 μF on the input, 1 μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10 μF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.



FIXED-OUTPUT REGULATOR

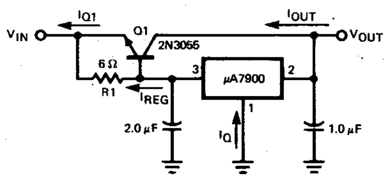


NEGATIVE OUTPUT VOLTAGE CIRCUIT



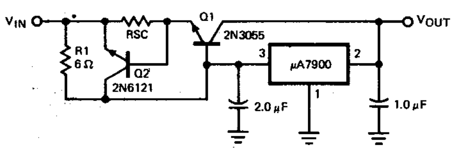
$$\text{OUTPUT CURRENT} = \frac{5.0\ \text{V}}{R1} + I_Q$$

BASIC CURRENT REGULATOR



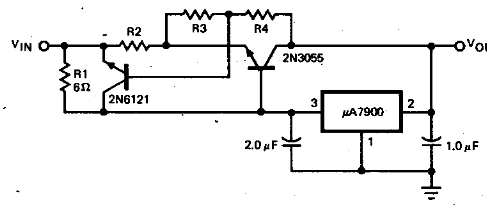
$$R1 = \frac{V_{BE(Q1)}}{I_{REG}} \qquad I_{Q1} = \beta(Q1) I_{REG}$$

HIGH CURRENT VOLTAGE REGULATOR

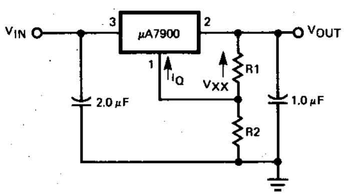


$$R_{SC} = \frac{V_{BE(Q2)}}{I_{SC}}$$

HIGH OUTPUT CURRENT, SHORT CIRCUIT PROTECTED

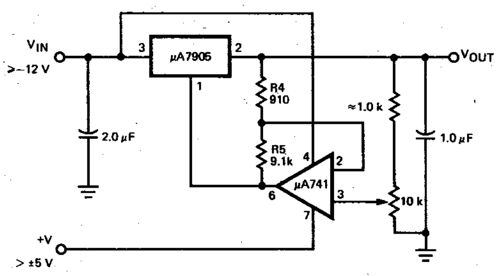


HIGH OUTPUT CURRENT, FOLDBACK CURRENT LIMITED



$$|V_{OUT}| = V_{XX}\left(1 + \frac{R2}{R1}\right) + I_Q R2$$

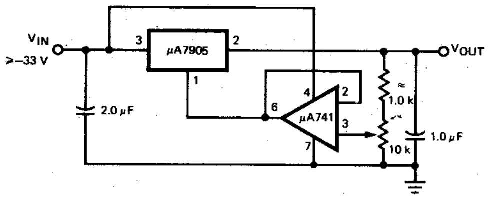
VARIABLE OUTPUT VOLTAGE REGULATOR



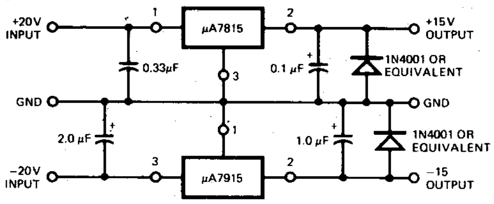
VARIABLE OUTPUT VOLTAGE, −0.5 V TO −10 V

TYPICAL APPLICATIONS (Cont'd)

VARIABLE OUTPUT VOLTAGE, −30 V TO −7 V



OPERATIONAL AMPLIFIER SUPPLY (± 15 V @ 1.0 A)



µA78G • µA79G

4-TERMINAL POSITIVE AND NEGATIVE ADJUSTABLE VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

GENERAL DESCRIPTION – The µA78G and µA79G are 4-Terminal Adjustable Voltage Regulators. They are designed to deliver continuous load currents of up to 1.0 A with a maximum input voltage of 40 V for the positive regulator 78G and −40 V for the negative regulator 79G. Output current capability can be increased to greater than 1.0 A through use of one or more external transistors. The output voltage range of the 78G positive voltage regulator is 5 V to 30 V and the output voltage range of the negative 79G is −30 V to −2.2 V. For systems requiring both a positive and negative, the 78G and 79G are excellent for use as a dual tracking regulator with appropriate external circuitry. These 4-terminal voltage regulators are constructed using the Fairchild Planar* process.

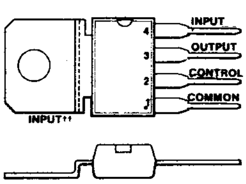
- **OUTPUT CURRENT IN EXCESS OF 1A**
- **µA78G POSITIVE OUTPUT VOLTAGE 5 TO 30 V**
- **µA79G NEGATIVE OUTPUT VOLTAGE −30 TO −2.2 V**
- **INTERNAL THERMAL OVERLOAD PROTECTION**
- **INTERNAL SHORT CIRCUIT CURRENT PROTECTION**
- **OUTPUT TRANSISTOR SAFE AREA PROTECTION**
- **MILITARY AND COMMERCIAL VERSIONS AVAILABLE**
- **AVAILABLE IN 4-PIN TO-202 TYPE AND 4-PIN TO-3**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	
µA78G, µA78GC	40 V
µA79G, µA79GC	−40 V
Control Pin Voltage	
µA78G, µA78GC	$0 \leq V \leq V_{OUT}$
µA79G, µA79GC	$-V_{OUT} \leq -V \leq 0$
Power Dissipation	Internally Limited
Operating Junction Temperature Range	
Military (µA78G, µA79G)	−55°C to 150°C
Commercial (µA78GC, µA79GC)	0°C to 150°C
Storage Temperature Range	
4-Pin Power Watt (U1)	−55°C to +150°C
4-Pin TO-3 (K)	−65°C to +150°C
Lead Temperature	
4-Pin Power Watt (U1) (Soldering, 10 s)	230°C
4-Pin TO-3 (K) (Soldering, 60 s)	300°C

µA79G CONNECTION DIAGRAMS

POWER WATT PACKAGE

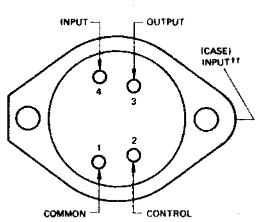


ORDER INFORMATION

TYPE	PART NO.
µA79GC	µA79GU1C

TO-3 PACKAGE

(TOP VIEW)

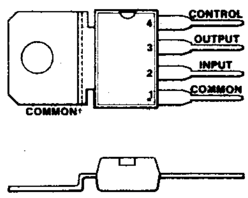


ORDER INFORMATION

TYPE	PART NO.
µA79G	µA79GKM
µA79GC	µA79GKC

††NOTE:
Heat sink tabs connected to input through device substrate. Not recommended for direct electrical connection.

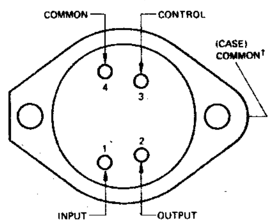
µA78G
POWER WATT PACKAGE
CONNECTION DIAGRAMS



ORDER INFORMATION

TYPE	PART NO.
µA78GC	µA78GU1C

TO-3 PACKAGE
(TOP VIEW)



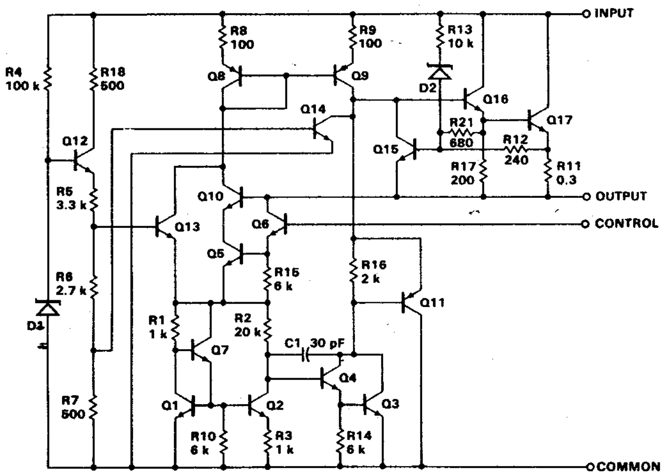
ORDER INFORMATION

TYPE	PART NO.
µA78G	µA78GKM
µA78GC	µA78GKC

†NOTE:
Heat sink tabs connected to common through device substrate.

*Planar is a patented Fairchild process.

μA78G EQUIVALENT CIRCUIT



μA78G, μA78GC

ELECTRICAL CHARACTERISTICS: $0°C \leq T_J \leq 125°C$ for 78GC, $C_{IN} = 0.33\ \mu F$, $C_{OUT} = 0.1\ \mu F$ and $-55°C \leq T_J \leq 150°C$ for 78G, $V_{IN} = 10$ V, $I_{OUT} = 500$ mA, Test Circuit 1, unless otherwise specified.

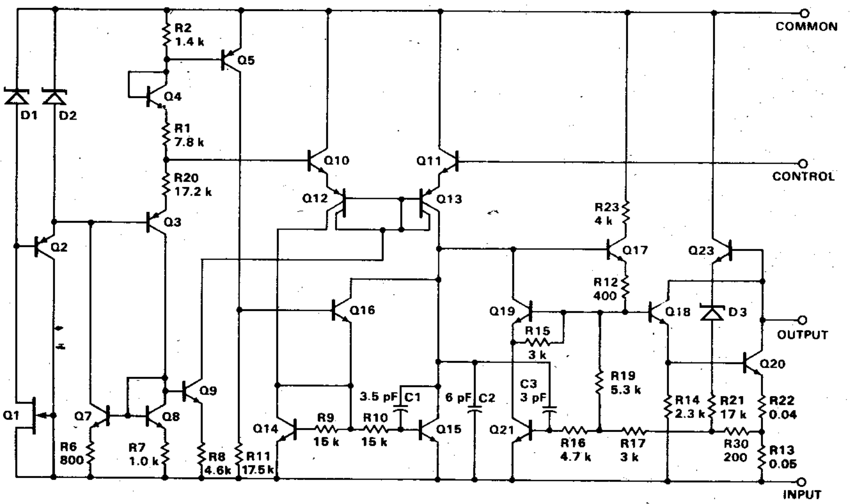
CHARACTERISTICS	CONDITIONS (Notes 1 & 3)		MIN	TYP	MAX	UNITS
Input Voltage Range	$T_J = 25°C$		7.5		40	V
Output Voltage Range	$V_{IN} = V_{OUT} + 5$ V		5.0		30	V
Output Voltage Tolerance	$V_{OUT} + 3\ V \leq V_{IN} \leq V_{OUT} + 15$ V, $5\ mA \leq I_{OUT} \leq 1.0$ A, $P_D \leq 15$ W, $V_{IN(MAX)} = 38$ V	$T_J = 25°C$			4.0	%(V_{OUT})
					5.0	%(V_{OUT})
Line Regulation	$T_J = 25°C$, $V_{OUT} \leq 10$ V, $(V_{OUT} + 2.5\ V) \leq V_{IN} \leq (V_{OUT} + 20\ V)$				1.0	%(V_{OUT})
	$T_J = 25°C$, $V_{OUT} \geq 10$ V, $(V_{OUT} + 3\ V) \leq V_{IN} \leq (V_{OUT} + 15\ V)$				0.75	%(V_{OUT})
	$(V_{OUT} + 3\ V) \leq V_{IN} \leq (V_{OUT} + 7\ V)$				0.67	
Load Regulation	$T_J = 25°C$, $V_{IN} = V_{OUT} + 5$ V	$250\ mA \leq I_{OUT} \leq 750$ mA			1.0	%(V_{OUT})
		$5\ mA \leq I_{OUT} \leq 1.5$ A			2.0	
Control Pin Current	$T_J = 25°C$			1.0	5.0	μA
					8.0	μA
Quiescent Current	$T_J = 25°C$			3.2	5.0	mA
					6.0	mA
Ripple Rejection	$8\ V \leq V_{IN} \leq 18$ V, f = 120 Hz, $V_{OUT} = 5$ V	μA78G	68	78		dB
		μA78GC	62	78		dB
Output Noise Voltage	$T_J = 25°C$, 10 Hz < f < 100 kHz, $V_{OUT} = 5$ V, $I_{OUT} = 5$ mA			8	40	μV/V_{OUT}
Dropout Voltage	Note 2	μA78G		2	2.5	V
		μA78GC			2.5	V
Short Circuit Current	$T_J = 25°C$, $V_{IN} = 30$ V			.750	1.2	A
Peak Output Current	$T_J = 25°C$		1.3	2.2	3.3	A
Average Temperature Coefficient of Output Voltage	$V_{OUT} = 5$ V, $I_{OUT} = 5$ mA	$T_J = -55°C$ to $+25°C$			.4	mV/°C/V_{OUT}
		$T_J = +25°C$ to $+150°C$			.3	
Control Pin Voltage (Reference)	$T_J = 25°C$		4.8	5.0	5.2	V
			4.75		5.25	V

NOTES:

1. V_{OUT} is defined for the 78GC as $V_{OUT} = \frac{R1 + R2}{R2}(5.0)$; The 79GC as $V_{OUT} = \frac{R1 + R2}{R2}(-2.23)$.
2. Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.
3. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

7

79G EQUIVALENT CIRCUIT



μA79G, μA79GC

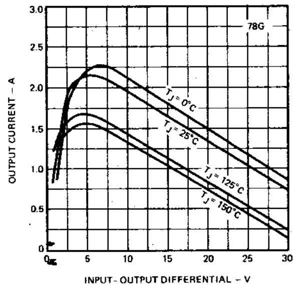
ELECTRICAL CHARACTERISTICS: $0^\circ C \leq T_J \leq 125^\circ C$ for 79GC and $-55^\circ C \leq T_J \leq 150^\circ C$ for 79G, $V_{IN} = -10$ V, $I_{OUT} = 500$ mA, $C_{IN} = 2\ \mu F$, $C_{OUT} = 1\ \mu F$, Test Circuit 2 and Note 3 unless otherwise specified.

CHARACTERISTICS	CONDITIONS (Note 1)		MIN	TYP	MAX	UNITS
Input Voltage Range	$T_J = 25^\circ C$		−40		−7.0	V
Nominal Output Voltage Range	$V_{IN} = V_{OUT} - 5$ V		−30		−2.23	V
Output Voltage Tolerance	$V_{OUT} - 15\ V \leq V_{IN} \leq V_{OUT} - 3\ V$, $5\ mA \leq I_{OUT} \leq 1.0\ A$, $P_D \leq 15\ W$, $V_{IN(MAX)} = -38$ V	$T_J = 25^\circ C$			4.0	%(V_{OUT})
					5.0	%(V_{OUT})
Line Regulation	$T_J = 25^\circ C$, $V_{OUT} \geq -10$ V, $(V_{OUT} - 20\ V) \leq V_{IN} \leq (V_{OUT} - 2.5\ V)$				1.0	%(V_{OUT})
	$T_J = 25^\circ C$, $V_{OUT} \leq -10$ V, $(V_{OUT} - 15\ V) \leq V_{IN} \leq (V_{OUT} - 3\ V)$				0.75	%(V_{OUT})
	$(V_{OUT} - 7\ V) \leq V_{IN} \leq (V_{OUT} - 3\ V)$				0.67	
Load Regulation	$T_J = 25^\circ C$, $V_{IN} = V_{OUT} - 5$ V	$250\ mA \leq I_{OUT} \leq 750\ mA$			1.0	%(V_{OUT})
		$5\ mA \leq I_{OUT} \leq 1.5\ A$			2.0	%(V_{OUT})
Control Pin Current	$T_J = 25^\circ C$			0.4	2.0	μA
					3.0	μA
Quiescent Current	$T_J = 25^\circ C$			0.5	1.5	mA
					2.0	mA
Ripple Rejection	$-18\ V \leq V_{IN} \leq -8\ V$, $V_{OUT} = -5$ V, f = 120 Hz	μA79G	50	60		dB
		μA79GC	50	60		dB
Output Noise Voltage	$T_J = 25^\circ C$, 10 Hz ≤ f ≤ 100 kHz, $V_{OUT} = -5$ V, $I_{OUT} = 5$ mA			25	80	μV/V_{OUT}
Dropout Voltage	Note 2	μA79G		1.1	2.3	V
		μA79GC			2.3	V
Short Circuit Current	$T_J = 25^\circ C$, $V_{IN} = -30$ V			0.25	1.2	A
Peak Output Current	$T_J = 25^\circ C$		1.3	2.1	3.3	A
Average Temperature Coefficient of Output Voltage	$V_{OUT} = -5$ V, $I_{OUT} = 5$ mA	$T_J = -55^\circ C$ to $+25^\circ C$			0.3	mV/°C/V_{OUT}
		$T_J = +25^\circ C$ to $+150^\circ C$			0.3	mV/°C/V_{OUT}
Control Pin Voltage (Reference)	$T_J = 25^\circ C$		−2.32	−2.23	−2.14	V
			−2.35		−2.11	V

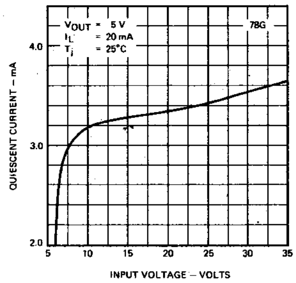
NOTES:
1. V_{OUT} is defined for the 78GC as $V_{OUT} = \frac{R1 + R2}{R2}(5.0)$; The 79GC as $V_{OUT} = \frac{R1 + R2}{R2}(-2.23)$.
2. Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.
3. The convention for negative regulators is the algebraic value, thus −15 is less than −10V.
4. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_w \leq 10$ ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

TYPICAL PERFORMANCE CURVES FOR μA78G

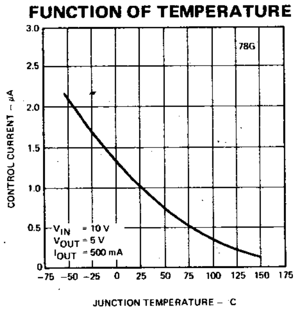
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



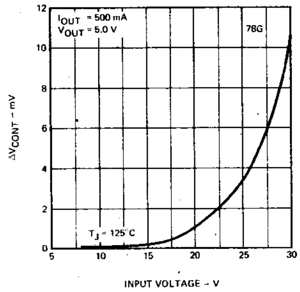
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



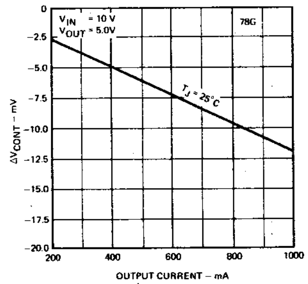
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



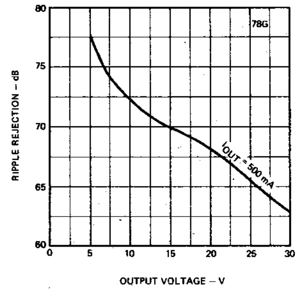
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



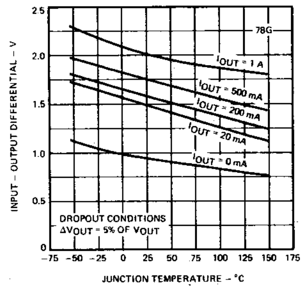
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



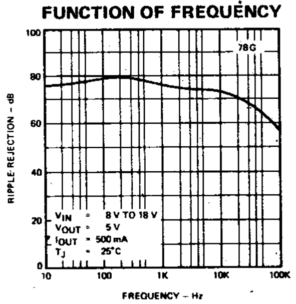
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGE



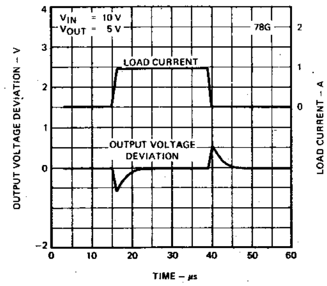
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



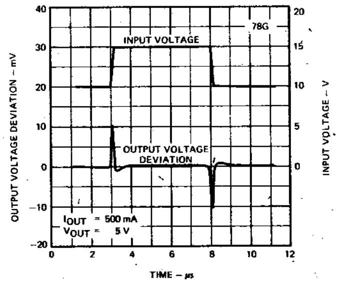
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



LOAD TRANSIENT RESPONSE



LINE TRANSIENT RESPONSE



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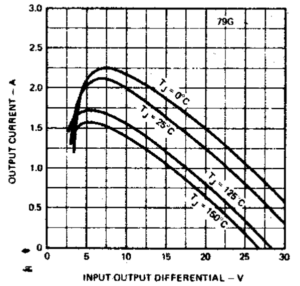
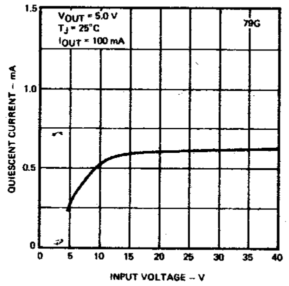
TYPICAL PERFORMANCE CURVES FOR μA79G

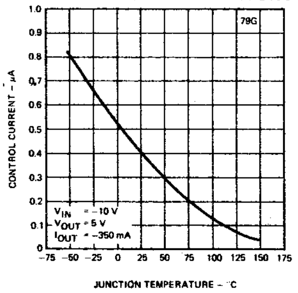
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



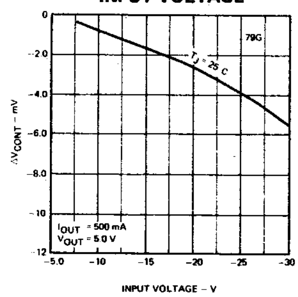
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



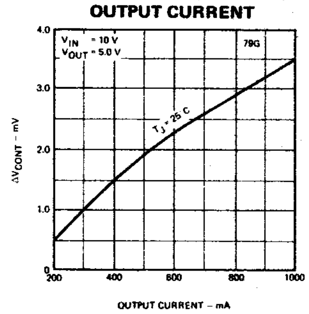
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



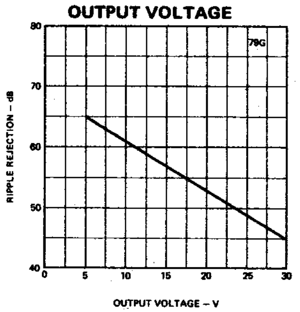
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



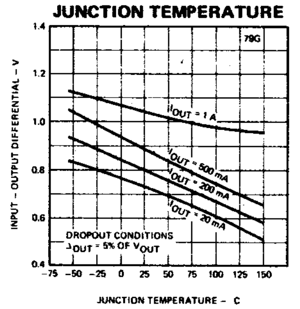
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



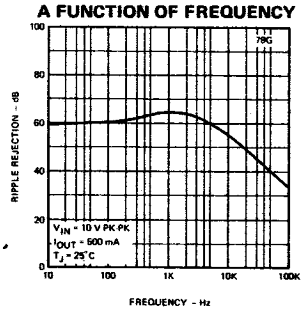
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGE



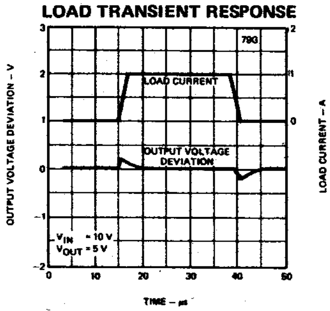
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



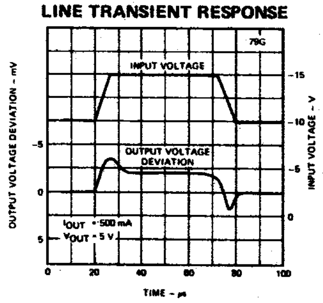
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



LOAD TRANSIENT RESPONSE



LINE TRANSIENT RESPONSE



DESIGN CONSIDERATIONS – The 78G and 79G adjustable voltage regulators have an output voltage which varies from $V_{CONTROL}$ to typically $V_{IN} - 2$ V by $V_{OUT} = V_{CONTROL} \frac{(R1 + R2)}{R2}$. The nominal reference in the 78G is 5.0 V and 79G is –2.23 V. If we allow 1.0 mA to flow in the control string to eliminate bias current effects, we can make R2 = 5 kΩ in the 78G. The output voltage is then: $V_{OUT} = (R1 + R2)$ V, where R1 and R2 are in kΩs.

Example: If R2 = 5 kΩ and R1 = 10 kΩ then V_{OUT} = 15 V nominal, for the 78G;
R2 = 2.2 kΩ and R1 = 12.8 kΩ then V_{OUT} = –15.2 V nominal, for the 79G.

By proper wiring of the feedback resistors, load regulation of the devices can be improved significantly.

Both 78G and 79G regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across each pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

Package	TYP θ_{JC}	MAX θ_{JC}	TYP θ_{JA}	MAX θ_{JA}
POWER WATT	7.5°C/W	11°C/W	75°C/W	80°C/W
TO-3	4.0°C/W	6°C/W	44°C/W	47°C/W

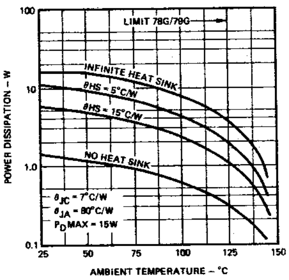
$$P_{D\,(MAX)} = \frac{T_{J\,(MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_{J\,(MAX)} - T_A}{\theta_{JA}} \text{ (Without a heat sink)}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

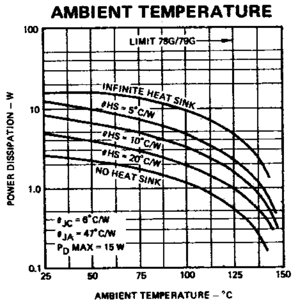
Solving for T_J: $T_J = T_A + P_D\,(\theta_{JC} + \theta_{CA})$ or $T_A + P_D\theta_{JA}$ (Without heat sink)

Where
T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation
$\theta_{J\text{-}A}$ = Junction to ambient thermal resistance
θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to Ambient thermal resistance
θ_{CS} = Case to heat sink resistance
θ_{SA} = Heat sink to ambient thermal resistance

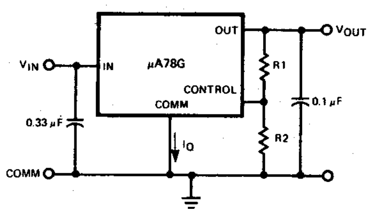
μA78G AND μA79G
POWER TAB (U1) PACKAGE
WORST CASE POWER DISSIPATION
AS A FUNCTION OF
AMBIENT TEMPERATURE



μA78G AND μA79G
TO-3 PACKAGE
WORST CASE POWER DISSIPATION
VERSUS
AMBIENT TEMPERATURE



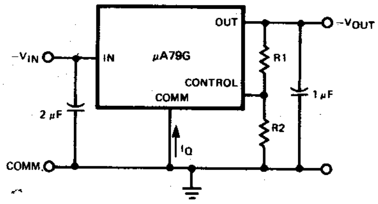
μA78G TEST CIRCUIT 1



$$V_{OUT} = \left(\frac{R1 + R2}{R2}\right) V_{CONTROL}$$

$V_{CONTROL}$ Nominal = 5 V

μA79G TEST CIRCUIT 2



$$V_{OUT} = \left(\frac{R1 + R2}{R2}\right) V_{CONTROL}$$

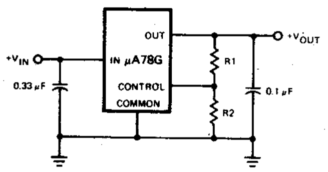
$V_{CONTROL}$ Nominal = −2.23 V

Recommended R2 current ≈ 1 mA
∴R2 = 5 kΩ (78G)
R2 = 2.2 kΩ (79G)

TYPICAL APPLICATIONS FOR μA78G

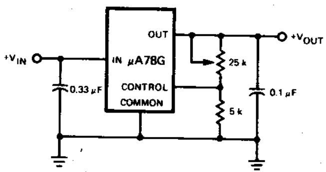
In many μA78G applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33 μF and 0.1 μF, respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

BASIC POSITIVE REGULATOR

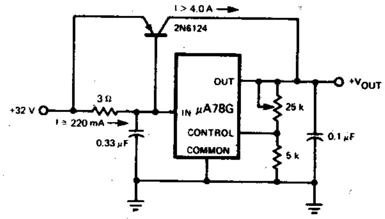


$$V_{OUT} = V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR

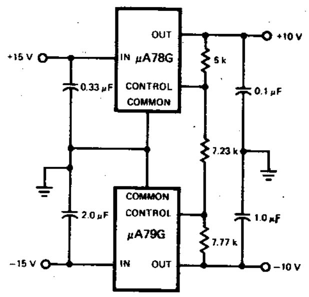


POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR $I_{OUT} > 5.0$ A



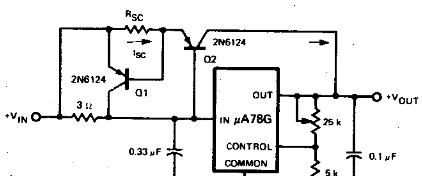
NOTE: External series pass device is not short circuit protected.

±10 V, 1.0 A DUAL TRACKING REGULATOR



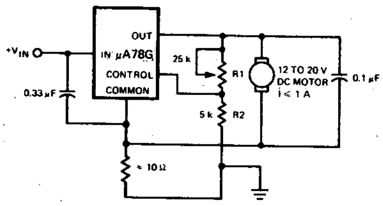
If load is not ground referenced, connect reverse biased diodes from outputs to ground.

POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



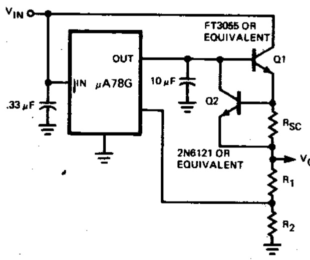
$$\left(R_{SC} = \frac{V_{BE}\,[Q1]}{I_{SC}}\right)$$

MOTOR SPEED CONTROL

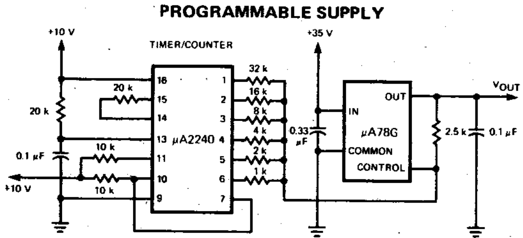


Use flyback diode across motor if necessary.

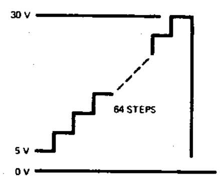
POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



PROGRAMMABLE SUPPLY



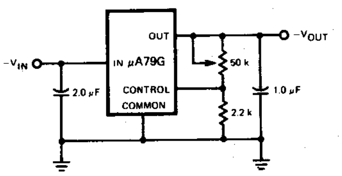
OUTPUT WAVEFORM



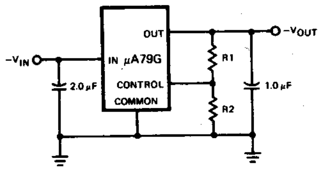
TYPICAL APPLICATIONS FOR μA79G

All μA78G applications apply to the μA79G under the following conditions; R2 values are 2.2 kΩ, all external transistors and diodes reverse polarity.

−30 V TO −2.2 V ADJUSTABLE REGULATOR

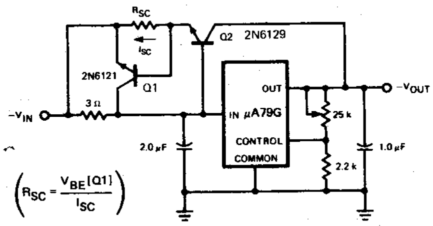


BASIC NEGATIVE REGULATOR



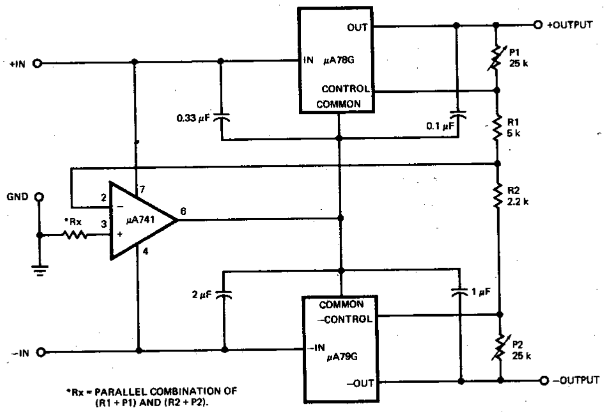
$$V_{OUT} = -V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

NEGATIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



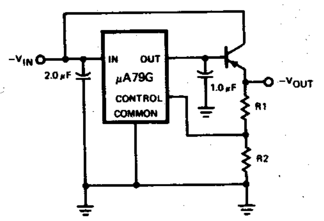
$$\left(R_{SC} = \frac{V_{BE}(Q1)}{I_{SC}}\right)$$

ADJUSTABLE DUAL TRACKING REGULATOR



*Rx = PARALLEL COMBINATION OF (R1 + P1) AND (R2 + P2).

NEGATIVE HIGH CURRENT VOLTAGE REGULATOR EXTERNAL SERIES PASS



NOTE:

Bypass capacitors are recommended for stable operation of the μA79G series of regulators over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

The bypass capacitors, (2 μF on the input, 1 μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10 μF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

μA79HG

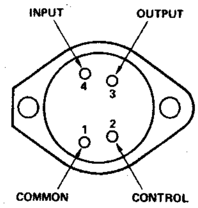
5 AMP NEGATIVE ADJUSTABLE VOLTAGE REGULATOR

FAIRCHILD HYBRID PRODUCTS

GENERAL DESCRIPTION — The μA79HG is an adjustable 4-terminal negative voltage regulator capable of supplying in excess of -5 A over a -24 V to -2.2 V output range. The μA79HG hybrid voltage regulator has been designed with all the inherent characteristics of the monolithic 4-terminal regulator; i.e., full thermal overload and short-circuit protection. The μA79HG is packaged in a hermetically-sealed 4-pin TO-3 package providing 50 W power dissipation. The regulator consists of a monolithic chip driving a discrete-series pass element and short-circuit detection transistors.

- **-5 A OUTPUT CURRENT**
- **INTERNAL CURRENT AND THERMAL LIMITING**
- **INTERNAL SHORT-CIRCUIT CURRENT LIMIT**
- **LOW DROP-OUT VOLTAGE**
- **50 W POWER DISSIPATION**
- **ELECTRICALLY NEUTRAL CASE**

CONNECTION DIAGRAM
TO-3 PACKAGE
(TOP VIEW)



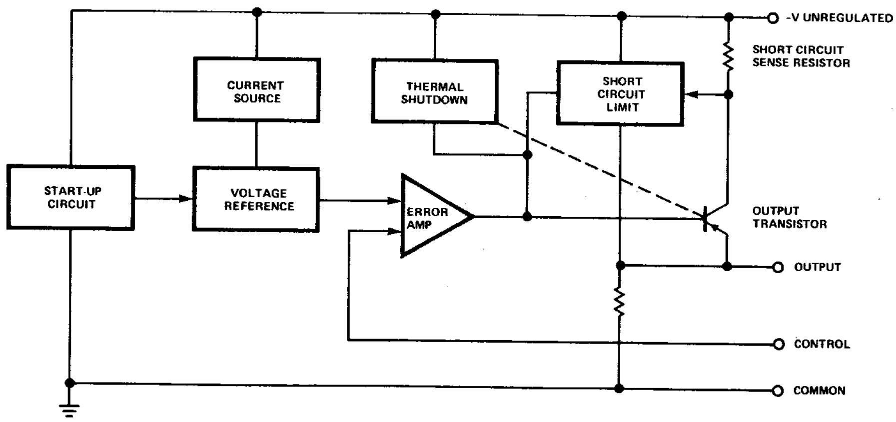
ORDER INFORMATION

TYPE	PART NO.
79HGC	μA79HGKC

ABSOLUTE MAXIMUM RATINGS

Input Voltage	-40 V
Internal Power Dissipation	50 W @ 25°C Case
Maximum Input-to-Output Voltage Differential	-20 V
Operating Junction Temperature Range	-0°C to 150°C
Storage Temperature Range	-55°C to 150°C
Lead Temperature (Soldering, 60 s)	300°C

BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS: T_J = 25°C, I_{OUT} = -2.0 A unless otherwise specified.

CHARACTERISTIC	CONDITION	MIN	TYP	MAX	UNITS
Input Voltage Range		-40		-7.0	V
Nominal Output Voltage Range	$V_{IN} = V_{OUT}$ - 5V	-24		-2.23	V
Output Voltage Tolerance	-40 V ≤ V_{IN} ≤ -7 V			4%	%(V_{OUT})
Line Regulation	-40 ≤ V_{IN} ≤ -7 V		0.4	1.0	%(V_{OUT})
Load Regulation	$V_{IN} = V_{OUT}$ - 10 V, -10 mA ≤ I_{OUT} ≤ -5.0 A		0.7	1.0	%(V_{OUT})
Control Pin Current				3.0	μA
Quiescent Current	V_{IN} = -10 V			-5.0	mA
Ripple Rejection	-18 V ≤ V_{IN} ≤ -8.5 V V_{OUT} = -5 V, f = 120 Hz		50		dB
Output Noise Voltage	10 Hz ≤ f ≤ 100 kHz, V_{OUT} = -5.0 V		200		μV
Dropout Voltage	I_{OUT} = -5 A		-2.0		V
Peak Output Current	V_{IN} = -10 V		-8		A
Control Pin Voltage (Reference)	V_{IN} = -10 V	-2.35		-2.11	V

DESIGN CONSIDERATIONS — The nominal reference in the μA79HG is -2.23 V. If we allow -1.0 mA to flow in the control string to eliminate bias current effects, we can make R2 = 2.2 kΩ in the μA79HG. The output voltage is then: V_{OUT} = (R1 + R2) Volts, where R1 and R2 are in kΩs.

Example: R2 = 2.2 kΩ and R1 = 12.8 kΩ, then V_{OUT} = -15.2 V nominal.

By proper wiring of the feedback resistors, load regulation of the devices can be improved significantly.

The μA79HG regulator has thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across the pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature (150°C) in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYPICAL θ_{JC}	TYPICAL θ_{JA}
TO-3	3.0	33 (Without heat sink)

$$P_D\ (MAX) = \frac{T_{J\ (MAX)} - T_A}{\theta_{JC} + \theta_{CA}} \text{ or } \frac{T_{J\ (MAX)} - T_A}{\theta_{JA}}$$

$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

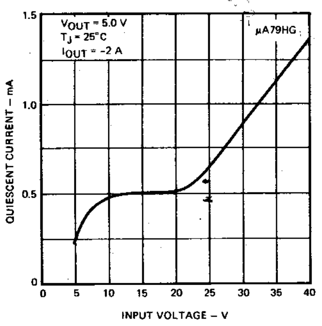
Solving for T_J: $T_J = T_A + P_D\ (\theta_{JC} + \theta_{CA})$ or $T_A + P_D\theta_{JA}$ (Without heat sink)

Where T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation
θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to ambient thermal resistance
θ_{CS} = Case to heat sink thermal resistance
θ_{SA} = Heat sink to ambient thermal resistance
θ_{JA} = Junction to ambient thermal resistance

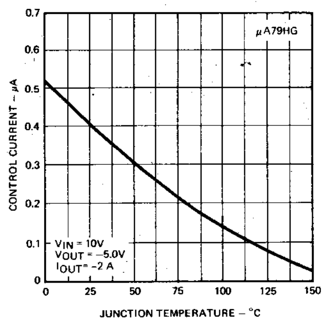
7

TYPICAL PERFORMANCE CURVES

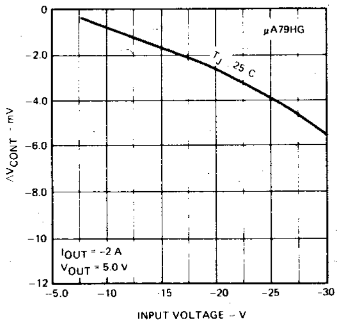
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



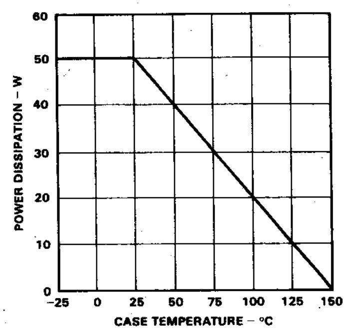
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



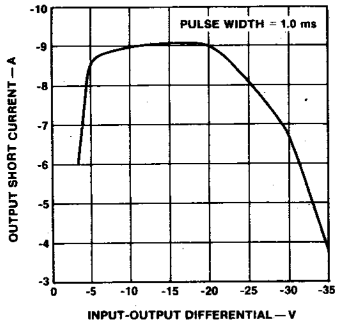
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



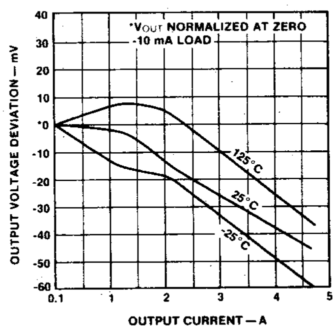
MAXIMUM POWER DISSIPATION



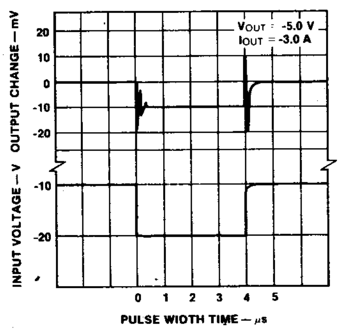
OUTPUT SHORT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



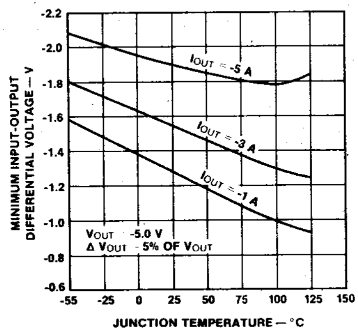
LOAD REGULATION AS A FUNCTION OF OUTPUT CURRENT



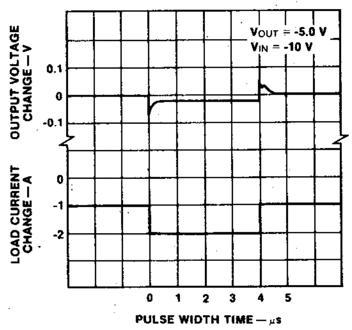
LINE TRANSIENT RESPONSE



DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



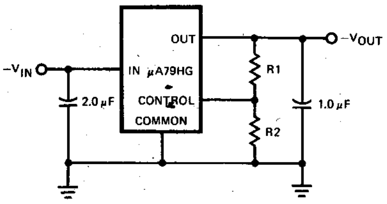
LOAD TRANSIENT RESPONSE



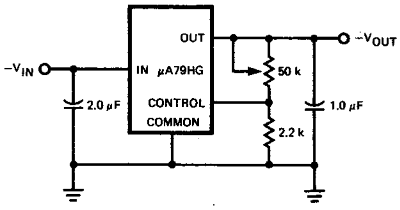
TYPICAL APPLICATIONS FOR 79HG

Bypass capacitors are recommended for stable operation of the μA79HG over all input voltage and output current ranges. The bypass capacitors, (2 μF on the input, 1 μF on the output) should be solid tantalum which have good high frequency characteristics. The bypass capacitors should be mounted with the shortest possible leads, and directly across the regulator terminals.

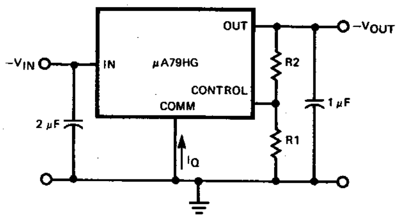
BASIC NEGATIVE REGULATOR



–30 V TO –2.2 V ADJUSTABLE REGULATOR



μA79HG TEST CIRCUIT 2



µA78MG • µA79MG

4-TERMINAL POSITIVE AND NEGATIVE ADJUSTABLE VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

GENERAL DESCRIPTION — The µA78MG and µA79MG are 4-Terminal Adjustable Voltage Regulators. They are designed to deliver continuous load currents of up to 500 mA with a maximum input voltage of 40 V for the positive regulator 78MG and −40 V for the negative regulator 79MG. Output current capability can be increased to greater than 10 A through use of one or more external transistors. The output voltage range of the 78MG positive voltage regulator is 5 V to 30 V and the output voltage range of the negative 79MG is −30 V to −2.2 V. For systems requiring both a positive and negative, the 78MG and 79MG are excellent for use as a dual tracking regulator. These 4-terminal voltage regulators are constructed using the Fairchild Planar* process.

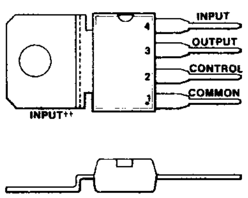
- OUTPUT CURRENT IN EXCESS OF 0.5 A
- µA78MG POSITIVE OUTPUT VOLTAGE 5 TO 30 V
- µA79MG NEGATIVE OUTPUT VOLTAGE −30 V TO −2.2 V
- INTERNAL THERMAL OVERLOAD PROTECTION
- INTERNAL SHORT CIRCUIT CURRENT PROTECTION
- OUTPUT TRANSISTOR SAFE AREA PROTECTION
- POWER MINI DUAL IN-LINE PACKAGE

ABSOLUTE MAXIMUM RATINGS

Input Voltage	
µA78MG, µA79MGC	40V
µA79MG, µA79MGC	−40V
Control Pin Voltage	
µA78MG, µA78MGC	$0 < V < V_{OUT}$
µA79MG, µA79MGC	$-V_{OUT} < -V < 0$
Power Dissipation	Internally Limited
Operating Junction Temperature Range (Note 1)	
Military (µA78MG, µA79MG)	−55°C to 150°C
Commercial (µA78MGC, µA79MGC)	0°C to 150°C
Storage Temperature Range	
4-Pin TO-39	−65°C to +150°C
Power Mini DIP and Power Watt	−55°C to +150°C
Lead Temperature	
Power Watt and Power Mini DIP (Soldering, 10 s)	230°C
4-Pin TO-39(Soldering, 60 s)	300°C

µA79MG CONNECTION DIAGRAMS

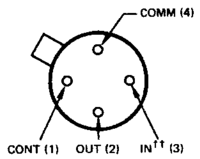
POWER WATT



ORDER INFORMATION

TYPE	PART NO.
µA79MG	µA79MGU1C

4-PIN TO-39 (TOP VIEW)



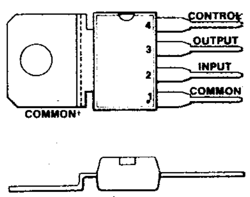
ORDER INFORMATION

TYPE	PART NO.
µA79MG	µA79MGHM
µA79MGC	µA79MGHC

††NOTE:
Heat sink tabs connected to input through device substrate. Not recommended for direct electrical connection.

µA78MG CONNECTION DIAGRAMS

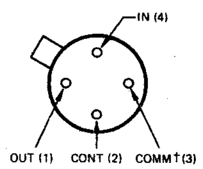
POWER WATT



ORDER INFORMATION

TYPE	PART NO.
µA78MGC	µA78MGU1C

4-PIN TO-39 (TOP VIEW)

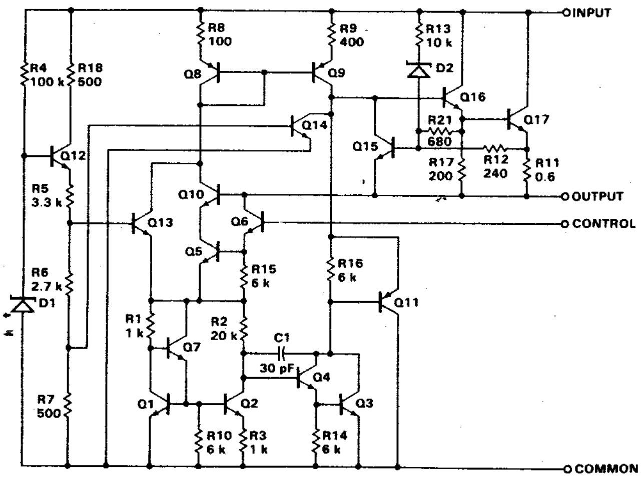


ORDER INFORMATION

TYPE	PART NO.
µA78MG	µA78MGHM
µA78MGC	µA78MGHC

†NOTE:
Heat sink tabs connected to common through device substrate.

78MG EQUIVALENT CIRCUIT



Resistor values in Ω unless otherwise noted.

µA78MG (C, HC, HM)

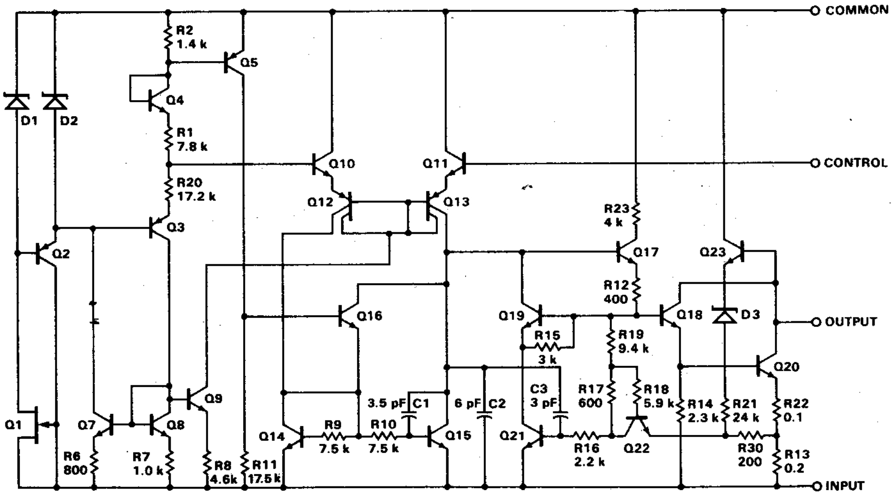
ELECTRICAL CHARACTERISTICS: $0°C \leq T_J \leq 125°C$ for µA78MGHC and µA78MGC, $-55°C \leq T_J \leq 150°C$ for µA78MGHM, $V_{IN} = 10$ V, $I_{OUT} = 350$ mA, $C_{IN} = 0.33\mu F$, $C_{OUT} = 0.1\ \mu F$, Test Circuit 1, unless otherwise specified.

CHARACTERISTICS	CONDITIONS (1 and 3)		MIN	TYP	MAX	UNITS
Input Voltage Range	$T_J = 25°C$		7.5		40	V
Output Voltage Range	$V_{IN} = V_{OUT} + 5$ V		5.0		30	V
Output Voltage Tolerance	$V_{OUT} + 3\text{ V} \leq V_{IN} \leq V_{OUT} + 15$ V, $5\text{ mA} \leq I_{OUT} \leq 350$ mA, $P_D \leq 5$ W, $V_{INMAX} = 38$ V	$T_J = 25°C$			4.0	$\%(V_{OUT})$
					5.0	$\%(V_{OUT})$
Line Regulation	$T_J = 25°C$, $I_{OUT} = 200$ mA, $V_{OUT} \leq 10$ V, $(V_{OUT} + 2.5\text{ V}) \leq V_{IN} \leq (V_{OUT} + 20\text{ V})$				1.0	$\%(V_{OUT})$
	$T_J = 25°C$, $I_{OUT} = 200$ mA, $V_{OUT} \geq 10$ V, $(V_{OUT} + 3\text{ V}) \leq V_{IN} \leq (V_{OUT} + 15\text{ V})$				0.75	$\%(V_{OUT})$
	$(V_{OUT} + 3\text{ V}) \leq V_{IN} \leq (V_{OUT} + 7\text{ V})$				0.67	$\%(V_{OUT})$
Load Regulation	$T_J = 25°C$, $5\text{ mA} \leq I_{OUT} \leq 500$ mA, $V_{IN} = V_{OUT} + 7$ V				1.0	$\%(V_{OUT})$
Control Pin Current	$T_J = 25°C$			1.0	5.0	µA
					8.0	µA
Quiescent Current	$T_J = 25°C$			2.8	4.0	mA
					5.0	mA
Ripple Rejection	$8\text{ V} \leq V_{IN} \leq 18$ V, $V_{OUT} = 5$ V, f = 120 Hz	$I_{OUT} = 300$ mA, $T_J = 25°C$	62	80		dB
		$I_{OUT} = 100$ mA	62			dB
Output Noise Voltage	$10\text{ Hz} \leq f \leq 100$ kHz, $V_{OUT} = 5$ V			8	40	$\mu V/V_{OUT}$
Dropout Voltage	(Note 2)	µA78MGHM		2	2.5	V
		µA78MG(HC and C)			2.5	V
Short Circuit Current	$V_{IN} = 35$ V, $T_J = 25°C$				600	mA
Peak Output Current	$T_J = 25°C$		0.4	0.8	1.4	A
Average Temperature Coefficient of Output Voltage	$V_{OUT} = 5$ V, $I_{OUT} = 5$ mA	$T_J = -55°C$ to $+25°C$			0.4	$mV/°C/V_{OUT}$
		$T_J = +25°C$ to $+150°C$			0.3	$mV/°C/V_{OUT}$
Control Pin Voltage (Reference)	$T_J = 25°C$		4.8	5.0	5.2	V
			4.75		5.25	V

NOTES:

1. V_{OUT} is defined for the 78MGC as $V_{OUT} = \frac{R1 + R2}{R2}(5.0)$; The 79MGC as $V_{OUT} = \frac{R1 + R2}{R2}(-2.23)$.
2. Dropout voltage is defined as that input-output voltage differential which causes the output voltage to decrease by 5% of its initial value.
3. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques ($t_W \leq 10$ ms, duty cycle $\leq 5\%$). Output voltage changes due to changes in internal temperature must be taken into account separately.

79MG EQUIVALENT CIRCUIT



Resistor values in Ω unless otherwise noted.

μA79MG (C, HC, HM)

ELECTRICAL CHARACTERISTICS: 0°C ≤ T_J ≤ 125°C for μA79MGHC and μA79MGC, −55°C ≤ T_J ≤ 150°C for μA79MGHM, V_{IN} = −10 V, I_{OUT} = 350 mA, C_{IN} = 2.0 μF, C_{OUT} = 1.0 μF, Test Circuit 2, unless otherwise specified.

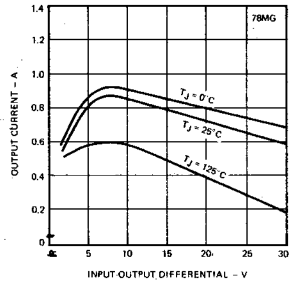
CHARACTERISTICS	CONDITIONS (1 and 2)		MIN	TYP	MAX	UNITS
Input Voltage Range	T_J = 25°C		−40		−7.0	V
Output Voltage Range	$V_{IN} = V_{OUT} - 5$ V		−30		−2.23	V
Output Voltage Tolerance	$V_{OUT} - 15\text{ V} \le V_{IN} \le V_{OUT} - 3$ V,	T_J = 25°C			4.0	%(V_{OUT})
	5 mA ≤ I_{OUT} ≤ 350 mA P_D ≤ 5 W, V_{INMAX} = −38 V				5.0	%(V_{OUT})
Line Regulation	T_J = 25°C, I_{OUT} = 200 mA, V_{OUT} ≥ −10 V (V_{OUT} − 20 V) ≤ V_{IN} ≤ (V_{OUT} − 2.5 V)				1.0	%(V_{OUT})
	T_J = 25°C, I_{OUT} = 200 mA, V_{OUT} ≤ −10 V (V_{OUT} − 15 V(≤ V_{IN} ≤ (V_{OUT} − 3 V)				0.75	%(V_{OUT})
	(V_{OUT} − 7 V) ≤ V_{IN} ≤(V_{OUT} − 3 V)				0.67	%(V_{OUT})
Load Regulation	V_{IN} = V_{OUT} − 7 V, 5 mA ≤ I_{OUT} ≤ 500 mA T_J = 25°C				1.0	%(V_{OUT})
Control Pin Current	T_J = 25°C				3.0	μA
					2.0	μA
Quiescent Current	T_J = 25°C			0.5	1.5	mA
					2.5	mA
Ripple Rejection	−18 V ≤ V_{IN} ≤ −8 V	T_J = 25°C, I_{OUT} = 300 mA	54	65		dB
	V_{OUT} = −5 V, f = 120 Hz	I_{OUT} = 100 mA	50			dB
Output Noise Voltage	10 Hz ≤ f ≤ 100 kHz, V_{OUT} = −5 V			25	80	μV/V_{OUT}
Dropout Voltage	(Note 2)	μA79MGHM		1.1	2.3	V
		μA79MG (HC and C)			2.3	V
Short Circuit Current	V_{IN} = −35 V				600	mA
Peak Output Current			0.4	.65	1.4	mA
Average Temperature Coefficient of Output Voltage	V_{OUT} = −5 V I_{OUT} = 5 mA	T_J = −55°C to +25°C			0.3	mV/°C/ V_{OUT}
		T_J = +25°C to +150°C			0.3	mV/°C/ V_{OUT}
Control Pin Voltage (Reference)	T_J = 25°C		−2.32	−2.23	−2.14	V
			−2.35		−2.11	V

NOTES:

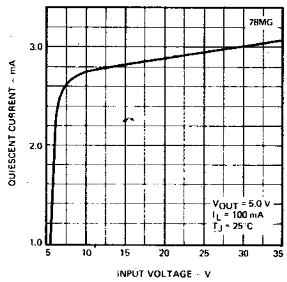
1. The convention for Negative Regulators is the Algebraic value, thus −15 is less than −10 V.
2. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_W ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

TYPICAL PERFORMANCE CURVES FOR μA78MG

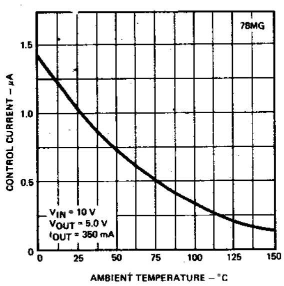
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



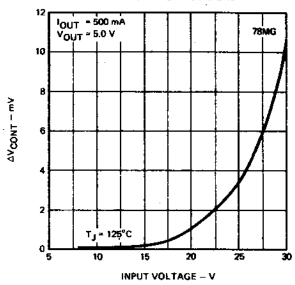
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



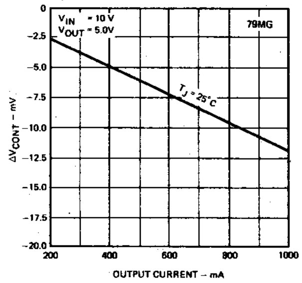
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



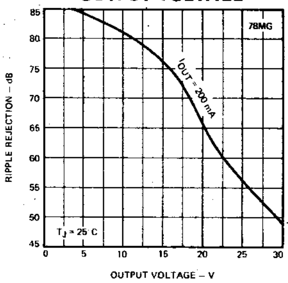
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



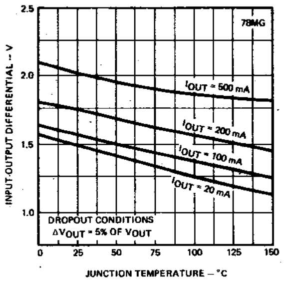
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



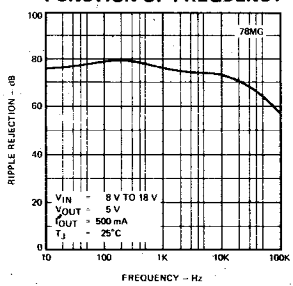
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGE



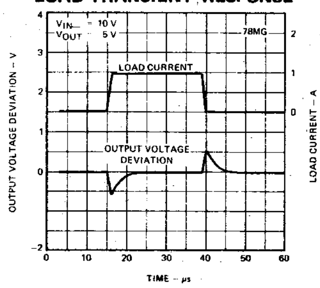
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



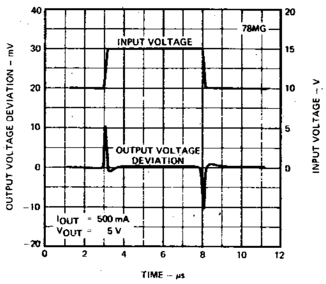
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



LOAD TRANSIENT RESPONSE



LINE TRANSIENT RESPONSE



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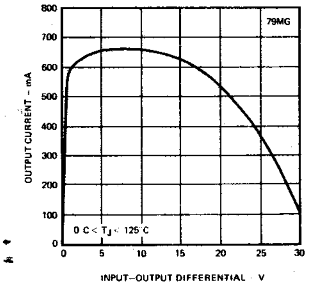
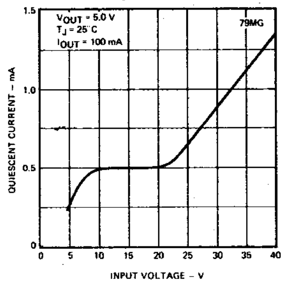
TYPICAL PERFORMANCE CURVES FOR µA79MG

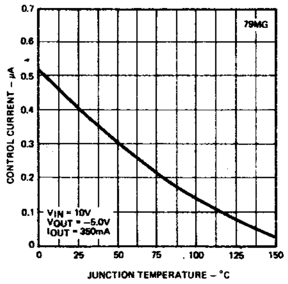
PEAK OUTPUT CURRENT AS A FUNCTION OF INPUT-OUTPUT DIFFERENTIAL VOLTAGE



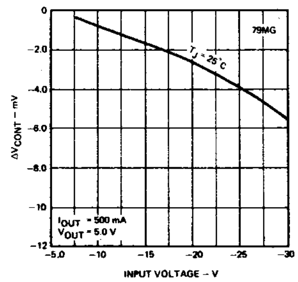
QUIESCENT CURRENT AS A FUNCTION OF INPUT VOLTAGE



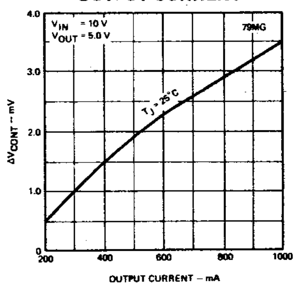
CONTROL CURRENT AS A FUNCTION OF TEMPERATURE



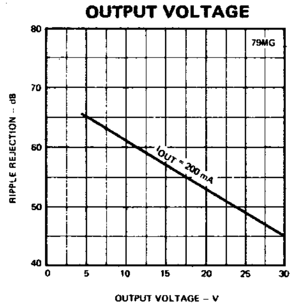
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF INPUT VOLTAGE



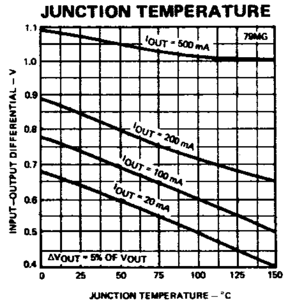
DIFFERENTIAL CONTROL VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



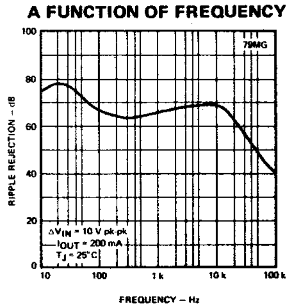
RIPPLE REJECTION AS A FUNCTION OF OUTPUT VOLTAGE



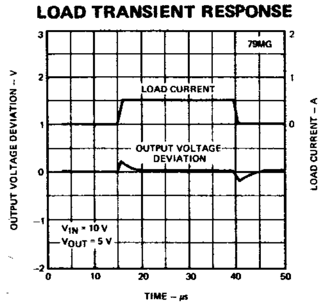
DROPOUT VOLTAGE AS A FUNCTION OF JUNCTION TEMPERATURE



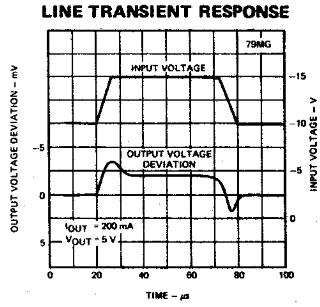
RIPPLE REJECTION AS A FUNCTION OF FREQUENCY



LOAD TRANSIENT RESPONSE



LINE TRANSIENT RESPONSE



DESIGN CONSIDERATIONS – The 78MG and 79MG variable voltage regulators have an output voltage which varies from $V_{CONTROL}$ to typically $V_{IN} - 2$ V by $V_{OUT} = V_{CONTROL} \frac{(R1 + R2)}{R2}$. The nominal reference in the 78MG is 5.0 V and 79MG is –2.23 V. If we allow 1.0 mA to flow in the control string to eliminate bias current effects, we can make R2 = 5 kΩ in the 78MG. The output voltage is then: V_{OUT} = (R1 + R2) Volts, where R1 and R2 are in kΩs.

Example: If R2 = 5 kΩ and R1 = 10 kΩ then V_{OUT} = 15 V nominal, for the 78MG;
R2 = 2.2 kΩ and R1 = 12.8 kΩ then V_{OUT} = –15.2 V nominal, for the 79MG.

By proper wiring of the feedback resistors, load regulation of the devices can be improved significantly.

Both 78MG and 79MG regulators have thermal overload protection from excessive power, internal short circuit protection which limits each circuit's maximum current, and output transistor safe area protection for reducing the output current as the voltage across each pass transistor is increased.

Although the internal power dissipation is limited, the junction temperature must be kept below the maximum specified temperature in order to meet data sheet specifications. To calculate the maximum junction temperature or heat sink required, the following thermal resistance values should be used:

PACKAGE	TYPICAL θ_{JC}	MAX θ_{JC}	TYPICAL θ_{JA}	MAX θ_{JA}
Power Mini DIP (T2)	7.5	11.0	75	80
Power Watt	8.0	12.0	75	80
TO-39	18.0	25.0	125	185

$$P_D\,(MAX) = \frac{T_J\,(MAX) - T_A}{\theta_{JC} + \theta_{CA}} \quad \text{or} \quad \frac{T_J\,(MAX) - T_A}{\theta_{JA}} \quad \text{(Without a heat sink)}$$

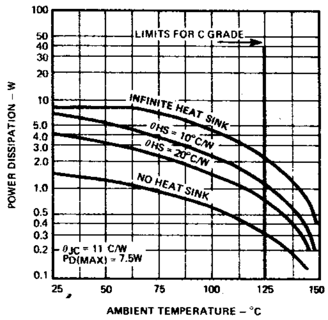
$$\theta_{CA} = \theta_{CS} + \theta_{SA}$$

Solving for T_J: $T_J = T_A + P_D\,(\theta_{JC} + \theta_{CA})$ or $T_A + P_D\theta_{JA}$ (Without heat sink)

Where T_J = Junction Temperature
T_A = Ambient Temperature
P_D = Power Dissipation
θ_{JC} = Junction to case thermal resistance
θ_{CA} = Case to ambient thermal resistance
θ_{CS} = Case to ambient thermal resistance
θ_{SA} = Heat sink to ambient thermal resistance
θ_{JA} = Junction to ambient thermal resistance

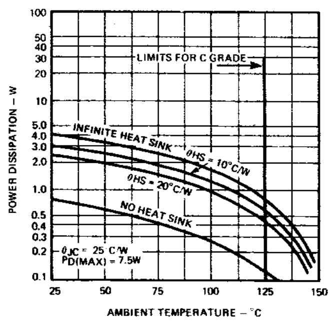
μA78MG AND μA79MG POWER MINI DIP (T2)

WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE



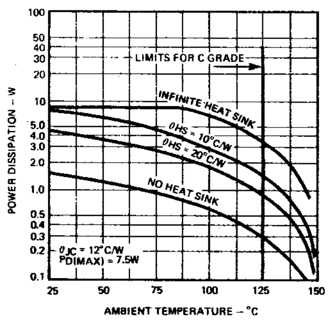
μA78MG AND μA79MG TO-39

WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE



μA78MG AND μA79MG POWER WATT (U1)

WORST CASE POWER DISSIPATION VERSUS AMBIENT TEMPERATURE

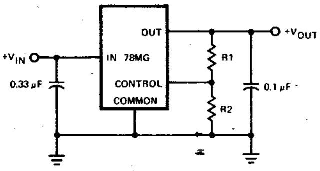


7

TYPICAL APPLICATIONS FOR μA78MG

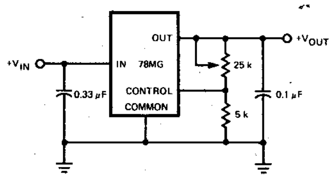
In many μA78MG applications, compensation capacitors may not be required. However, for stable operation of the regulator over all input voltage and output current ranges, bypassing of the input and output (0.33 μF and 0.1 μF, respectively) is recommended. Input bypassing is necessary if the regulator is located far from the filter capacitor of the power supply. Bypassing the output will improve the transient response of the regulator.

BASIC POSITIVE REGULATOR

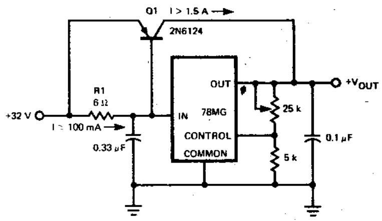


$$V_{OUT} = V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR



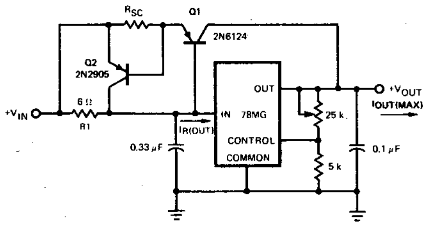
POSITIVE 5 TO 30 V ADJUSTABLE REGULATOR $I_{OUT} > 1.5$ A



$$R1 = \frac{\beta V_{BE(Q1)}}{I_{R(MAX)}(\beta) - I_{OUT(MAX)}}$$

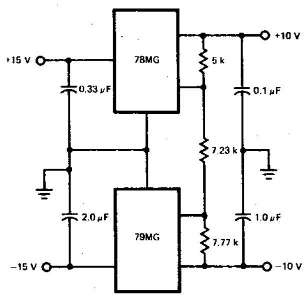
NOTE: External series pass device is not short circuit protected.

POSITIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



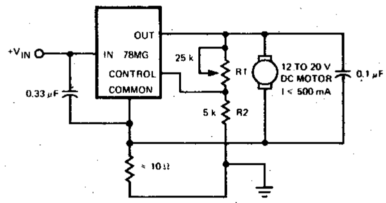
$$R1 = \frac{\beta V_{BE(Q1)}}{V_{R(MAX)}(\beta+1) - I_{OUT(MAX)}}$$

±10 V, 500 mA DUAL TRACKING REGULATOR



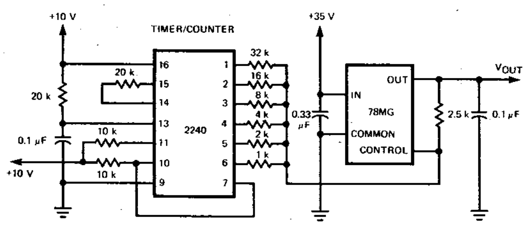
If load is not ground referenced, connect reverse biased diodes from outputs to ground.

MOTOR SPEED CONTROL

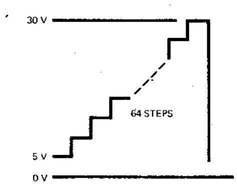


Use flyback diode across motor if necessary.

PROGRAMMABLE SUPPLY

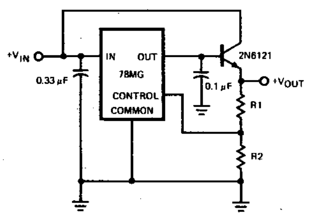


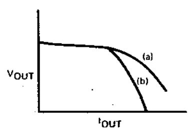
OUTPUT WAVEFORM



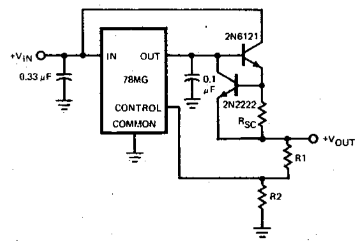
POSITIVE HIGH CURRENT VOLTAGE REGULATOR

EXTERNAL SERIES PASS (a)





SHORT CIRCUIT LIMIT (b)

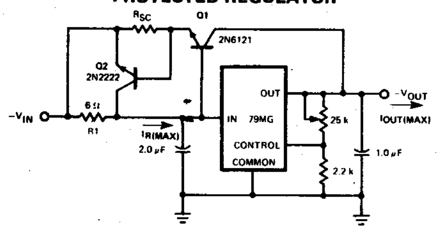


TYPICAL APPLICATIONS FOR 79MG

Bypass capacitors are recommended for stable operation of the μA79MG over the input voltage and output current ranges. Output bypass capacitors will improve the transient response of the regulator.

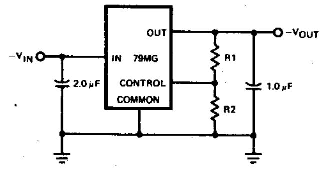
The bypass capacitors, (2 μF on the input, 1 μF on the output) should be ceramic or solid tantalum which have good high frequency characteristics. If aluminum electrolytics are used, their values should be 10 μF or larger. The bypass capacitors should be mounted with the shortest leads, and if possible, directly across the regulator terminals.

NEGATIVE HIGH CURRENT SHORT CIRCUIT PROTECTED REGULATOR



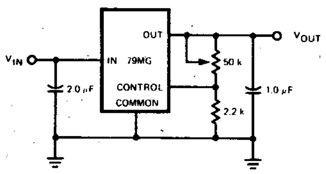
$$R1 = \frac{\beta V_{BE(Q1)}}{I_{R(MAX)}(\beta) - I_{OUT(MAX)}}$$

BASIC NEGATIVE REGULATOR

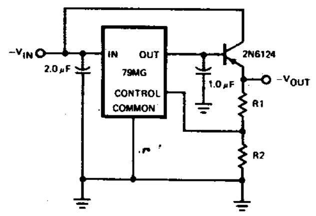


$$V_{OUT} = -V_{CONT}\left(\frac{R1 + R2}{R2}\right)$$

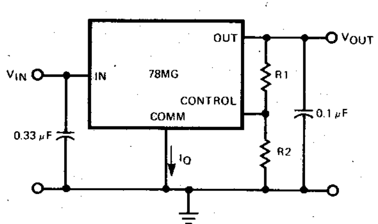
−30 V TO −2.2 V ADJUSTABLE REGULATOR



NEGATIVE HIGH CURRENT VOLTAGE REGULATOR EXTERNAL SERIES PASS



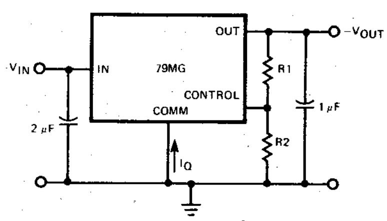
78MG TEST CIRCUIT 1



$$V_{OUT} = \left(\frac{R1 + R2}{R2}\right) V_{CONTROL}$$

$V_{CONTROL}$ Nominally = 5 V

79MG TEST CIRCUIT 2



$$V_{OUT} = \left(\frac{R1 + R2}{R2}\right) V_{CONTROL}$$

$V_{CONTROL}$ Nominally = −2.23 V

Recommended R2 current ≈ 1 mA
∴R2 = 5 kΩ(78MG)
R2 = 2.2 kΩ (79MG)

7

µA723
PRECISION VOLTAGE REGULATOR
FAIRCHILD LINEAR INTEGRATED CIRCUITS

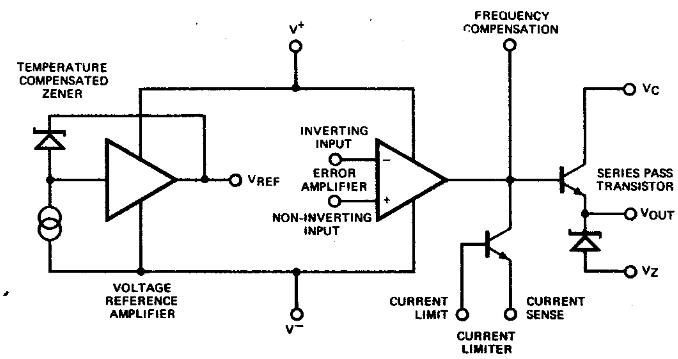
GENERAL DESCRIPTION — The µA723 is a monolithic Voltage Regulator constructed using the Fairchild Planar* epitaxial process. The device consists of a temperature compensated reference amplifier, error amplifier, power series pass transistor and current limit circuitry. Additional NPN or PNP pass elements may be used when output currents exceeding 150 mA are required. Provisions are made for adjustable current limiting and remote shutdown. In addition to the above, the device features low standby current drain, low temperature drift and high ripple rejection. The µA723 is intended for use with positive or negative supplies as a series, shunt, switching or floating regulator. Applications include laboratory power supplies, isolation regulators for low level data amplifiers, logic card regulators, small instrument power supplies, airborne systems and other power supplies for digital and linear circuits.

- **POSITIVE OR NEGATIVE SUPPLY OPERATION**
- **SERIES, SHUNT, SWITCHING OR FLOATING OPERATION**
- **0.01% LINE AND LOAD REGULATION**
- **OUTPUT VOLTAGE ADJUSTABLE FROM 2 TO 37 VOLTS**
- **OUTPUT CURRENT TO 150 mA WITHOUT EXTERNAL PASS TRANSISTOR**

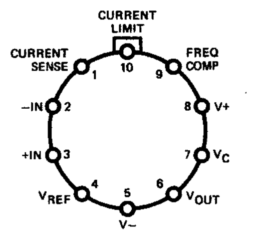
ABSOLUTE MAXIMUM RATINGS

Pulse Voltage from V+ to V−, (50 ms) (µA723)	50 V
Continuous Voltage from V_+ to V_-	40 V
Input/Output Voltage Differential	40 V
Differential Input Voltage	±5 V
Voltage Between Non-Inverting Input and V_-	+8 V
Current from V_Z	25 mA
Current from V_{REF}	15 mA
Internal Power Dissipation (Note 1)	
Metal Can	800 mW
DIP	1000 mW
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	
Military (µA723)	−55°C to +125°C
Commercial (µA723C)	0°C to +70°C
Lead Temperature (Soldering, 60 s)	300°C

EQUIVALENT CIRCUIT



CONNECTION DIAGRAMS
10-LEAD METAL CAN
(TOP VIEW)

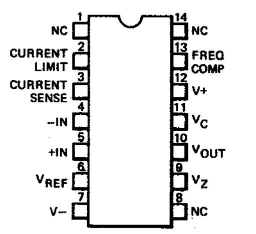


Note: Pin 5 connected to case.

ORDER INFORMATION

TYPE	PART NO.
µA723	µA723HM
µA723C	µA723HC

14-LEAD DIP
(TOP VIEW)



ORDER INFORMATION

TYPE	PART NO.
µA723	µA723DM
µA723C	µA723DC
µA723C	µA723PC

Notes on following pages.

*Planar is a patented Fairchild process

μA723

ELECTRICAL CHARACTERISTICS: $T_A = 25°C$, $V_{IN} = V+ = V_C = 12$ V, $V- = 0$, $V_{OUT} = 5$ V, $I_L = 1$ mA, $R_{SC} = 0$, C1 = pF, $C_{ref} = 0$, unless otherwise specified. Divider impedance as seen by error amplifier ≤ 10 kΩ connected shown in Fig. 1. Line and load regulation specifications are given for the condition of constant chip temperature Temperature drifts must be taken into account separately for high dissipation conditions.

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
Line Regulation	$V_{IN} = 12V$ to $V_{IN} = 15V$		0.01	0.1	$\%V_O$
	$V_{IN} = 12V$ to $V_{IN} = 40V$		0.02	0.2	$\%V_O$
	$-55°C \leq T_A \leq +125°C$, $V_{IN} = 12V$ to $V_{IN} = 15V$			0.3	$\%V_O$
Load Regulation	$I_L = 1$ mA to $I_L = 50$ mA		0.03	0.15	$\%V_O$
	$-55°C \leq T_A \leq +125°C$, $I_L = 1$ mA to $I_L = 50$ mA			0.6	$\%V_O$
Ripple Rejection	f = 50 Hz to 10 kHz		74		dB
	f = 50 Hz to 10 kHz, $C_{REF} = 5\ \mu F$		86		dB
Average Temperature Coefficient of Output Voltage	$-55°C \leq T_A \leq +125°C$		0.002	0.015	%/°C
Short Circuit Current Limit	$R_{SC} = 10\ \Omega$, $V_O = 0$		65		mA
Reference Voltage		6.95	7.15	7.35	V
Output Noise Voltage	BW = 100 Hz to 10 kHz, $C_{REF} = 0$		20		μV_{rms}
	BW = 100 Hz to 10 kHz, $C_{REF} = 5\ \mu F$		2.5		μV_{rms}
Long Term Stability			0.1		%/1000 hrs
Standby Current Drain	$I_L = 0$, $V_{IN} = 30V$		2.3	3.5	mA
Input Voltage Range		9.5		40	V
Output Voltage Range		2.0		37	V
Input/Output Voltage Differential		3.0		38	V

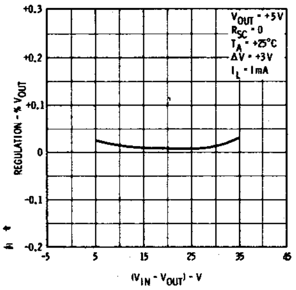
μA723C

ELECTRICAL CHARACTERISTICS: $T_A = 25°C$, $V_{IN} = V+ = V_C = 12$ V, $V- = 0$, $V_{OUT} = 5$ V, $I_L = 1$ mA, $R_{SC} = 0$, C1 = 100 pF, $C_{ref} = 0$, unless otherwise specified. Divider impedance as seen by error amplifier ≤ 10 kΩ connected as shown in Fig. 1. Line and load regulation specifications are given for the condition of constant chip temperature. Temperature drifts must be taken into account separately for high dissipation conditions.

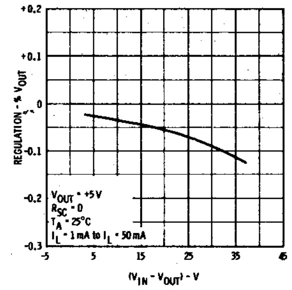
CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
Line Regulation	$V_{IN} = 12V$ to $V_{IN} = 15V$		0.01	0.1	$\%V_O$
	$V_{IN} = 12V$ to $V_{IN} = 40V$		0.1	0.5	$\%V_O$
	$0°C \leq T_A \leq 70°C$, $V_{IN} = 12V$ to $V_{IN} = 15V$			0.3	$\%V_O$
Load Regulation	$I_L = 1$ mA to $I_L = 50$ mA		0.03	0.2	$\%V_O$
	$0°C \leq T_A \leq 70°C$, $I_L = 1$ mA to $I_L = 50$ mA			0.6	$\%V_O$
Ripple Rejection	f = 50 Hz to 10 kHz		74		dB
	f = 50 Hz to 10 kHz, $C_{REF} = 5\ \mu F$		86		dB
Average Temperature Coefficient of Output Voltage	$0°C \leq T_A \leq 70°C$		0.003	0.015	%/°C
Short Circuit Current Limit	$R_{SC} = 10\ \Omega$, $V_O = 0$		65		mA
Reference Voltage		6.80	7.15	7.50	V
Output Noise Voltage	BW = 100 Hz to 10 kHz, $C_{REF} = 0$		20		μV_{rms}
	BW = 100 Hz to 10 kHz, $C_{REF} = 5\ \mu F$		2.5		μV_{rms}
Long Term Stability			0.1		%/1000 hrs
Standby Current Drain	$I_L = 0$, $V_{IN} = 30V$		2.3	4.0	mA
Input Voltage Range		9.5		40	V
Output Voltage Range		2.0		37	V
Input/Output Voltage Differential		3.0		38	V

TYPICAL PERFORMANCE CURVES FOR μA723 AND μA723C

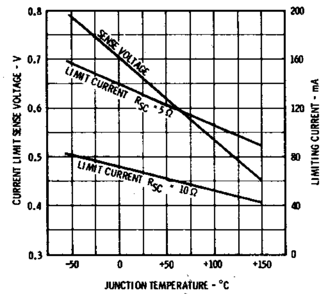
LINE REGULATION AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



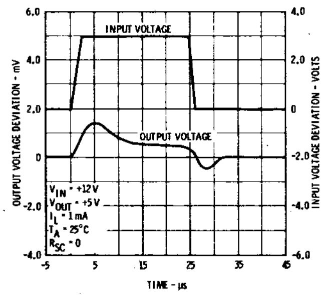
LOAD REGULATION AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



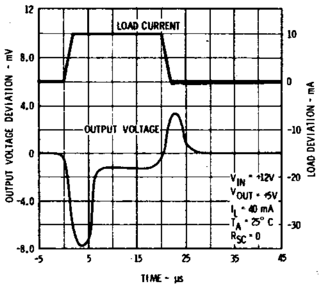
CURRENT LIMITING CHARACTERISTICS AS A FUNCTION OF JUNCTION TEMPERATURE



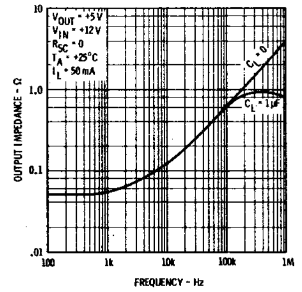
LINE TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE



OUTPUT IMPEDANCE AS A FUNCTION OF FREQUENCY



NOTES:

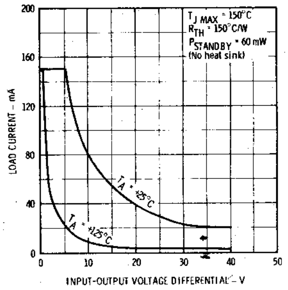
1. Rating applies to ambient temperatures up to 25°C. Above 25°C ambient derate based on the following thermal resistance values:

	θ_{JA} TYP	θ_{JA} MAX
TO-5	150	190
Plastic DIP	150	190
Ceramic DIP	125	160

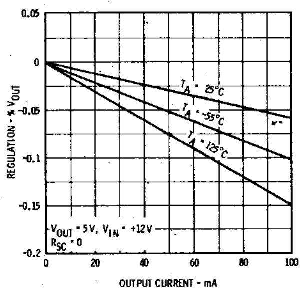
2. L_1 is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 pot core or equivalent with 0.009" air gap.
3. Figures in parentheses may be used if R_1/R_2 divider is placed on opposite side of error amp.
4. Replace R_1/R_2 in figures with divider shown in figure 13.
5. V^+ must be connected to a +3 V or greater supply.
6. For metal can applications where V_Z is required, an external 6.2 volt zener diode should be connected in series with V_{OUT}.

TYPICAL PERFORMANCE CURVES FOR μA723

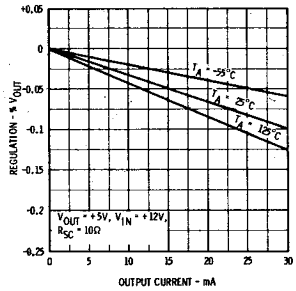
MAXIMUM LOAD CURRENT AS A FUNCTION OF INPUT-OUTPUT VOLTAGE DIFFERENTIAL



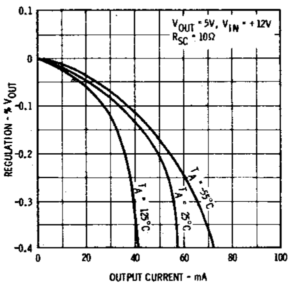
LOAD REGULATION CHARACTERISTICS WITHOUT CURRENT LIMITING



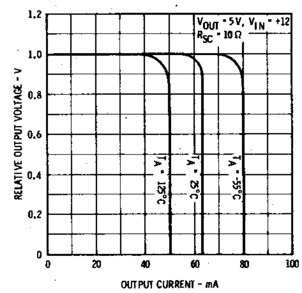
LOAD REGULATION CHARACTERISTICS WITH CURRENT LIMITING



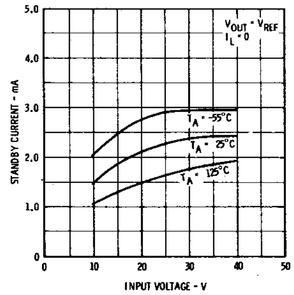
LOAD REGULATION CHARACTERISTICS WITH CURRENT LIMITING



CURRENT LIMITING CHARACTERISTICS

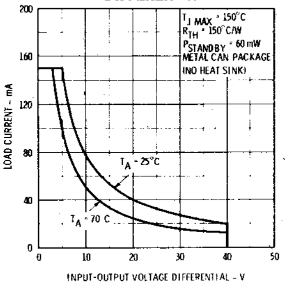


STANDBY CURRENT DRAIN AS A FUNCTION OF INPUT VOLTAGE

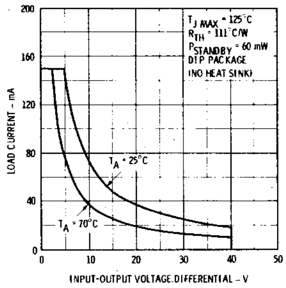


TYPICAL PERFORMANCE CURVES FOR μA723C

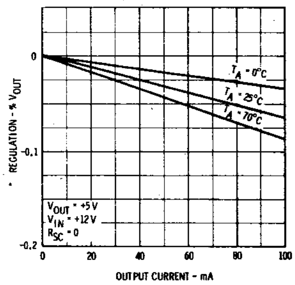
MAXIMUM LOAD CURRENT AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



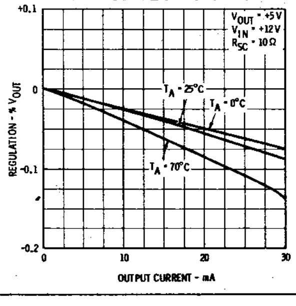
MAXIMUM LOAD CURRENT AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



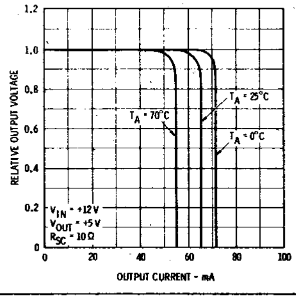
LOAD REGULATION CHARACTERISTICS WITHOUT CURRENT LIMITING



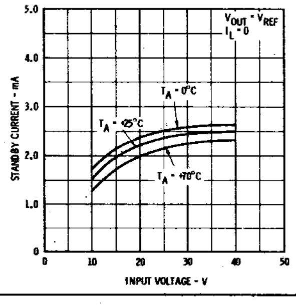
LOAD REGULATION CHARACTERISTICS WITH CURRENT LIMITING



CURRENT LIMITING CHARACTERISTICS



STANDBY CURRENT DRAIN AS A FUNCTION OF INPUT VOLTAGE



7

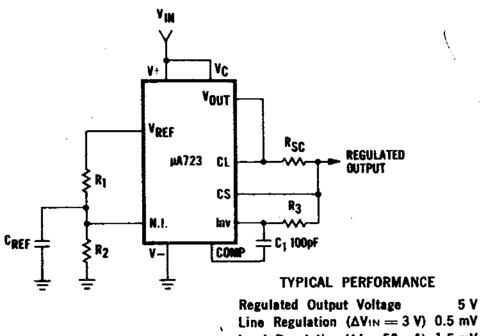
TABLE I
RESISTOR VALUES (kΩ) FOR STANDARD OUTPUT VOLTAGES

POSITIVE OUTPUT VOLTAGE	APPLICABLE FIGURES	FIXED OUTPUT ±5%		OUTPUT ADJUSTABLE ±10% (Note 4)			NEGATIVE OUTPUT VOLTAGE	APPLICABLE FIGURES	FIXED OUTPUT ±5%		5% OUTPUT ADJUSTABLE ±10%		
	(Note 3)	R_1	R_2	R_1	P_1	R_2			R_1	R_2	R_1	P_1	R_2
+3.0	1, 5, 6, 9, 12 (4)	4.12	3.01	1.8	0.5	1.2	+100	7	3.57	102	2.2	10	91
+3.6	1, 5, 6, 9, 12 (4)	3.57	3.65	1.5	0.5	1.5	+250	7	3.57	255	2.2	10	240
+5.0	1, 5, 6, 9, 12 (4)	2.15	4.99	.75	0.5	2.2	−6 (Note 5)	3, (10)	3.57	2.43	1.2	0.5	.75
+6.0	1, 5, 6, 9, 12 (4)	1.15	6.04	0.5	0.5	2.7	−9	3, 10	3.48	5.36	1.2	0.5	2.0
+9.0	2, 4, (5, 6, 12, 9)	1.87	7.15	.75	1.0	2.7	−12	3, 10	3.57	8.45	1.2	0.5	3.3
+12	2, 4, (5, 6, 9, 12)	4.87	7.15	2.0	1.0	3.0	−15	3, 10	3.65	11.5	1.2	0.5	4.3
+15	2, 4, (5, 6, 9, 12)	7.87	7.15	3.3	1.0	3.0	−28	3, 10	3.57	24.3	1.2	0.5	10
+28	2, 4, (5, 6, 9, 12)	21.0	7.15	5.6	1.0	2.0	−45	8	3.57	41.2	2.2	10	33
+45	7	3.57	48.7	2.2	10	39	−100	8	3.57	97.6	2.2	10	91
+75	7	3.57	78.7	2.2	10	68	−250	8	3.57	249	2.2	10	240

TABLE II
FORMULAE FOR INTERMEDIATE OUTPUT VOLTAGES

Outputs from +2 to +7 volts [Figures 1, 5, 6, 9, 12, (4)]	Outputs from +4 to +250 volts [Figure 7]	Current Limiting
$V_{OUT} = [V_{REF} \times \frac{R_2}{R_1 + R_2}]$	$V_{OUT} = [\frac{V_{REF}}{2} \times \frac{R_2 - R_1}{R_1}]$; $R_3 = R_4$	$I_{LIMIT} = \frac{V_{SENSE}}{R_{sc}}$
Outputs from +7 to +37 volts [Figures 2, 4, (5, 6, 9, 12)]	**Outputs from −6 to −250 volts [Figures 3, 8, 10]**	**Foldback Current Limiting**
$V_{OUT} = [V_{REF} \times \frac{R_1 + R_2}{R_2}]$	$V_{OUT} = [\frac{V_{REF}}{2} \times \frac{R_1 + R_2}{R_1}]$; $R_3 = R_4$	$I_{KNEE} = [\frac{V_{OUT} R_3}{R_{sc} R_4} + \frac{V_{SENSE} (R_3 + R_4)}{R_{sc} R_4}]$ $I_{SHORT\ CKT} = [\frac{V_{SENSE}}{R_{sc}} \times \frac{R_3 + R_4}{R_4}]$

BASIC LOW VOLTAGE REGULATOR
(V_{OUT} = 2 to 7 V)



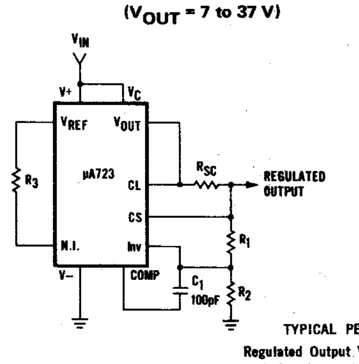
TYPICAL PERFORMANCE

Regulated Output Voltage 5 V
Line Regulation (ΔV_{IN} = 3 V) 0.5 mV
Load Regulation (ΔI_L=50 mA) 1.5 mV

Note: $R_3 = \frac{R_1 R_2}{R_1 + R_2}$ for minimum temperature drift.

Fig. 1

BASIC HIGH VOLTAGE REGULATOR
(V_{OUT} = 7 to 37 V)



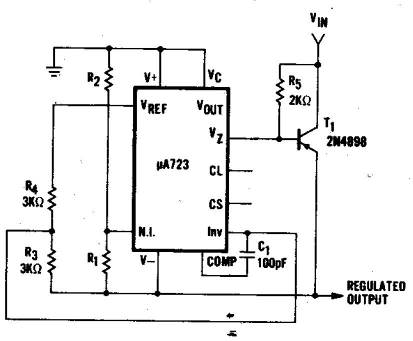
TYPICAL PERFORMANCE

Regulated Output Voltage 15 V
Line Regulation (ΔV_{IN} = 3 V) 1.5 mV
Load Regulation (ΔI_L=50 mA) 4.5 mV

Note: $R_3 = \frac{R_1 R_2}{R_1 + R_2}$ for minimum temperature drift.
R_3 may be eliminated for minimum component count.

Fig. 2

NEGATIVE VOLTAGE REGULATOR



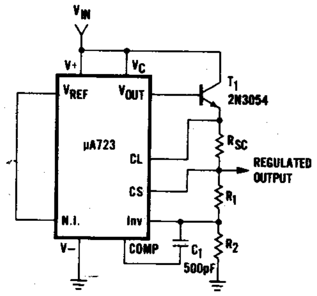
TYPICAL PERFORMANCE

Regulated Output Voltage	−15 V
Line Regulation (ΔV_{IN} = 3 V)	1 mV
Load Regulation (ΔI_L = 100 mA)	2 mV

Note 6

Fig. 3

POSITIVE VOLTAGE REGULATOR (External NPN Pass Transistor)

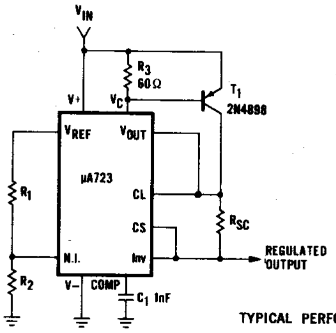


TYPICAL PERFORMANCE

Regulated Output Voltage	+15 V
Line Regulation (ΔV_{IN} = 3 V)	1.5 mV
Load Regulation (ΔI_L = 1 A)	15 mV

Fig. 4

POSITIVE VOLTAGE REGULATOR (External PNP Pass Transistor)

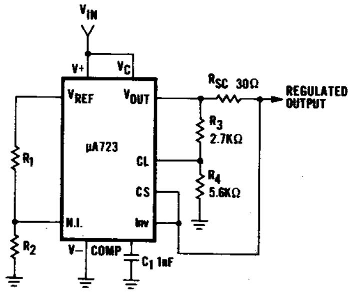


TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 3 V)	0.5 mV
Load Regulation (ΔI_L = 1 A)	5 mV

Fig. 5

FOLDBACK CURRENT LIMITING

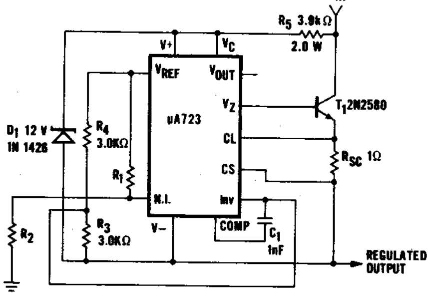


TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 3 V)	0.5 mV
Load Regulation (ΔI_L = 10 mA)	1 mV
Short Circuit Current	20 mA

Fig. 6

POSITIVE FLOATING REGULATOR



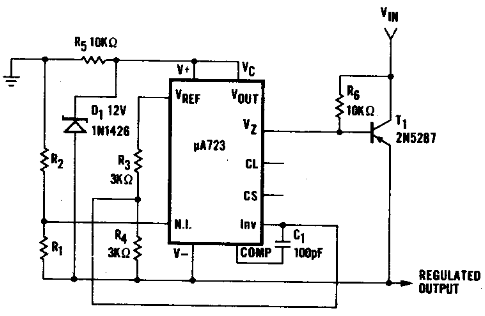
TYPICAL PERFORMANCE

Regulated Output Voltage	+50 V
Line Regulation (ΔV_{IN} = 20 V)	15 mV
Load Regulation (ΔI_L = 50 mA)	20 mV

Note 6

Fig. 7

NEGATIVE FLOATING REGULATOR



TYPICAL PERFORMANCE

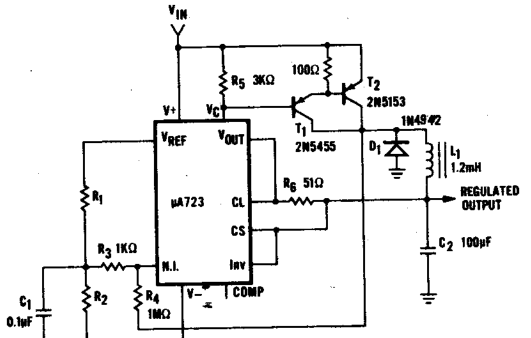
Regulated Output Voltage	−100 V
Line Regulation (ΔV_{IN} = 20 V)	30 mV
Load Regulation (ΔI_L=100 mA)	20 mV

Note 6

Fig. 8

7

POSITIVE SWITCHING REGULATOR



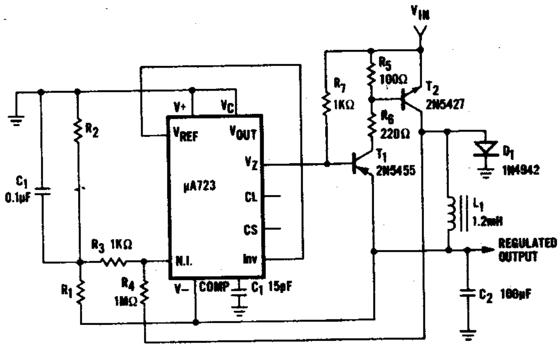
TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 30 V)	10 mV
Load Regulation (ΔI_L = 2 A)	80 mV

Note 2

Fig. 9

NEGATIVE SWITCHING REGULATOR



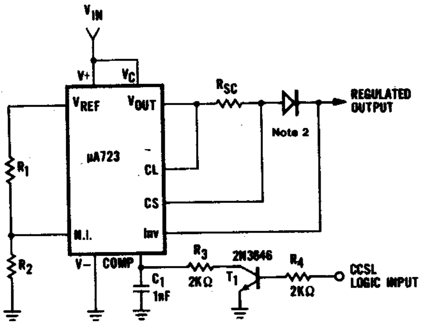
TYPICAL PERFORMANCE

Regulated Output Voltage	–15 V
Line Regulation (ΔV_{IN} = 20 V)	8 mV
Load Regulation (ΔI_L = 2 A)	6 mV

Notes 2, 6

Fig. 10

REMOTE SHUTDOWN REGULATOR WITH CURRENT LIMITING



Note 1: Current limit transistor may be used for shutdown if current limiting is not required.

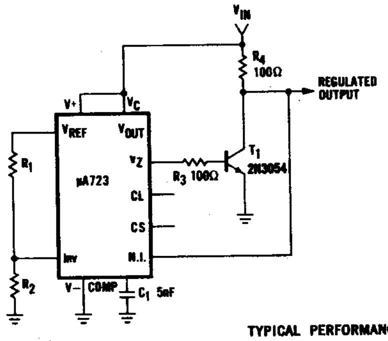
2: Add if Vout > 10V

TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 3 V)	0.5 mV
Load Regulation (ΔI_L=50 mA)	1.5 mV

Fig. 11

SHUNT REGULATOR



TYPICAL PERFORMANCE

Regulated Output Voltage	+5 V
Line Regulation (ΔV_{IN} = 10 V)	0.5 mV
Load Regulation (ΔI_L=100 mA)	1.5 mV

Note 6

Fig. 12

OUTPUT VOLTAGE ADJUST

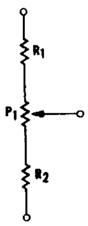
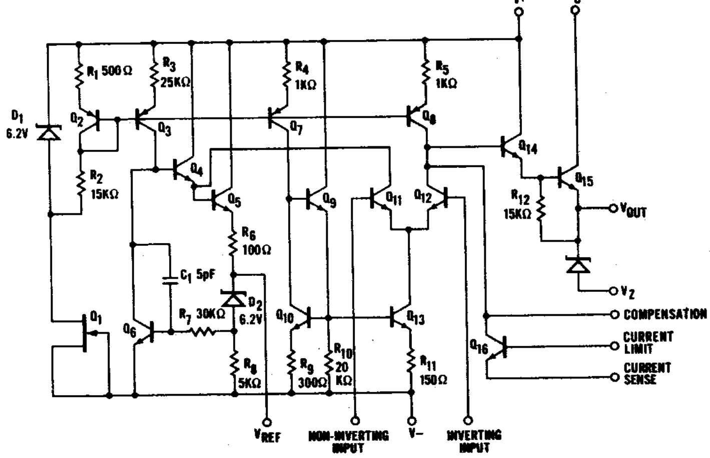


Fig. 13

EQUIVALENT CIRCUIT



µA105 • µA305 • µA305A • µA376

VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

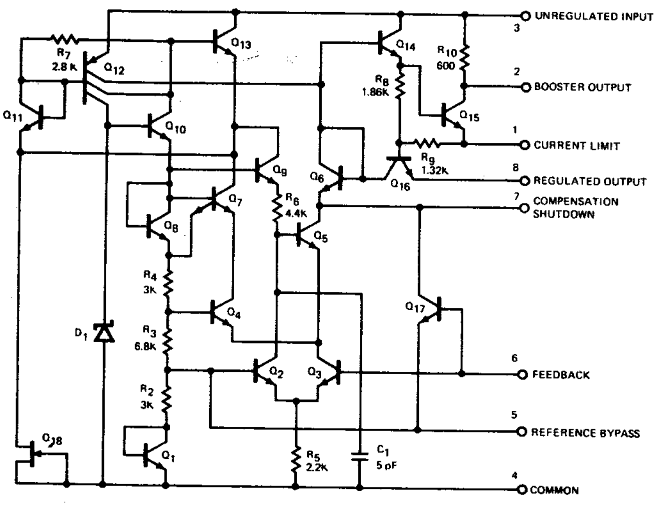
GENERAL DESCRIPTION – The 105/305/305A/376 are monolithic Positive Voltage Regulators constructed using the Fairchild Planar* epitaxial process. Applications for these devices include both linear and switching regulator circuits with output voltages greater than 4.5 V. These devices will not oscillate when confronted with varying resistive and reactive loads and will start reliably regardless of the load within the ratings of the circuit. They also feature fast response to both load and line transients. Used independently, the 105/305 will supply 12 mA, the 305A, 45 mA and 376, 25 mA. The 105 is specified for the military temperature range (–55°C to +125°C) and the 305/376/305A are specified for 0°C to +70°C operation. The 105/305/305A are in an 8-lead TO-5 package and the 376 is available in the space and cost saving mini DIP.

- **LOW STANDBY CURRENT DRAIN**
- **ADJUSTABLE OUTPUT VOLTAGE FROM 4.5 V TO 40 V**
- **HIGH OUTPUT CURRENTS EXCEEDING 10A WITH EXTERNAL COMPONENTS**
- **LOAD REGULATION BETTER THAN 0.1%, FULL LOAD WITH CURRENT LIMITING**
- **DC LINE REGULATION GUARANTEED AT 0.03%/V**
- **RIPPLE REJECTION OF 0.01%/V**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	
µA105, µA305A	50 V
µA305, µA376	40 V
Input/Output Voltage Differential	40 V
Internal Power Dissipation (Note 1)	
µA105, µA305, µA305A	500 mW
µA376	450 mW
Operating Temperature Range	
Military (µA105)	–55°C to +125°C
Commercial (µA305, µA305A, µA376)	0°C to +70°C
Storage Temperature Range	
Metal Can	–65°C to +150°C
Mini DIP	–55°C to +125°C
Lead Temperature	
Metal Can (Soldering, 60 s)	300°C
Mini DIP (Soldering, 10 s)	260°C

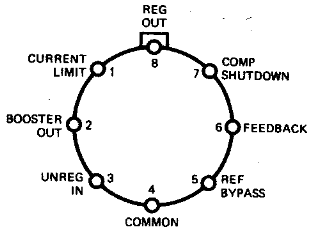
EQUIVALENT CIRCUIT



PIN CONNECTIONS SHOWN ARE FOR METAL CAN

Notes on following pages.

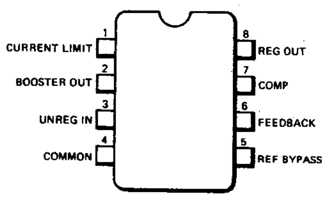
CONNECTION DIAGRAMS
8-LEAD METAL CAN
(TOP VIEW)



ORDER INFORMATION

TYPE	PART NO.
µA105	µA105HM
µA305	µA305HC
µA305A	µA305AHC

8-LEAD MINI DIP
(TOP VIEW)



ORDER INFORMATION

TYPE	PART NO.
µA376	µA376TC

*Planar is a patented Fairchild process.

7

μA105

ELECTRICAL CHARACTERISTICS: T_A = 25°C unless otherwise specified Note 2

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			8.5		50	V
Output Voltage Range			4.5		40	V
Output/Input Voltage Differential			3.0		30	V
Load Regulation (Note 3)	$0 \leq I_L \leq 12$ mA	R_{SC} = 10Ω, T_A = 25°C		0.02	0.05	%
		R_{SC} = 10Ω, T_A = 125°C		0.03	0.1	%
		R_{SC} = 10Ω, T_A = −55°C		0.03	0.1	%
Line Regulation	$V_{IN} - V_O \leq 5$ V			0.025	0.06	%/V
	$V_{IN} - V_O > 5$ V			0.015	0.03	%/V
Ripple Rejection	C_{REF} = 10 μF, f = 120 Hz			0.003	0.01	%/V
Temperature Stability (Note 5)	−55°C ≤ T_A ≤ 125°C			0.3	1.0	%
Feedback Sense Voltage			1.63	1.7	1.81	V
Output Noise Voltage	10 Hz ≤ f ≤ 10 kHz	C_{REF} = 0		0.005		%
		C_{REF} > 0.1 μF		0.002		%
Current Limit Sense Voltage (Note 4)	R_{SC} = 10Ω, T_A = 25°C, V_O = 0 V		225	300	375	mV
Standby Current Drain	V_{IN} = 50 V			0.8	2.0	mA
Long Term Stability				0.1	1.0	%

μA305

ELECTRICAL CHARACTERISTICS: T_A = 25°C unless otherwise specified Note 2

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			8.5		40	V
Output Voltage Range			4.5		30	V
Output/Input Voltage Differential			3.0		30	V
Load Regulation (Note 3)	$0 \leq I_L \leq 12$ mA	R_{SC} = 10Ω, T_A = 25°C		0.02	0.05	%
		R_{SC} = 15Ω, T_A = 70°C		0.03	0.1	%
		R_{SC} = 10Ω, T_A = 0°C		0.03	0.1	%
Line Regulation	$V_{IN} - V_O \leq 5$ V			0.025	0.06	%/V
	$V_{IN} - V_O > 5$ V			0.015	0.03	%/V
Ripple Rejection	C_{REF} = 10 μF, f = 120 Hz			0.003	0.01	%/V
Temperature Stability (Note 5)	0°C ≤ T_A ≤ 70°C			0.3	1.0	%
Feedback Sense Voltage			1.63	1.7	1.81	V
Output Noise Voltage	10 Hz ≤ f ≤ 10 kHz	C_{REF} = 0		0.005		%
		C_{REF} > 0.1 μF		0.002		%
Current Limit Sense Voltage (Note 4)	R_{SC} = 10Ω, T_A = 25°C V_O = 0 V		225	300	375	mV
Standby Current Drain	V_{IN} = 40 V			0.8	2.0	mA
Long Term Stability				0.1	1.0	%

NOTES

1. Rating applies to ambient temperatures up to 70°C. Above 70°C ambient derate linearly at 6.25 mW/°C for the metal can and 5.6 mW/°C for the mini Dip.
2. These specifications apply for input and output voltages within the ranges given, and for a divider impedance seen by the feedback terminal of 2 kΩ, unless otherwise specified. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation.
3. The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.
4. With no external pass transistor.
5. Temperature Stability is defined as the percentage change in output voltage for a thermal variation from room temperature to either temperature extreme.

μA305A

ELECTRICAL CHARACTERISTICS: $T_A = 25°C$ unless otherwise specified Note 2

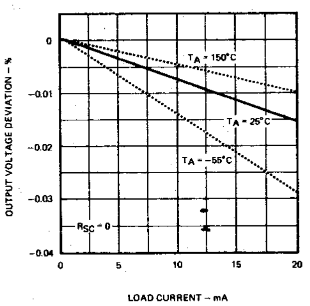
CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			8.5		50	V
Output Voltage Range			4.5		40	V
Output/Input Voltage Differential			3.0		30	V
Load Regulation (Note 3)	$0 \leq I_L \leq 45$ mA	$R_{SC} = 0\Omega$, $T_A = 25°C$		0.02	0.2	%
		$R_{SC} = 0\Omega$, $T_A = 70°C$		0.03	0.4	%
		$R_{SC} = 0\Omega$ $T_A = 0°C$		0.03	0.4	%
Line Regulation		$V_{IN} - V_O \leq 5$ V		0.025	0.06	%/V
		$V_{IN} - V_O > 5$ V		0.015	0.03	%/V
Ripple Rejection		$C_{REF} = 10$ μF, f = 120 Hz		0.003		%/V
Temperature Stability (Note 5)		$0°C \leq T_A \leq 70°C$		0.3	1.0	%
Feedback Sense Voltage			1.55	1.7	1.85	V
Output Noise Voltage	10 Hz ≤ f ≤ 10 kHz	$C_{REF} = 0$		0.005		%
		$C_{REF} > 0.1$ μF		0.002		%
Current Limit Sense Voltage (Note 4)		$R_{SC} = 10\Omega$, $T_A = 25°C$, $V_O = 0$ V	225	300	375	mV
Standby Current Drain		$V_{IN} = 50$ V		0.8	2.0	mA
Long Term Stability				0.1	1.0	%

μA376

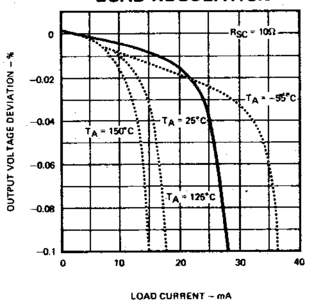
ELECTRICAL CHARACTERISTICS $0°C \leq T_A \leq 70°C$

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			9.0		40	V
Output Voltage Range			5.0		37	V
Output/Input Voltage Differential			3.0		30	V
Load Regulation	$0 \leq I_L \leq 25$ mA	$R_{SC} = 0\Omega$, $T_A = 25°C$			0.2	%
		$R_{SC} = 0\Omega$, $T_A = 70°C$			0.5	%
		$R_{SC} = 0\Omega$, $T_A = 0°C$			0.5	%
Line Regulation					0.03	%/V
					0.1	%/V
Ripple Rejection		f = 120 Hz, $T_A = 25°C$			0.1	%/V
Standby Current Drain		$V_{IN} = 30$ V, $T_A = 25°C$			2.5	mA
Reference Voltage			1.60	1.72	1.80	V
Current Limit Sense Voltage				360		mV

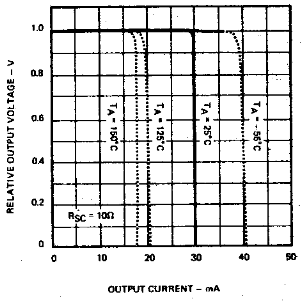
TYPICAL PERFORMANCE CURVES FOR μA105/μA305/μA305A



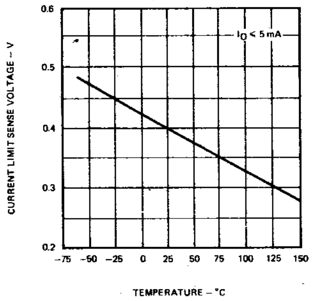
LOAD REGULATION



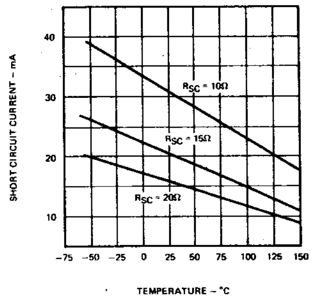
CURRENT LIMITING CHARACTERISTICS



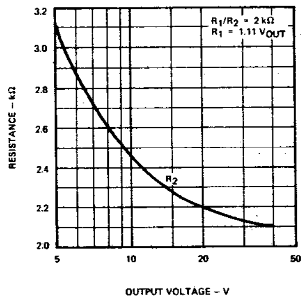
CURRENT LIMIT SENSE VOLTAGE AS A FUNCTION OF TEMPERATURE



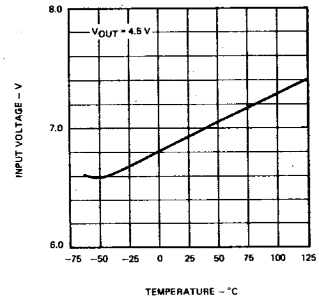
SHORT CIRCUIT CURRENT AS A FUNCTION OF TEMPERATURE



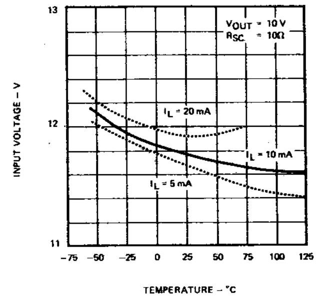
OPTIMUM DIVIDER RESISTANCE VALUES



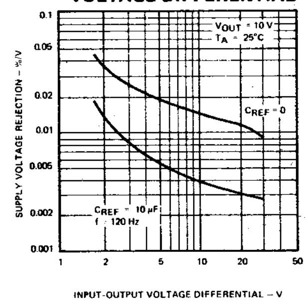
MINIMUM INPUT VOLTAGE AS A FUNCTION OF TEMPERATURE



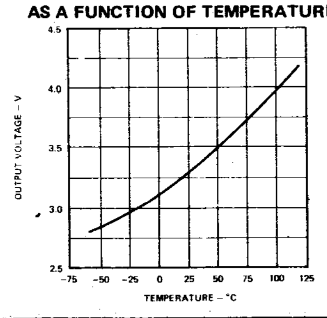
REGULATOR DROPOUT VOLTAGE



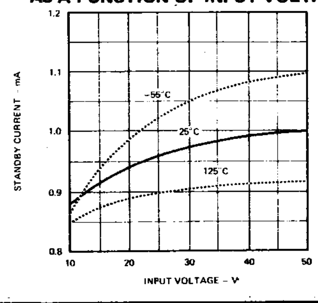
SUPPLY VOLTAGE REJECTION AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



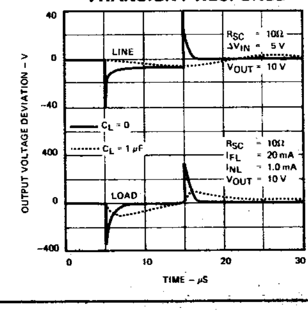
MINIMUM OUTPUT VOLTAGE AS A FUNCTION OF TEMPERATURE



STANDBY CURRENT DRAIN AS A FUNCTION OF INPUT VOLTAGE

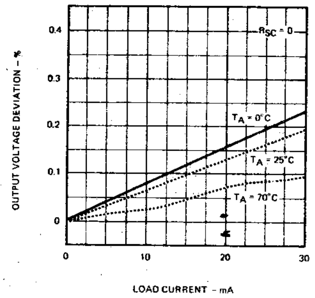


TRANSIENT RESPONSE

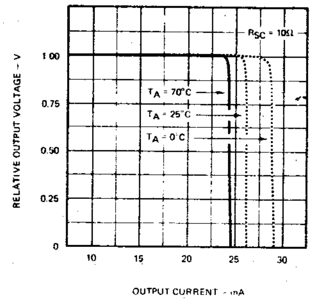


TYPICAL PERFORMANCE CURVES FOR μA376

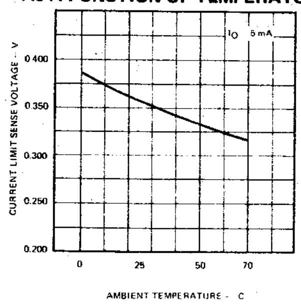
LOAD REGULATION



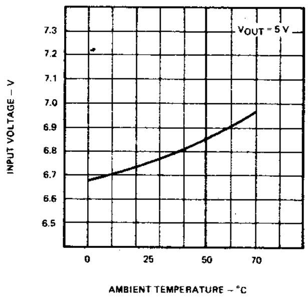
CURRENT LIMITING CHARACTERISTICS



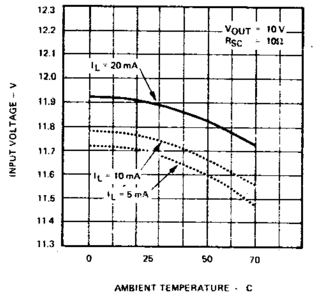
CURRENT LIMIT SENSE VOLTAGE AS A FUNCTION OF TEMPERATURE



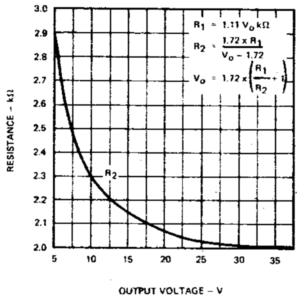
MINIMUM INPUT VOLTAGE AS A FUNCTION OF TEMPERATURE



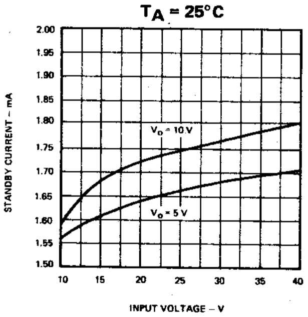
REGULATOR DROPOUT VOLTAGE



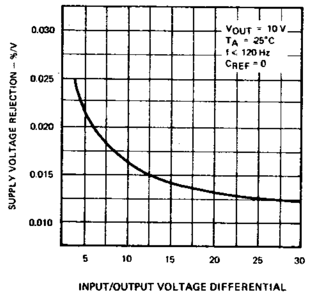
OPTIMUM DIVIDER RESISTANCE



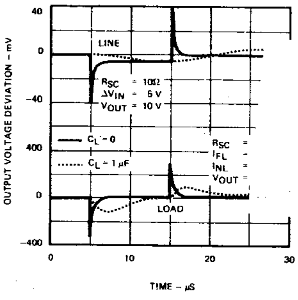
STANDBY CURRENT DRAIN AS A FUNCTION OF INPUT VOLTAGE T_A = 25°C



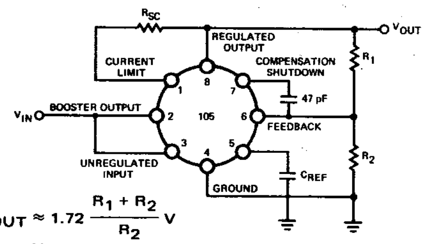
SUPPLY VOLTAGE REJECTION AS A FUNCTION OF INPUT/OUTPUT VOLTAGE DIFFERENTIAL



TRANSIENT RESPONSE



BASIC POSITIVE REGULATOR WITH CURRENT LIMITING

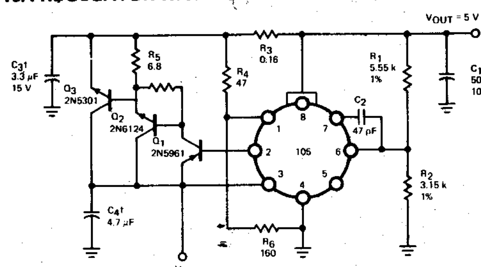


$$V_{OUT} \approx 1.72 \frac{R_1 + R_2}{R_2} \text{ V}$$

$$I_{SC} \approx \frac{V_{SENSE}}{R_{SC}} \text{ mA}$$

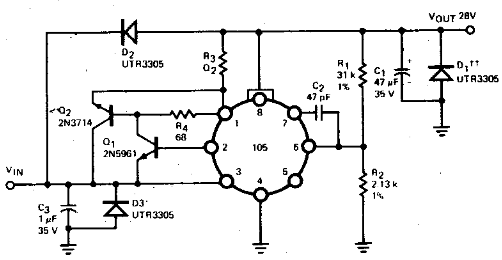
TYPICAL APPLICATIONS

10A REGULATOR WITH FOLDBACK CURRENT LIMITING



† Solid tantalum
* Electrolytic

1.0A REGULATOR WITH PROTECTIVE DIODES

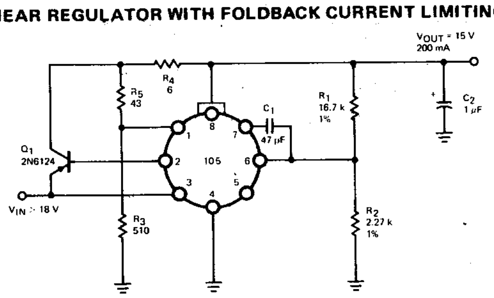


* Protects against input voltage reversal

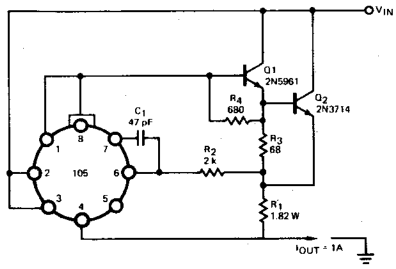
†† Protects against output voltage reversal

† Protects against shorted input or inductive loads on unregulated supply

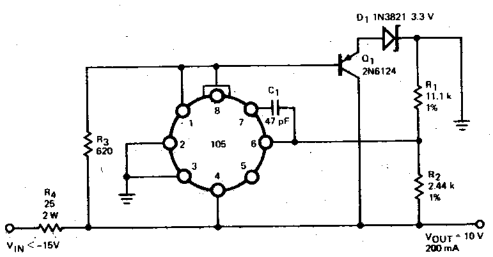
LINEAR REGULATOR WITH FOLDBACK CURRENT LIMITING



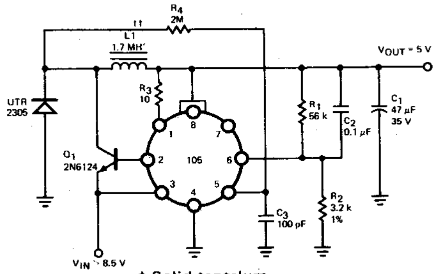
CURRENT REGULATOR



SHUNT REGULATOR



SWITCHING REGULATOR



† Solid tantalum

†† 125 turns #22 on Arnold Engineering A262123-2 molybdenum permalloy core.

μA104 • μA304

NEGATIVE VOLTAGE REGULATORS

FAIRCHILD LINEAR INTEGRATED CIRCUITS

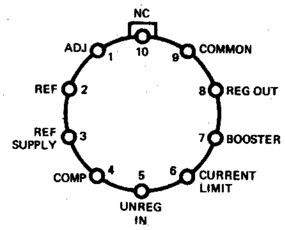
GENERAL DESCRIPTION – The 104 family of Precision Negative Voltage Regulators is constructed using the Fairchild Planar* epitaxial process. This device can be programmed by a single external resistor to supply any voltage from 0 V to 30 V from a single unregulated supply. When used with a separate floating bias supply, the 104/304 can provide 0.01% regulation with the output voltage limited only by the breakdown of external pass transistors. The 104 and 304 provide complementary operation with the 105 positive regulator family. Although primarily designed as a linear series regulator, the 104 family can be used as a current regulator, switching regulator, or in control applications. Without external pass elements, the device can supply currents up to 25 mA; with external pass transistors, the output current is limited only by the capacity of the pass transistors. External resistors establish the output voltage and either constant or fold-back current limiting.

- **1 mV REGULATION WITH FULL LOAD**
- **0.01%/V LINE REGULATION**
- **0.2 mV/V RIPPLE REJECTION**
- **0.3% TEMPERATURE STABILITY OVER FULL TEMPERATURE RANGE**

ABSOLUTE MAXIMUM RATINGS

Input Voltage	
μA104	50 V
μA304	40 V
Input/Output Voltage Differential	
μA104	50 V
μA304	40 V
Power Dissipation (Note 1)	500 mW
Operating Temperature Range	
Military grade (μA104)	−55°C to +125°C
Commercial grade (μA304)	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 s)	300°C

CONNECTION DIAGRAM
10-LEAD METAL CAN
(TOP VIEW)

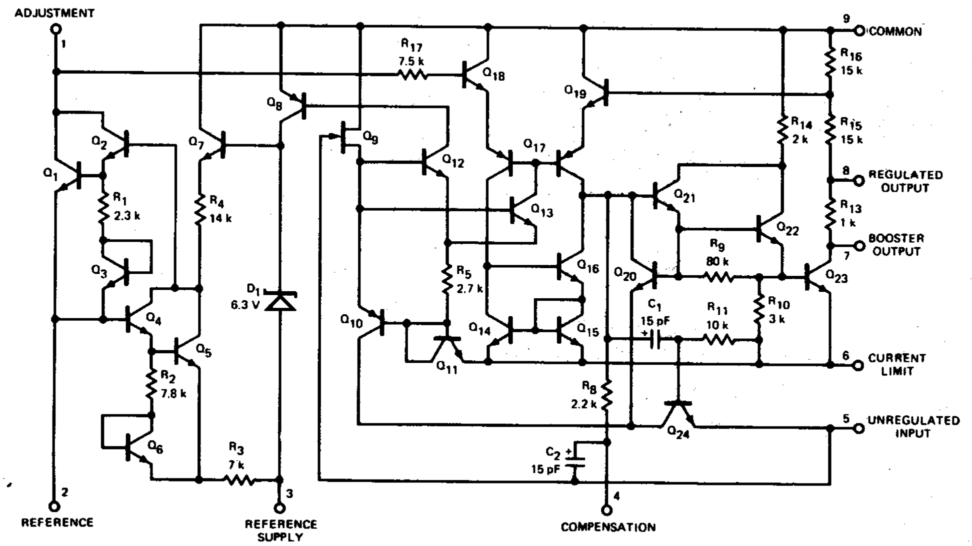


Note: Pin 5 connected to case.

ORDER INFORMATION

TYPE	PART NO.
μA104	μA104HM
μA304	μA304HC

EQUIVALENT CIRCUIT



Notes on following pages.

*Planar is a patented Fairchild process.

μA104

ELECTRICAL CHARACTERISTICS: $V_{IN} = -40$ V to -8.0 V, $T_A = 0°C$ to $70°C$, unless otherwise specified, Note 2

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			−50		−8.0	V
Output Voltage Range			−40		−0.015	V
Output/Input Voltage Differential (Note 3)	$I_L = 20$ mA		2.0		50	V
	$I_L = 5$ mA		0.5		50	V
Load Regulation (Note 4)	$0 \leq I_L \leq 20$ mA, $R_{SC} = 15\ \Omega$			1.0	5.0	mV
Line Regulation (Note 5)	$V_O \leq -5$ V, $\Delta V_{IN} = 0.1\ V_{IN}$			0.056	0.1	%
Ripple Rejection	C2 = 10 μF,	$V_{IN} \geq -15$ V		0.2	0.5	mV/V
	f = 120 Hz,	$-7\ V \geq V_{IN} \geq -15$ V		0.5	1.0	mV/V
Output Voltage Scale Factor $V_O/R2$	R1 = 2.4 kΩ		1.8	2.0	2.2	V/kΩ
Temperature Stability	$V_O \leq -1$ V, $-55°C \leq T_A \leq 125°C$			0.3	1.0	%
Output Noise Voltage	10 Hz ≤ f ≤ 10 kHz,	C2 = 0		0.007		%
	$V_O \leq -5$ V,	C2 = 10 μF		15		μV
Standby Current Drain	$I_L = 5$ mA	$V_O = 0$		1.7	2.5	mA
		$V_O = -40$ V		3.6	5.0	mA
Long Term Stability	$V_O \leq -1$ V			0.1	1.0	%

μA304

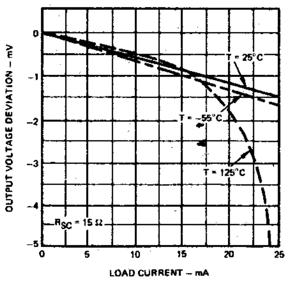
ELECTRICAL CHARACTERISTICS: $V_{IN} = -50$ V to -8.0 V, $T_A = -55°C$ to $125°C$, unless otherwise specified, Note 2

CHARACTERISTICS	CONDITIONS		MIN	TYP	MAX	UNITS
Input Voltage Range			−40		−8.0	V
Output Voltage Range			−30		−0.035	V
Output/Input Voltage Differential (Note 3)	$I_L = 20$ mA		2.0		40	V
	$I_L = 5$ mA		0.5		40	V
Load Regulation (Note 4)	$0 \leq I_L \leq 20$ mA, $R_{SC} = 15\ \Omega$			1.0	5.0	mV
Line Regulation (Note 5)	$V_O \leq -5$ V, $\Delta V_{IN} = 0.1\ V_{IN}$			0.056	0.1	%
Ripple Rejection	C2 = 10 μF,	$V_{IN} < -15$ V		0.2	0.5	mV/V
	f = 120 Hz,	$-7\ V \geq V_{IN} \geq -15$ V		0.5	1.0	mV/V
Output Voltage Scale Factor $V_O/R2$	R1 = 2.4 kΩ		1.8	2.0	2.2	V/kΩ
Temperature Stability	$V_O \leq -1$ V, $0°C \leq T_A \leq 70°C$			0.3	1.0	%
Output Noise Voltage	10 Hz ≤ f ≤ 10 kHz,	C2 = 0		0.007		%
	$V_O \leq -5$ V,	C2 = 10 μF		15		μV
Standby Current Drain	$I_L = 5$ mA	$V_O = 0$		1.7	2.5	mA
		$V_O = -30$ V		3.6	5.0	mA
Long Term Stability	$V_O \leq -1$ V			0.1	1.0	%

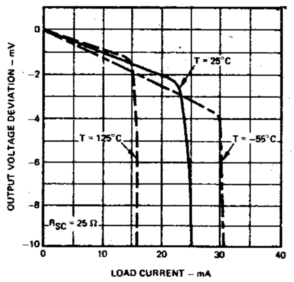
NOTES:
1. Rating applies to ambient temperatures up to 70°C. Above 70°C ambient derate linearly at 6.3 mW/°C.
2. The load and line regulation specifications are for constant junction temperature. Temperature drift effects must be taken into account separately when the unit is operating under conditions of high dissipation. See Basic Regulator Circuit.
3. When external booster transistors are used, the minimum output-input voltage differential is increased, in the worst case, by approximately 1 V.
4. The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.
5. With zero output, the dc line regulation is determined from the ripple rejection. Hence, with output voltages between 0 V and −5 V, a dc output variation, determined from the ripple rejection, must be added to find the worst-case line regulation.

TYPICAL PERFORMANCE CURVES FOR μA104

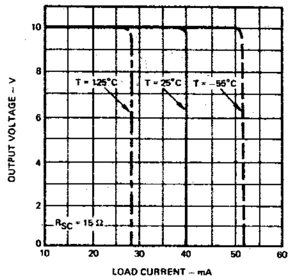
LOAD REGULATION



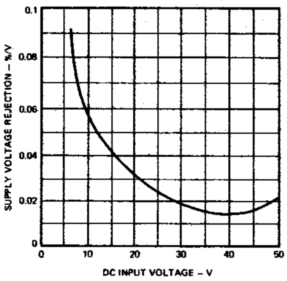
LOAD REGULATION



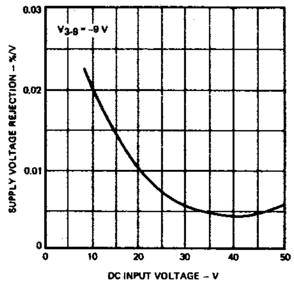
CURRENT LIMITING



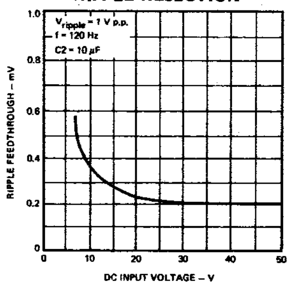
SUPPLY VOLTAGE REJECTION AS A FUNCTION OF DC INPUT VOLTAGE



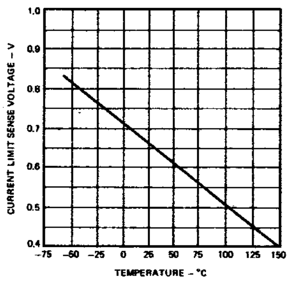
SUPPLY VOLTAGE REJECTION WITH PREREGULATED REFERENCE SUPPLY



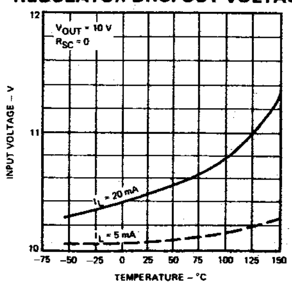
RIPPLE REJECTION



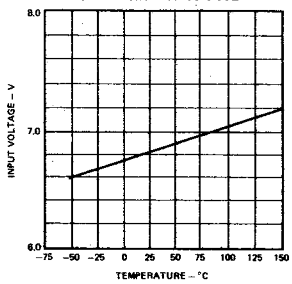
CURRENT LIMIT SENSE VOLTAGE AS A FUNCTION OF TEMPERATURE



REGULATOR DROPOUT VOLTAGE

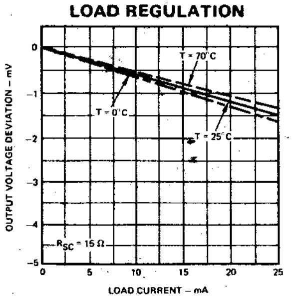


MINIMUM INPUT VOLTAGE AS A FUNCTION OF TEMPERATURE

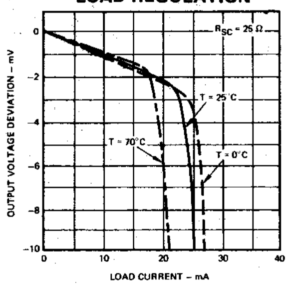


TYPICAL PERFORMANCE CURVES FOR μA304

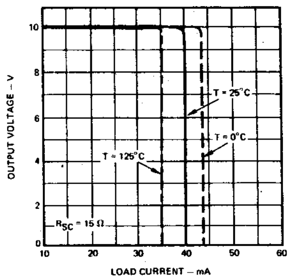
LOAD REGULATION



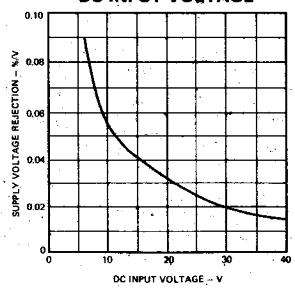
LOAD REGULATION



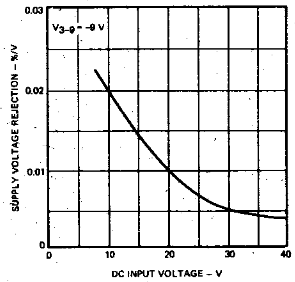
CURRENT LIMITING



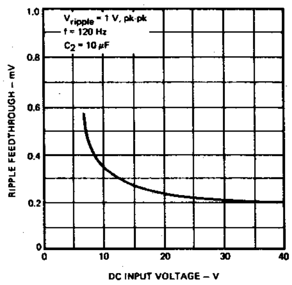
SUPPLY VOLTAGE REJECTION AS A FUNCTION OF DC INPUT VOLTAGE



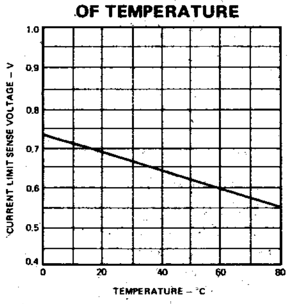
SUPPLY VOLTAGE REJECTION WITH PREREGULATED REFERENCE SUPPLY



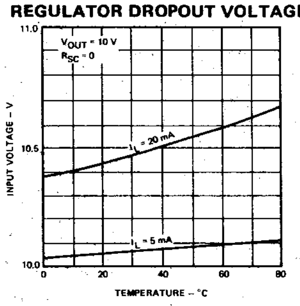
RIPPLE REJECTION



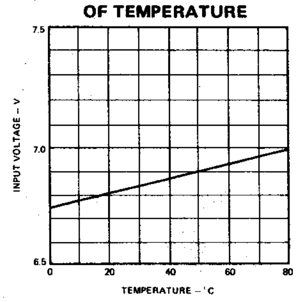
CURRENT LIMIT SENSE VOLTAGE AS A FUNCTION OF TEMPERATURE



REGULATOR DROPOUT VOLTAGE

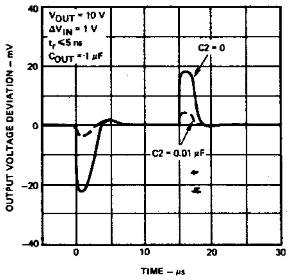


MINIMUM INPUT VOLTAGE AS A FUNCTION OF TEMPERATURE

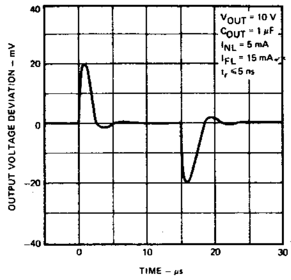


TYPICAL PERFORMANCE CURVES FOR μA104 AND μA304

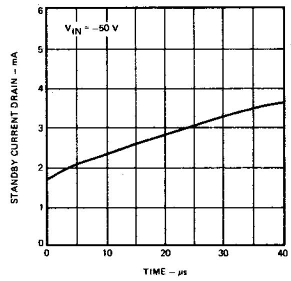
LINE TRANSIENT RESPONSE



LOAD TRANSIENT RESPONSE

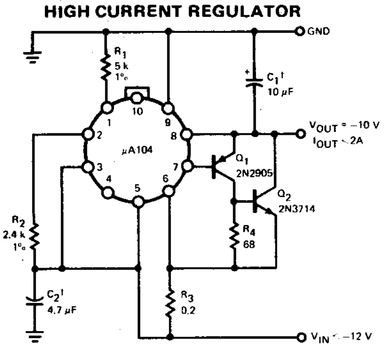


STANDBY CURRENT DRAIN AS A FUNCTION OF TIME



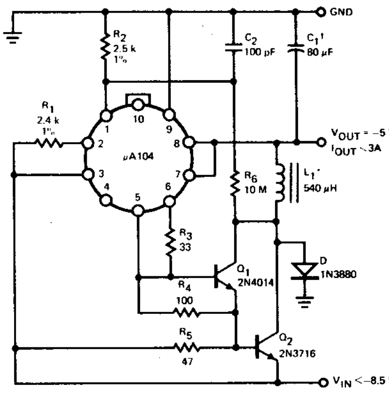
TYPICAL APPLICATIONS

HIGH CURRENT REGULATOR



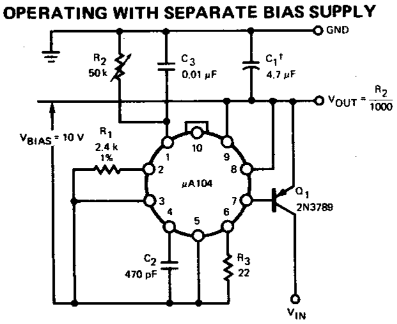
†Solid Tantalum

SWITCHING REGULATOR



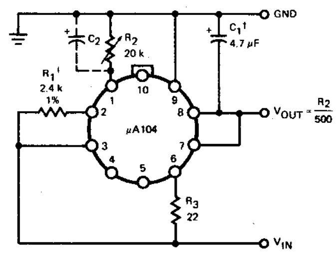
†Solid Tantalum
*60 Turns #20 on Arnold Engineering A930157-2 Molybdenum Permalloy Core.

OPERATING WITH SEPARATE BIAS SUPPLY



†Solid Tantalum

BASIC REGULATOR CIRCUIT



†Solid Tantalum
‡Trim R1 for exact scale factor

NOTE:

A 0.01 μF capacitor may be required across the input if long leads are used from the unregulated power source. Line transient response, noise and ripple rejection can be improved by shunting R2 with a 10 μF capacitor C2.

μA78S40

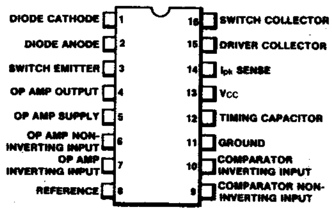
UNIVERSAL SWITCHING REGULATOR SUBSYSTEM

FAIRCHILD LINEAR INTEGRATED CIRCUITS

GENERAL DESCRIPTION — The μA78S40 is a Monolithic Regulator Subsystem consisting of all the active building blocks necessary for switching regulator systems. The device consists of a temperature-compensated voltage reference, a duty-cycle controllable oscillator with an active current limit circuit, an error amplifier, high-current, high-voltage output switch, a power diode and an uncommitted operational amplifier. The device can drive external npn or pnp transistors when currents in excess of 1.5 A or voltages in excess of 40 V are required. The device can be used for step down, step up or inverting switching regulators as well as for series pass regulators. It features wide supply voltage range, low standby power dissipation, high efficiency and low drift. It is useful for any stand-alone, low part-count switching system and works extremely well in battery operated systems.

- **STEP UP, STEP DOWN OR INVERTING SWITCHING REGULATORS**
- **OUTPUT ADJUSTABLE FROM 1.3 to 40 V**
- **OUTPUT CURRENTS TO 1.5 A WITHOUT EXTERNAL TRANSISTORS**
- **OPERATION FROM 2.5 TO 40 V INPUT**
- **LOW STANDBY CURRENT DRAIN**
- **80 dB LINE AND LOAD REGULATION**
- **HIGH GAIN, HIGH CURRENT, INDEPENDENT OP AMP**

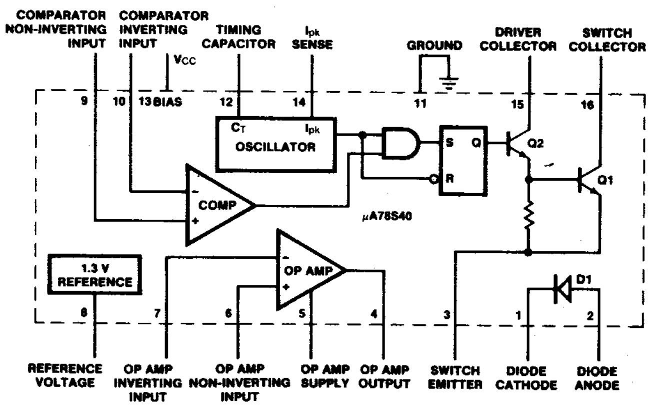
CONNECTION DIAGRAM
16-PIN DIP
(TOP VIEW)



ORDER INFORMATION

TYPE	PART NO.
μA78S40	μA78S40DM
μA78S40	μA78S40DC
μA78S40	μA78S40PC

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Input voltage from V^+ to V^-	40 V
Input voltage from V^+ op amp to V^-	40 V
Common mode input range (Error Amplifier and Op Amp)	-0.3 to V +
Differential input voltage (Note 1)	±30 V
Output Short Circuit Duration (Op Amp)	continuous
Current from V_{REF}	10 mA
Voltage from Switch Collectors to GND	40 V
Voltage from Switch Emitters to GND	40 V
Voltage from Switch Collectors to Emitter	40 V
Voltage from Power Diode to GND	40 V
Reverse Power Diode Voltage	40 V
Current through Power Switch	1.5 A
Current through Power Diode	1.5 A
Internal Power Dissipation (Note 2)	
Plastic DIP	1500 mW
Hermetic DIP	1000 mW
Storage Temperature Range	−65°C to + 150°C
Operating Temperature Range	
Military (μA78S40M)	−55°C to 125°C
Commercial (μA78S40C)	0°C to 70°C
Lead Temperature	
Hermetic DIP (Soldering, 60 s)	300°C
Plastic DIP (Soldering, 10 s)	260°C

NOTES:
1. For supply voltages less than 30 V, the absolute maximum voltage is equal to the supply voltage.
2. Ratings apply to 25°C. Above 25°C ambient, derate hermetic DIP at 8 mW/°C and plastic DIP at 14 mW/°C.

ELECTRICAL CHARACTERISTICS: V_{IN} = 5.0 V, $V_{Op\ Amp}$ = 5.0 V, T_A = 25°C unless otherwise specified.

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
GENERAL CHARACTERISTICS					
Supply Voltage		2.5		40	V
Supply Current (Op Amp Disconnected)	V_{IN} = 5.0 V		1.8	2.5	mA
	V_{IN} = 40 V		2.3	3.5	mA
Supply Current Op Amp	V_{IN} = 5.0 V		0.4	1.0	
	V_{IN} = 40 V		0.5	1.5	
REFERENCE SECTION					
Reference Voltage	I_{REF} = 1.0 mA	1.180	1.245	1.310	V
Reference Voltage Temperature Coefficient	I_{REF} = 1.0 mA		100		ppm/°C
Reference Voltage Line Regulation	V_{IN} = 3.0 V to V_{IN} = 40 V, I_{REF} = 1.0 mA		0.04	0.2	mV/V
Reference Voltage Load Regulation	I_{REF} = 1.0 mA to I_{REF} = 10 mA		0.2	0.2	mV/mA
OSCILLATOR SECTION					
Charging Current			25		μA
ON Time	C_T = 0.01 μF		200		μs
Discharge Current			225		μA
OFF Time	C_T = 0.01 μF		22		μs
Oscillator Voltage Swing			0.5		V
CURRENT LIMIT SECTION					
Current Limit Sense Voltage			330		mV
OUTPUT SWITCH SECTION					
Output Saturation Voltage 1	I_{SW} = 1.0 A		1.1	1.3	V
Output Saturation Voltage 2	I_{SW} = 1.0 A		0.45	0.7	V
Output Transistor h_{FE}	I_C = 1.0 A, V_{CE} = 5.0 V		70		
Output Leakage Current	V_{OUT} = 40 V		10		nA

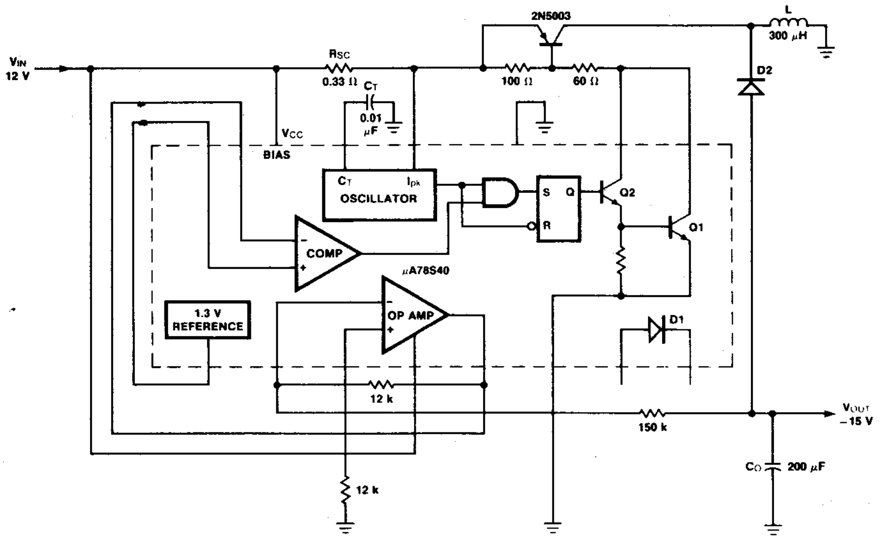
ELECTRICAL CHARACTERISTICS: V_{IN} = 5.0 V, $V_{Op\ Amp}$ = 5.0 V, T_A = 25°C unless otherwise specified.

CHARACTERISTICS	CONDITIONS	MIN	TYP	MAX	UNITS
POWER DIODE					
Forward Voltage Drop	I_D = 1.0 A		1.25	1.5	V
Diode Leakage Current	V_D = 40 V		10		nA
COMPARATOR					
Input Offset Voltage	$V_{CM} = V_{REF}$		1.5	10	mV
Input Bias Current	$V_{CM} = V_{REF}$		35	200	nA
Input Offset Current	$V_{CM} = V_{REF}$		5.0	75	nA
Common Mode Voltage Range		0		V+ -2	V
Power Supply Rejection Ratio	V_{IN} 3.0 V to 40 V	70	96		dB
OUTPUT OPERATIONAL AMPLIFIER					
Input Offset Voltage	V_{CM} = 2.5 V		4.0	10	mV
Input Bias Current	V_{CM} = 2.5 V		30	200	nA
Input Offset Current	V_{CM} = 2.5 V		5.0	75	nA
Voltage Gain +	R_L = 2.0 k to GND; V_O = 1.0 to 2.5 V	25 k	250 k		V/V
Voltage Gain -	R_L = 2.0 k to V+ Op Amp; V_O = 1.0 to 2.5 V	25 k	250 k		V/V
Common Mode Voltage Range		0		V+ -2	V
Common Mode Rejection Ratio	V_{CM} = 0 to 3.0 V	76	100		dB
Power Supply Rejection Ratio	V+ Op Amp = 3.0 to 40 V	76	100		dB
Output Source Current		100	150		mA
Output Sink Current		10	35		mA
Slew Rate			0.6		V/μs
Output Voltage LOW	I_L = -5.0 mA			1.0	V
Output Voltage HIGH	I_L = 50 mA	V+Op Amp -2.5 V			V

DESIGN FORMULAS

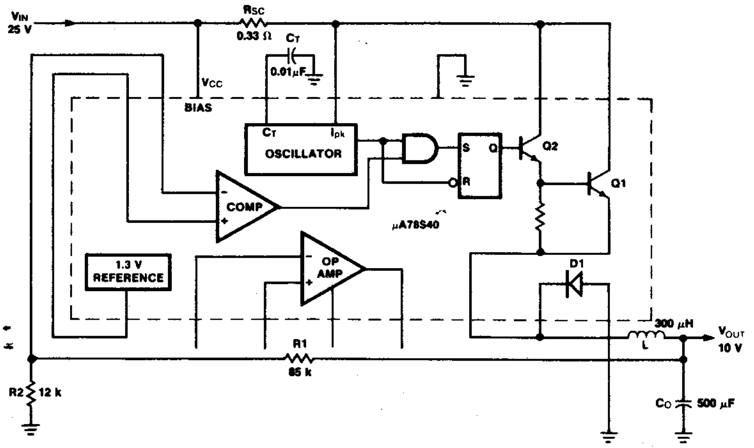
CHARACTERISTIC	STEP DOWN	STEP UP	INVERTING
I_{pk}	$2\ I_{OUT(max)}$	$2\ I_{OUT(max)} \bullet \dfrac{V_{OUT}+V_D-V_S}{V_{IN}-V_S}$	$2\ I_{OUT(max)} \bullet \dfrac{V_{IN}+\lvert V_{OUT}\rvert+V_D-V_S}{V_{IN}-V_S}$
R_{SC}*	$0.33\ V/I_{pk}$	$0.33\ V/I_{pk}$	$0.33\ V/I_{pk}$
$\dfrac{t_{on}}{t_{off}}$	$\dfrac{V_{OUT}+V_D}{V_{IN}-V_S-V_{OUT}}$	$\dfrac{V_{OUT}+V_D-V_{IN}}{V_{IN}-V_S}$	$\dfrac{\lvert V_{OUT}\rvert+V_D}{V_{IN}-V_S}$
L*	$\dfrac{V_{OUT}+V_D}{I_{pk}} \bullet t_{off}$	$\dfrac{V_{OUT}+V_D-V_{IN}}{I_{pk}} \bullet t_{off}$	$\dfrac{\lvert V_{OUT}\rvert+V_D}{I_{pk}} \bullet t_{off}$
t_{off}	$\dfrac{I_{pk} \cdot L}{V_{OUT}+V_D}$	$\dfrac{I_{pk} \cdot L}{V_{OUT}+V_D-V_{IN}}$	$\dfrac{I_{pk} \cdot L}{\lvert V_{OUT}\rvert+V_D}$
C_T*(μF)	$45 \times 10^{-5}\ t_{off}(\mu s)$	$45 \times 10^{-5}\ t_{off}(\mu s)$	$45 \times 10^{-5}\ t_{off}(\mu s)$
C_O*	$\dfrac{I_{pk} \cdot (t_{on}+t_{off})}{8\ V_{ripple}}$	$\dfrac{(I_{pk}-I_{OUT})^2 \cdot t_{off}}{2\ I_{pk} \cdot V_{ripple}}$	$\dfrac{(I_{pk}-I_{OUT})^2 \cdot t_{off}}{2\ I_{pk} \cdot V_{ripple}}$
Efficiency	$\dfrac{V_{IN}-V_S+V_D}{V_{IN}} \bullet \dfrac{V_{OUT}}{V_{OUT}+V_D}$	$\dfrac{V_{IN}-V_S}{V_{IN}} \bullet \dfrac{V_{OUT}}{V_{OUT}+V_D-V_S}$	$\dfrac{V_{IN}-V_S}{V_{IN}} \bullet \dfrac{\lvert V_{OUT}\rvert}{\lvert V_{OUT}\rvert+V_D}$
$I_{IN(avg)}$ (Max load condition)	$\dfrac{I_{pk}}{2} \bullet \dfrac{V_{OUT}+V_D}{V_{IN}-V_S+V_D}$	$\dfrac{I_{pk}}{2}$	$\dfrac{I_{pk}}{2} \bullet \dfrac{\lvert V_{OUT}\rvert+V_D}{V_{IN}+\lvert V_{OUT}\rvert+V_D-V_S}$

* Denotes Component Values



TYPICAL INVERSION OPERATIONAL PERFORMANCE
$T_A = 25°$

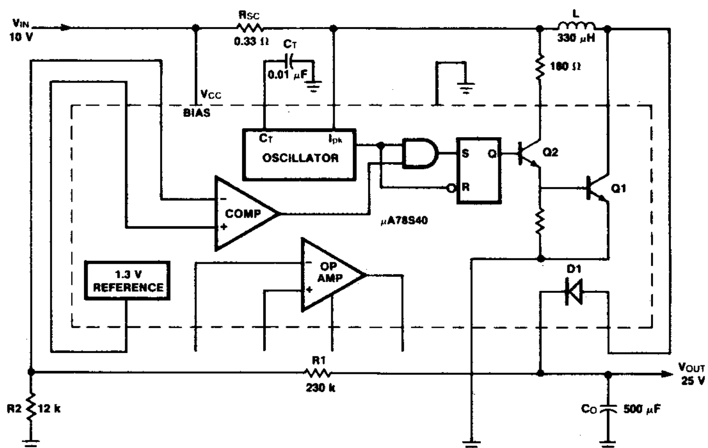
CHARACTERISTIC	CONDITIONS	TYPICAL VALUE
OUTPUT VOLTAGE	$I_{OUT} = 100$ mA	−15 V
LINE REGULATION	$8 \text{ V} \leq V_{IN} \leq 18 \text{ V}$	5.0 mV
LOAD REGULATION	$5 \text{ mA} \leq I_{OUT} \leq 150 \text{ mA}$	3.0 mV
MAX OUTPUT CURRENT	$V_{OUT} = 14.25$ V	160 mA
OUTPUT RIPPLE	$I_{OUT} = 100$ mA	20 mV
EFFICIENCY	$I_{OUT} = 100$ mA	70%
STANDBY CURRENT		2.3 mA



TYPICAL STEP-DOWN PERFORMANCE

TA = 25°

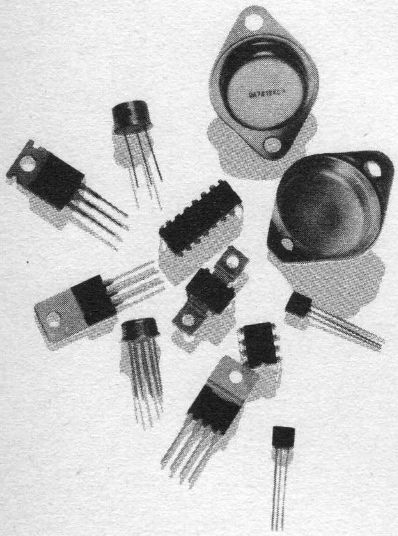
CHARACTERISTIC	CONDITION	TYPICAL VALUE
OUTPUT VOLTAGE	I_{OUT} = 200 mA	10 V
LINE REGULATION	$20 \le V_{IN} \le 30$ V	1.5 mV
LOAD REGULATION	5 mA $\le I_{OUT} \le$ 300 mA	3.0 mV
MAX OUTPUT CURRENT	V_{OUT} = 9.5 V	500 mA
OUTPUT RIPPLE	I_{OUT} = 200 mA	50 mV
EFFICIENCY	I_{OUT} = 200 mA	74%
STANDBY CURRENT		2.8 mA



TYPICAL STEP-UP OPERATIONAL PERFORMANCE

T_A = 25°C

CHARACTERISTIC	CONDITION	TYPICAL VALUE
OUTPUT VOLTAGE	I_{OUT} = 50 mA	25V
LINE REGULATION	$5V \le V_{IN} \le 15V$	4.0 mV
LOAD REGULATION	5 mA $\le I_{OUT} \le$ 100 mA	2.0 mA
MAX OUTPUT CURRENT	V_{OUT} = 23.75	160 mA
OUTPUT RIPPLE	I_{OUT} = 50 mA	30 mV
EFFICIENCY	I_{OUT} = 50 mA	79%
STANDBY CURRENT	I_{OUT} = 50 mA	2.6 mA



DEFINITIONS, ORDERING INFORMATION AND PACKAGE INFORMATION

DEFINITION OF TERMS

Average Temperature Coefficient of Output Voltage – The change in output voltage for a specified change in ambient temperature. ($\Delta V_{OUT}/\Delta T_A$) (mV/°C)

Dropout Voltage – The input-output voltage differential that causes the output voltage to decrease by 5% of its initial value. (V_{DO}) (V)

Feedback Sense Voltage – The voltage measured on the feedback terminal of the regulator, with respect to ground, when the device is operating in regulation. (V_{sense}) (V)

Input Current – The current flowing into the input with a specified voltage applied to the input. (I_{IN})

Input-Output Voltage Differential – The voltage range between the unregulated input voltage and the regulated output voltage in which a regulator operates within specifications.

Input Voltage – The voltage potential between the input terminal and the device ground reference. (V_{IN}) (V)

Line Regulation – The change in output voltage for a specified change in input voltage. ($\Delta V_{OUT}/\Delta V_{IN}$) (mV or %)

Load Regulation – The change in output voltage for a specified change in load current. ($\Delta V_{OUT}/\Delta I_L$) (mV or %)

Output Noise Voltage – The rms value of the noise voltage measured at the output with constant load current and no input ripple. (e_{no}) (μV)

Output Short Circuit Current – The output current obtainable with the output shorted to ground or to either supply. (I_{SC}) (mA)

Output Resistance – The small signal ac resistance seen looking into the output with no feedback applied and the output dc voltage near zero.

Quiescent Current – That part of a regulator input current that is not delivered to the load. (I_Q) (mA)

Output Voltage – The voltage present at the output terminal referred to ground. (V_{OUT}) (V)

Output Voltage Range – The range of output voltages over which the specifications apply. (ΔV_{OUT}) (V)

Peak Output Current – The maximum current delivered by the device for a period too short for thermal protection to be activated. ($I_{OUT(Pk)}$) (A)

Power Dissipation (Max) – The maximum power that can be dissipated in the device with a given heat sink beyond which the device may not perform to specification. ($P_{D(MAX)}$) (mW)

Reference (Control) Current – The current drawn or supplied by the reference (control) terminal. (I_{REF}) (μA)

Reference Voltage – The output of the reference amplifier measured with respect to the negative supply. (V_{REF}) (V)

Ripple Rejection – The ratio of the peak-to-peak input ripple voltage to the peask-to-peak output ripple voltage. (dB)

Short-Circuit Current Limit – The output current of a regulator with the output shorted to common (ground). (I_{SC}) (mA)

Standby Current Drain – The supply current drawn by a regulator with no output load and no reference voltage load (see Quiescent Current).

Temperature Stability – The percentage change in output voltage over a specified ambient temperature range. ($\Delta V_{OUT}/\Delta T_A$) (V/°C)

ORDERING INFORMATION

A standard voltage regulator order code includes three basic units of information, the device type, the package type, and the temperature range. Simply combining these three elements specifies exactly what product, package, and temperature range is desired.

The device type is available on the first page of each product data sheet. The package type is specified by a package code from the table in this section. The specific package outlines available for each product are listed in the columns under the type of package and the package ordering code. The temperature ranges available are listed on each product data sheet. There are four grades of commercial or industrial or consumer temperature ranges used, depending upon the product, specified in the ordering code by a C. There are two grades of military temperature ranges used, depending upon the product, specified in the ordering code by an M. An example of a complete ordering code is shown below.

μA723	D	C
Device Type	Package Code	Temperature Range

The device type specifies a 723 precision voltage regulator, the D specifies a ceramic DIP according to a 6A outline (from the following table), and the C specifies a commercial temperature range of 0°C to +70°C (from the data sheet).

All packages available for voltage regulators are specified by one of the following codes. The specific package outline can be determined by checking the table overleaf. Details of each package outline are provided following this table.

Package Code	Basic Package Style
D	Ceramic Hermetic Dual In-Line
P	Molded Plastic Dual In-Line
K	Metal Power (TO-3 Outline)
H	Metal Can (TO-39, TO-78, TO-99, TO-100 Outlines)
W	TO-92 Outline
U	Molded Plastic Power (TO-220 Outline)
U1	Power Watt (similar to TO-202)
T	Mini Dual In-Line
T2	Power Mini Dual In-Line

Temperature ranges available are listed below and specified by a suffix C for commercial ranges and a suffix M for military ranges. The specific range within each category is specified on each product data sheet.

Commercial/Industrial/Consumer (Suffix C)	Military (Suffix M)
0°C to +70°C	−55°C to +125°C

Additional processing to Fairchild Unique 38510 specifications is available and indicated by a QB or QC suffix on the order code, depending upon the processing required. Screening to the Fairchild Matrix VI program is indicated by a QM or QR suffix on the order code. For detailed information, consult the OEM price list.

PACKAGE OUTLINE GUIDE

PACKAGE TYPE	CERAMIC DIP	PLASTIC DIP	TO-3	TO-39/78/ 99/100	TO-92	TO-220	POWER WATT	MINI DIP	POWER MINI DIP
CODE	(D)	(P)	(K)	(H)	(W)	(U)	(U1)	(T)	(T2)
μA104				5F**					
μA105				5B**				9T	
μA109			HJ**						
μA209			HJ**						
μA304				5F*					
μA305				5B*				9T	
μA305A				5B*				9T	
μA309			HJ*						
μA376								9T*	
μA723	6A	9A*		5F					
μA7805			HJ			GH*			
μA7806			HJ			GH*			
μA7808			HJ			GH*			
μA7812			HJ			GH*			
μA7815			HJ			GH*			
μA7818			HJ			GH*			
μA7824			HJ			GH*			
μA7885			HJ			GH*			
μA78C08							8Y†		
μA78C10							8Y†		
μA78C12							8Y†		
μA78C15							8Y†		
μA78C17							8Y†		
μA78C18							8Y†		
μA78C20							8Y†		
μA78C22							8Y†		
μA78C24							8Y†		
μA78C82							8Y†		
μA78CB			HJ*			GH*			
μA78G			GK				8Z*		
μA78H05			HJ						
μA78H05A			AW						
μA78H12			HJ*						
μA78H15			HJ*						
μA78HG			HJ						

*Commercial Grade Only   **Military Grade Only   †Commercial Grade Only—U1 and U2 Configuration

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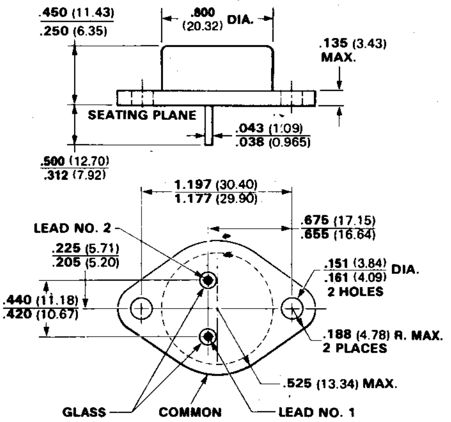
PACKAGE OUTLINE GUIDE

PACKAGE TYPE	CERAMIC DIP	PLASTIC DIP	TO-3	TO-39/78/ 99/100	TO-92	TO-220	POWER WATT	MINI DIP	POWER MINI DIP
CODE	(D)	(P)	(K)	(H)	(W)	(U)	(U1)	(T)	(T2)
μA78L05				HC*	EI*				
μA78L09				HC*	EI*				
μA78L12				HC*	EI*				
μA78L15				HC*	EI*				
μA78L18				HC*	EI*				
μA78L24				HC*	EI*				
μA78L26				HC*	EI*				
μA78L62				HC*	EI*				
μA78L82				HC*	EI*				
μA78M05				BF		GH*	8Y†		
μA78M06				BF		GH*	8Y†		
μA78M08				BF		GH*	8Y†		
μA78M12				BF		GH*	8Y†		
μA78M15				BF		GH*	8Y†		
μA78M20				BF		GH*	8Y†		
μA78M24				BF		GH*	8Y†		
μA78MG				5K			8Z*		9V*
μA78P05			AW*						
μA78S40	6B	9B*							
μA7905			HJ			GH*			
μA7906			HJ			GH*			
μA7908			HJ			GH*			
μA7912			HJ			GH*			
μA7915			HJ			GH*			
μA7918			HJ			GH*			
μA7924			HJ			GH*			
μA7952			HJ			GH*			
μA79G			GK				8Z*		
μA79HG			GK*						
μA79M05				BF		GH*			
μA79M06				BF		GH*			
μA79M08				BF		GH*			
μA79M12				BF		GH*			
μA79M15				BF		GH*			
μA79M20				BF		GH*			
μA79M24				BF		GH*			
μA79MG				5K			8Z*		9V*
SH123			AW**HJ**						
SH223			AW**HJ**						
SH323			AW*HJ*						
SH1605			NEED						
SH1705			GK*						

*Commercial Grade Only **Military Grade Only †Commercial Grade Only—U1 and U2 Configuration

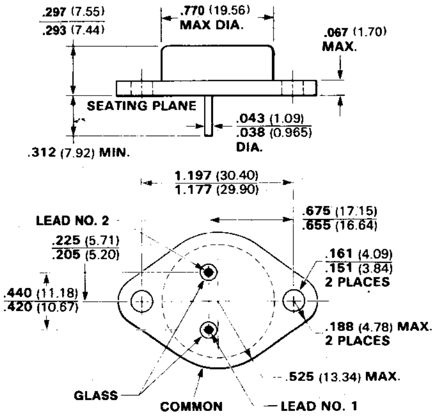
PACKAGE OUTLINES

In Accordance with JEDEC (TO-3) Outline — AW



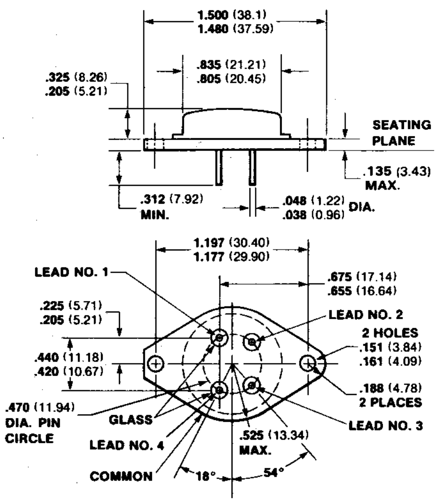
NOTES:
Leads 1 and 2 electrically-isolated from case
Case is third electrical connection
Steel base
Package weight is 12.27 grams

In Accordance with JEDEC (TO-3) Outline — HJ



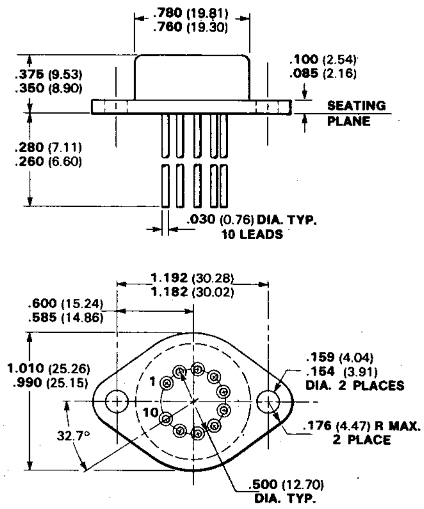
NOTES:
Leads are nickel plated solder-dipped Alloy 52
Leads 1 and 2 electrically-isolated from case
Case is third electrical connection
Steel package with copper slug, pins are soldered in package weight is 9.2 grams

In Accordance with JEDEC (TO-3) Outline — GK



NOTES:
Leads are gold-plated or solder dipped Alloy 52
All leads electrically-isolated from case
Package weight is 7.4 grams

Similar to* JEDEC (TO-3) Outline — 5H



NOTES:
Package material is nickel-plated CRS 1010
Lead material is Alloy 52
Glass material is Corning 9010
Lead, post and base are gold-plated

*Except 10 Leads

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

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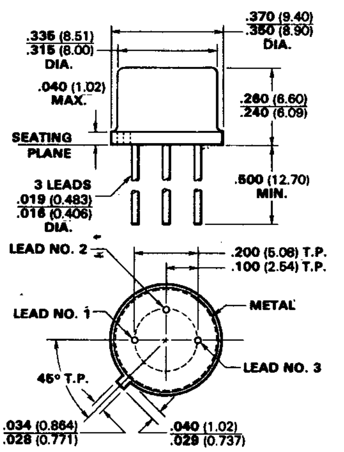
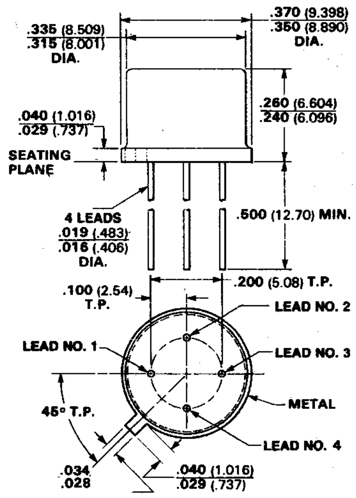
PACKAGE OUTLINES

In Accordance with JEDEC (TO-39) Outline — BF



NOTES:
Leads are gold-plated Kovar
Two leads through, lead 3 connected to case
Package weight is 1.23 grams

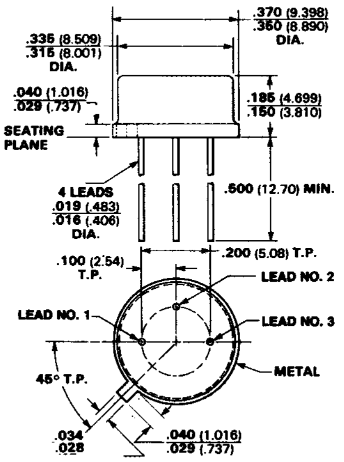
Similar to* JEDEC (TO-39) Outline — 5K



NOTES:
Leads are gold-plated Kovar
Three leads through, lead 3 connected to case
Package weight is 1.23 grams

*Except 4 leads

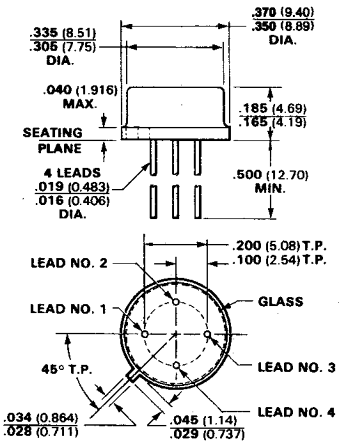
Similar to* JEDEC (TO-39) Outline — HC



NOTES:
Leads are gold-plated Kovar
Two leads through, lead 3 connected to case
Package weight is 1.23 grams

*Dimensions same as JEDEC TO-39 except for can height

In Accordance with JEDEC (TO-78) Outline — HA

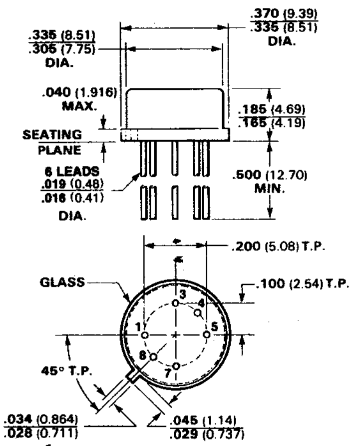


NOTES:
Leads are solder-dipped to seating plane
Four leads through
Package weight is 1.08 grams

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

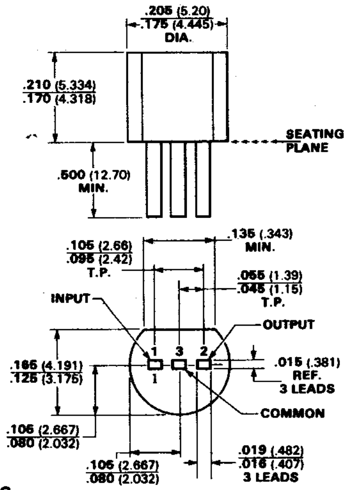
PACKAGE OUTLINES

5C — In Accordance with JEDEC (TO-78) Outline



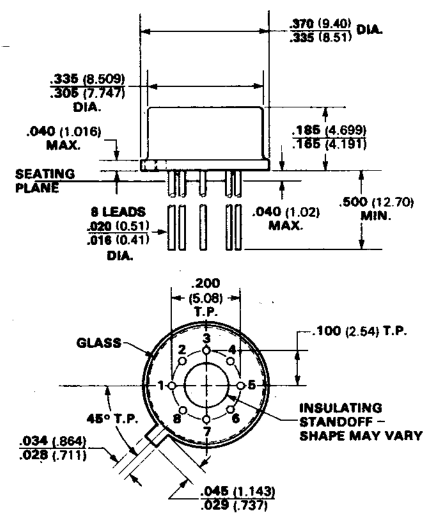
NOTES:
Leads are solder dipped to within .040 of seating plane
Six leads through
Leads 2 and 6 are omitted
Package weight is 0.95 gram

EI — In Accordance with JEDEC (TO-92) Outline



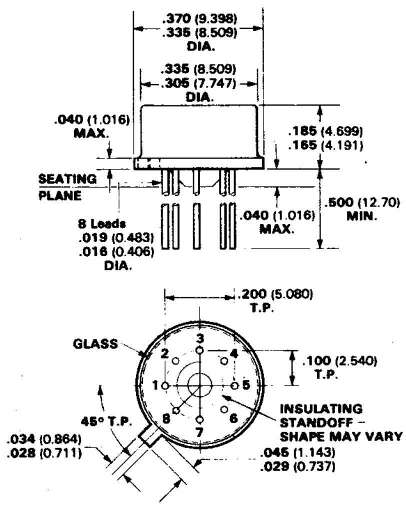
NOTES:
Leads are tin plated copper
Package material is transfer molded thermosetting plastic
ECB configuration
Package weight is 0.25 gram

5S — In Accordance with JEDEC (TO-99) Outline



NOTES:
Leads are solder-dipped to seating plane
Seven leads through, lead 4 connected to case
Package weight is 1.22 grams

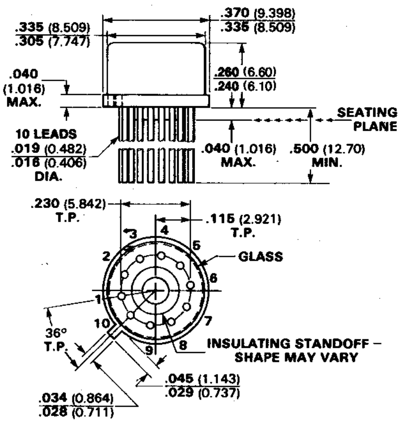
5B — In Accordance with JEDEC (TO-99) Outline



NOTES:
Leads are gold-plated Kovar
Seven leads through, lead 4 connected to case
Package weight is 1.22 grams

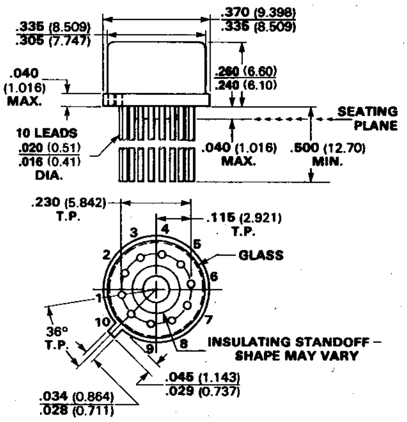
Dimensions nominal, in inches. Parentheses indicate metric dimensions.

In Accordance with JEDEC (TO-100) Outline 5F



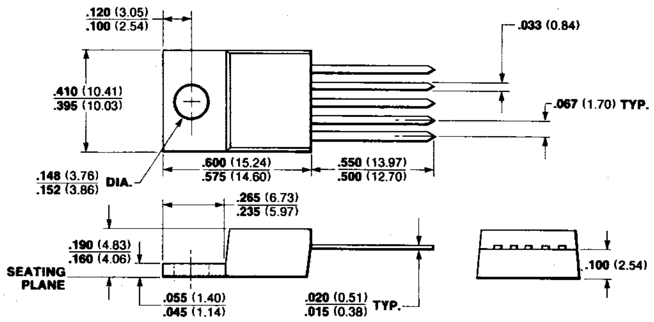
NOTES:
Leads are gold-plated Kovar
Nine leads through, lead 5 connected to case
Package weight is 1.32 grams

In Accordance with JEDEC (TO-100) Outline 5N



NOTES:
Leads are solder-dipped to the seating plane
Nine leads through, lead 5 connected to case
Package weight is 1.32 grams

TO-220 (5 Leads) Pentawatt GO

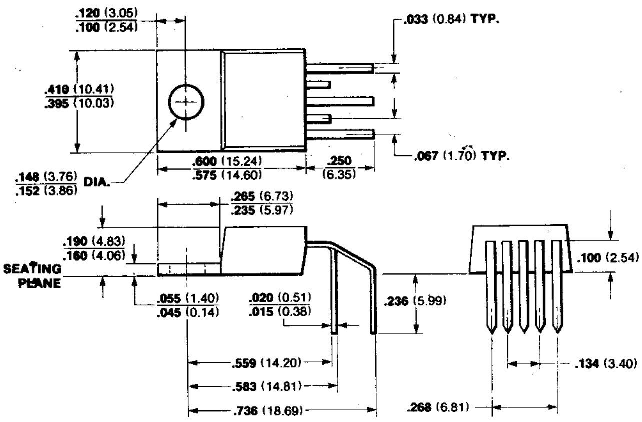


NOTES:
Mounting tab electrically-connected to center lead
Package is molded over a copper base material with solderable leads
Package weight is 2.1 grams

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

TO-220 (5 Leads) Pentawatt

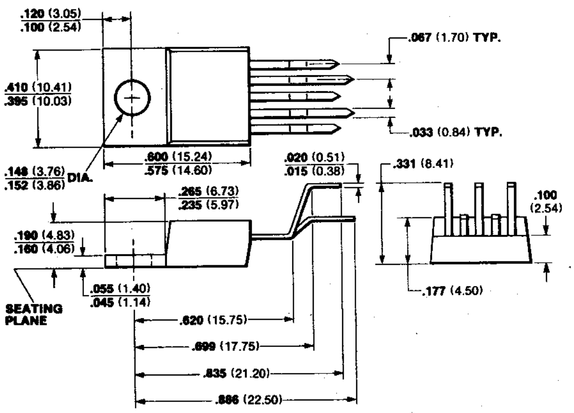
GO (H)



Mounting tab electrically-connected to center lead
Package is molded over a copper base material
with solderable leads
Package weight is 2.1 grams

TO-220 (5 Leads) Pentawatt

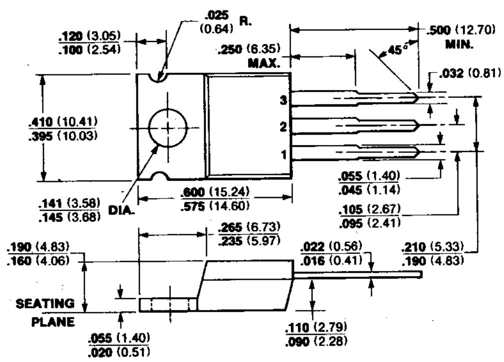
GO (V)



Mounting tab electrically-connected to center lead
Package is molded over a copper base material
with solderable leads
Package weight is 2.1 grams

In Accordance with JEDEC (TO-220) Outline* Plastic Power Package

GH (−3)



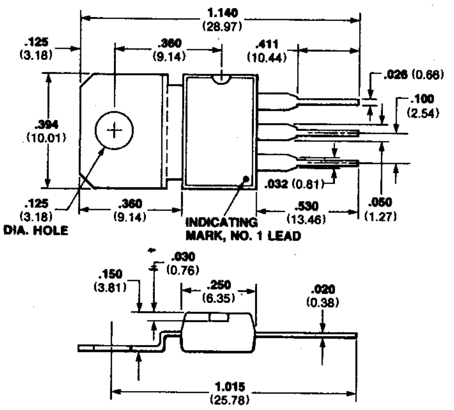
NOTES:
Package is epoxy plastic with plated copper tab
and leads
Center lead is electrical contact with the
mounting tab
Package weight is 2.1 grams

*Mechanically interchangeable with TO-66

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

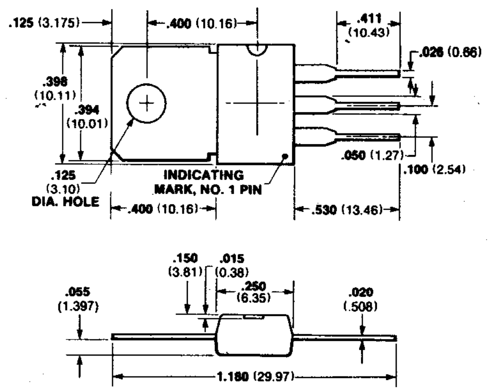
PACKAGE OUTLINES

3-Lead Single Side Power Plastic Mini DIP 8Y (U–1)



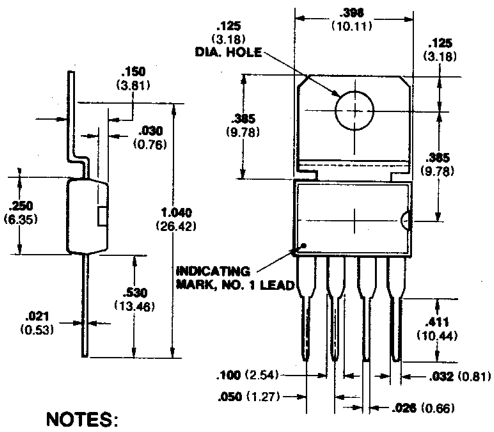
NOTES:
Package is plastic with tin-plated copper leads
Package weight is 0.6 gram
Center lead is electrical contact with mounting tab
This package is intended to be mounted with the tab flush with the top of the PC board or heat sink. A No. 4 screw may be used to secure the package. Thermal compound is recommended

3-Lead Single Side Power Plastic Mini DIP 8Y (U–2)



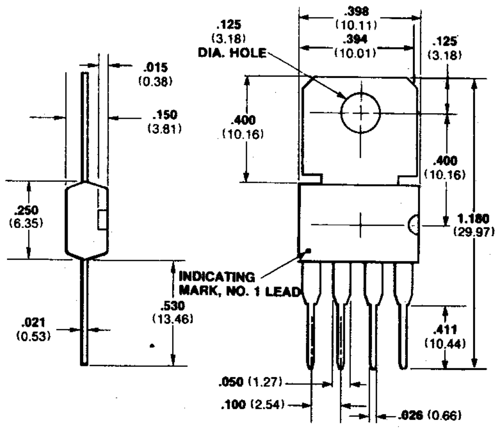
NOTES:
Package is plastic with tin-plated copper leads
Package weight is 0.6 gram
Center lead is electrical contact with mounting tab
For detailed package configuration, refer to FSB-90717

4-Lead Single Side Power Plastic Mini DIP 8Z (U–1)



NOTES:
Package is plastic with tin-plated copper leads
Board-drilling dimensions should equal your practice for .033(0.84) inch diameter leads
Package weight is 0.6 gram
Tab is electrically insulated from leads
This package is intended to be mounted with the tab flush with the top of the PC board or heat sink. A No. 4 screw may be used to secure the package. Thermal compound is recommended

4-Lead Single Side Power Plastic Mini DIP 8Z (U–2)

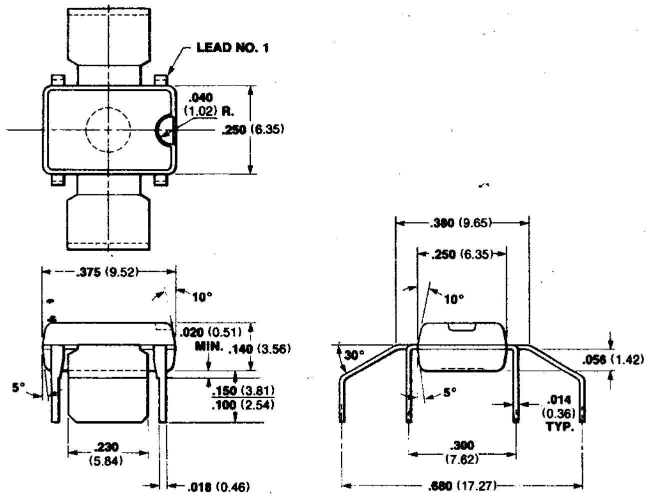


NOTES:
Package is plastic with tin-plated copper leads
Board-drilling dimensions should equal your practice for .033 (0.84) inch diameter lead
Package weight is 0.6 gram
Tab is electrically insulated from leads

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

4-Lead Power Mini DIP

9V (T–1)

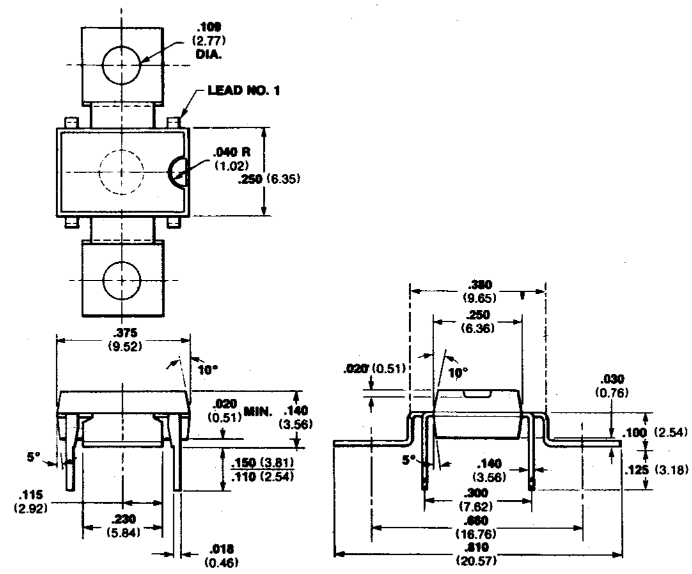


NOTES:
Package is plastic with tin-plated copper leads
For detailed package configuration refer to FSD-90669
Package weight is 0.6 gram

T-1 package can be soldered to the PC board through .0230" x .020" (0.584 x 0.51) slots. Double or single-sided boards may be used.

4-Lead Power Mini DIP

9V (T–2)



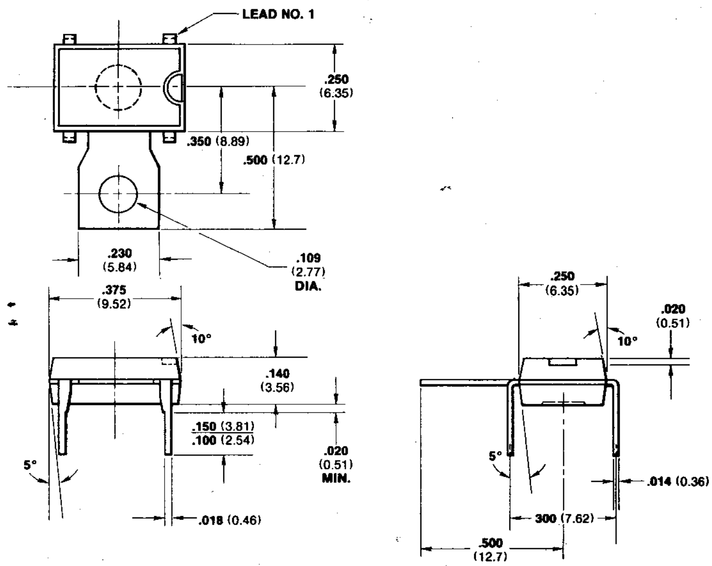
NOTES:
Package is plastic with tin-plated copper leads and wings
For detailed package configuration refer to FSD-90670
Package weight is 0.6 gram

T-2 package is intended to be mounted with the tabs flush with the top of the PC board. Either No. 2-56 screws or No. 2 rivets may be used to secure the package. Single or double-sided PC boards can be used. Thermal compound is recommended.

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

4-Lead Power Mini DIP

9V (T–3)

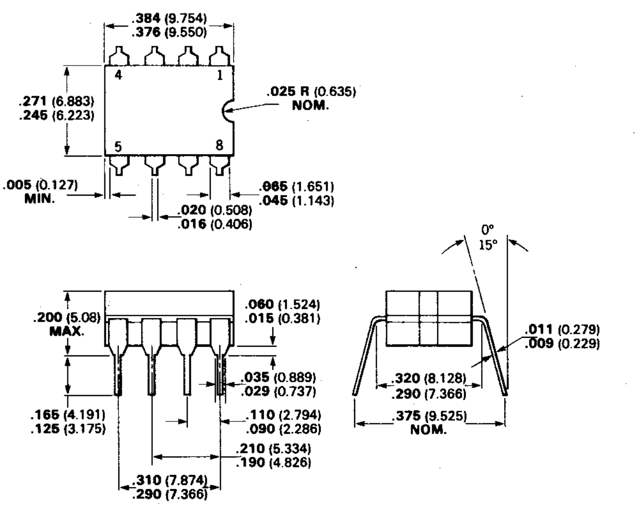


NOTES:
Package is plastic with tin-plated copper leads and wings
Package weight is 0.6 gram

T-3 package is intended for applications with an external heat sink. A No. 2 mounting hole is provided for case of mounting. The tab may be bent to any convenient angle.

8-Lead SSI Dual In-Line

6T



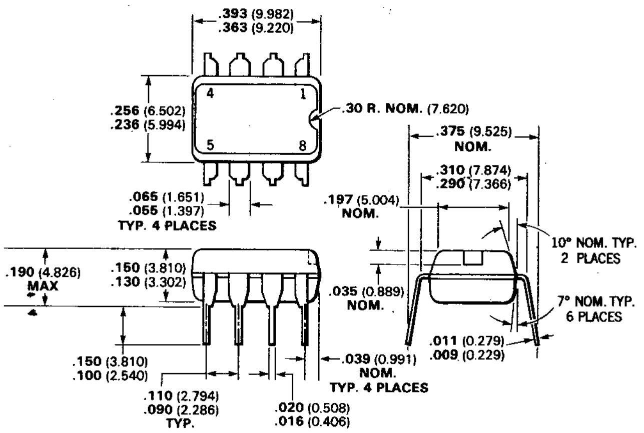
NOTES:
Leads are tin-plated Kovar
Leads are intended for insertion in hole rows on .300" centers (7.62)
Leads purposely have a "positive" misalignment to facilitate insertion

Board-drilling dimensions should equal your practice for .020 (0.51) inch diameter lead
Hermetically sealed alumina package
Cavity size is .110 x .140 (2.79 x 3.56)
Package weight is 1.0 gram

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

8-Lead Plastic Dual In-Line

9T



NOTES:

Package is plastic with tin or gold-plated Kovar leads

Leads are intended for insertion in hole rows on .300" centers (7.62)

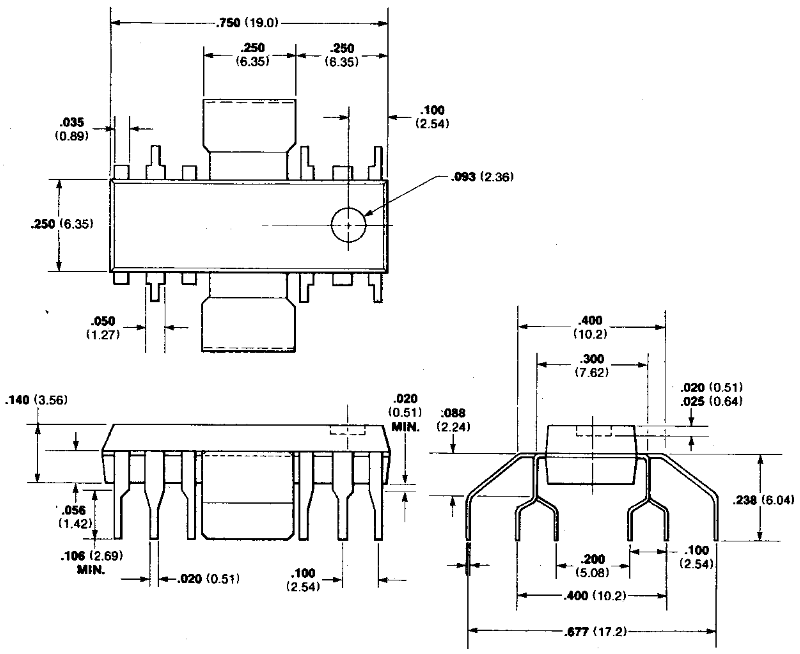
Leads purposely have a "positive" misalignment to facilitate insertion

Board-drilling dimensions should equal your practice for .020 (0.51) inch diameter lead

Package weight is 0.6 gram

12-Lead Power Plastic Dual In-Line

9W (P–3)



NOTES:

Package is plastic with tin plated copper leads and wings

For detailed package configuration refer to FSB-90698

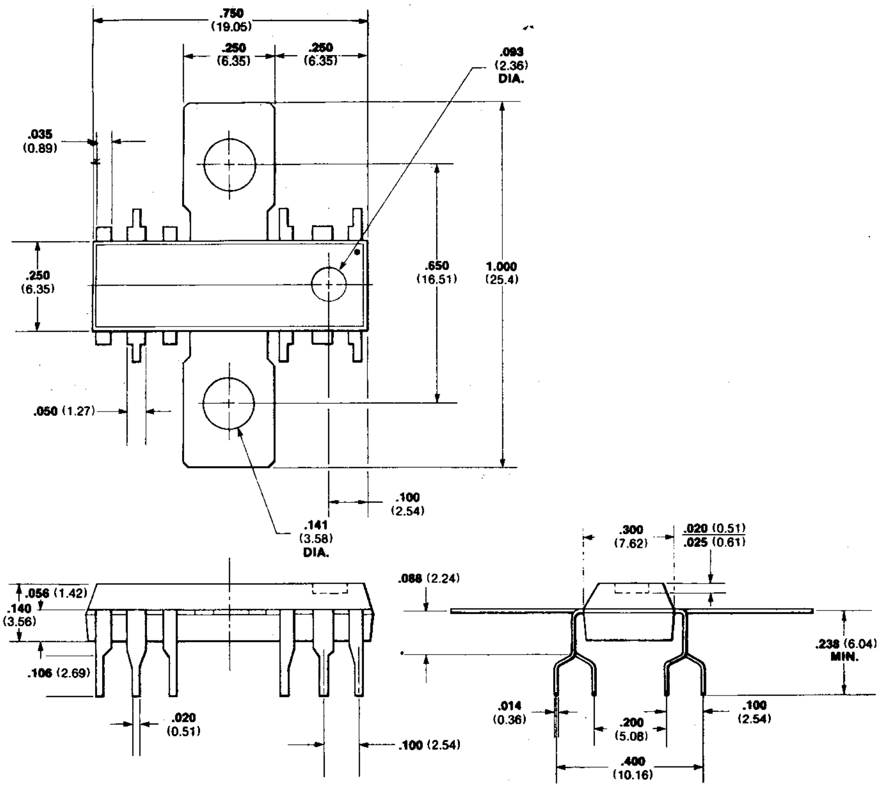
Package weight is 0.9 gram

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

8

12-Lead Power Plastic Dual In-Line

9W (P—4)

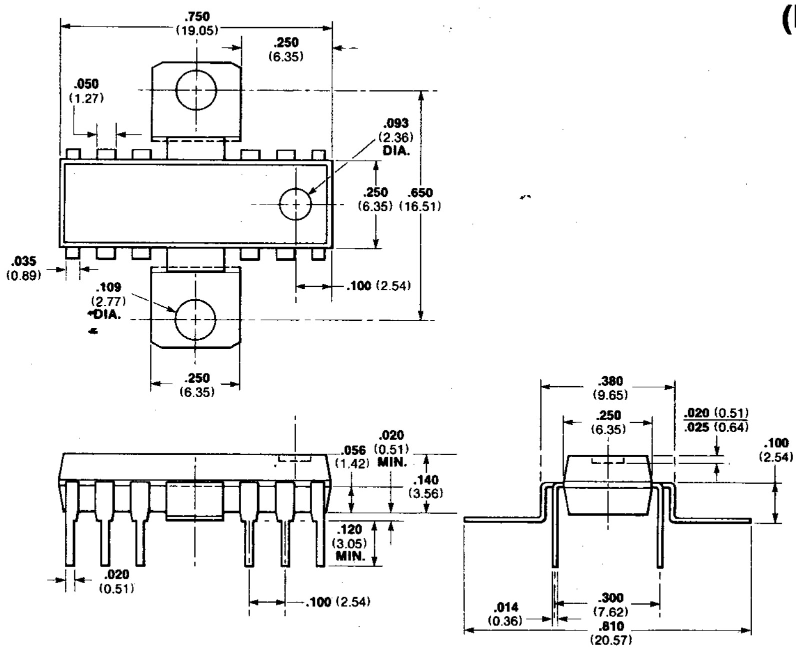


NOTES:
Package is plastic with tin-plated copper leads and wings
For detailed package configuration refer to FSB-90699
Package weight os 0.9 gram

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

12-Lead Power Plastic Dual In-Line

9W (P-5 CONF)

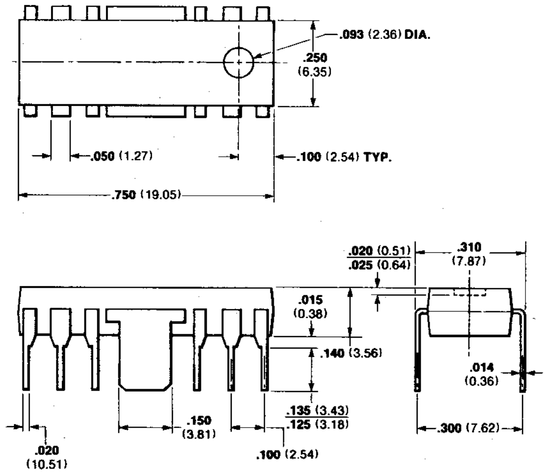


NOTES:
Package is plastic with tin-plated copper leads and wings

For detailed package configuration refer to FSD-90740
Package weight is 0.9 gram

12-Lead Power Plastic Dual In-Line

9W (P-6)



NOTES:
Package is plastic with tin-plated copper leads and wings

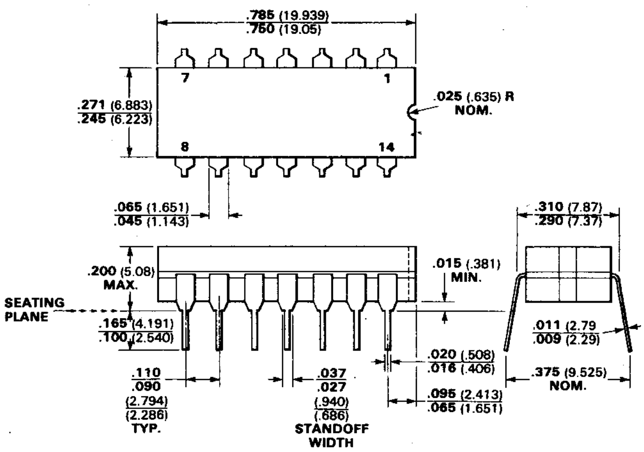
For detailed package configuration refer to FSB-90126
Package weight is 0.9 gram

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

8

In Accordance with JEDEC (TO-116) Outline 14-Lead SSI Dual In-Line

6A

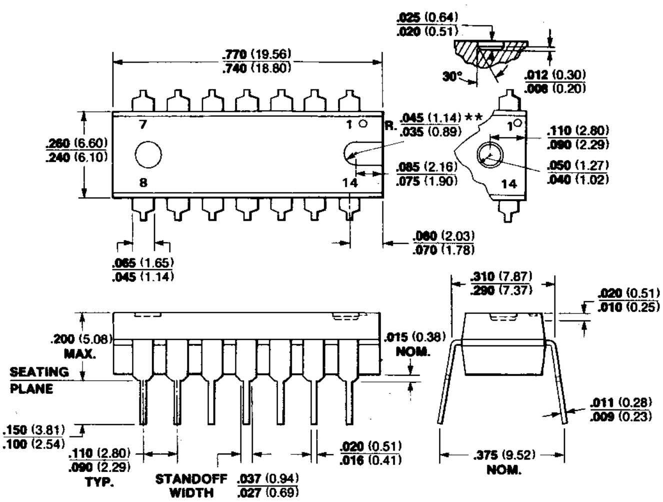


NOTES:

Leads are tin-plated 42 alloy
Leads are intended for insertion in hole rows on .300" centers (7.62)
Leads purposely have a "positive" misalignment to facilitate insertion
Board-drilling dimensions should equal your practice for .020 inch diameter lead (0.51)
Hermetically sealed alumina package
Cavity size is .110 x .140 (2.79 x 3.56)
Package weight is 2.0 grams

In Accordance with JEDEC (TO-116) Outline 14-Lead Plastic* Dual In-Line

9A



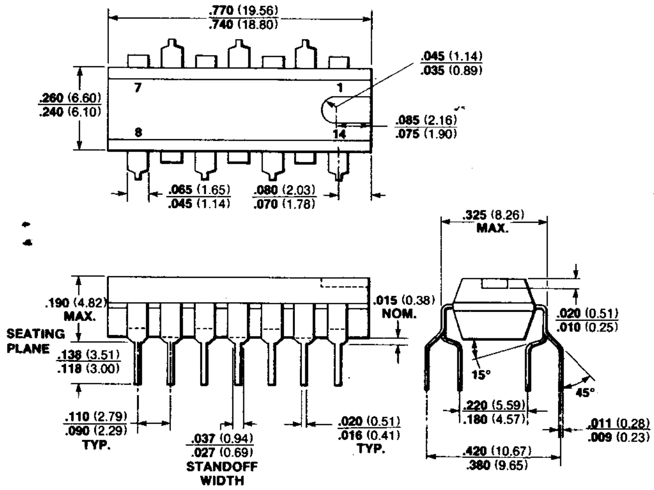
NOTES:

Leads are tin-plated Kovar
Leads are intended for insertion in hole rows on .300" centers (7.62)
Leads purposely have a "positive" misalignment to facilitate insertion
Board-drilling dimensions should equal your practice for .020 inch diameter lead (0.51)
Package weight is 0.9 gram
*Package material varies depending on the product line
**Notch or ejector hole varies depending on the product line

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

Similar to*
JEDEC (TO-116) Outline
14-Lead Epoxy Quad In-Line

9C

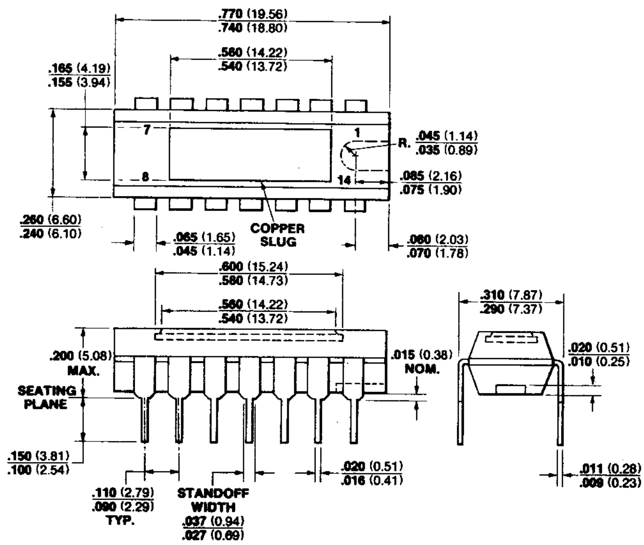


NOTES:
Package is epoxy with tin-plated Kovar leads
Board-drilling dimensions should equal your practice for .020 (0.51) inch diameter lead
Package weight is 0.9 gram

*This is a 9A package with the leads formed in assembly. Only the notched and epoxy version is used

14-Lead Epoxy Dual In-Line
(With Copper Slug)

9H



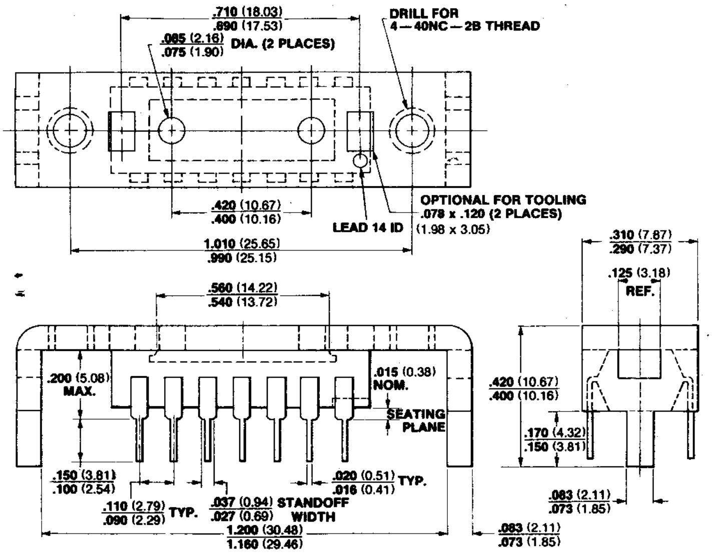
NOTES:
Package material is epoxy with copper slug
Leads are gold-plated Kovar

Board-drilling dimensions should equal your practice for .020 (0.51) inch diameter lead
Package weight is 0.9 gram

Dimensions nominal, in inches. Parentheses indicate metric dimensions.

8

14-Lead Epoxy Dual In-Line (Copper Slug and Heat Bracket)* 9J

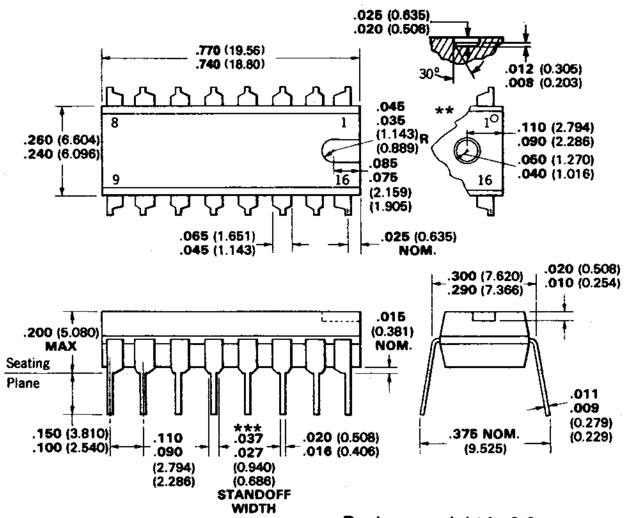


NOTES:
Package materal is epoxy with copper slug and tin-plated copper bracket
Leads are gold-plated Kovar

Board-drilling dimensions should equal your practice for .020 (0.51) diameter lead

*Package is the same as 9H except that a heat bracket is attached

16-Lead Plastic* Dual In-Line 9B

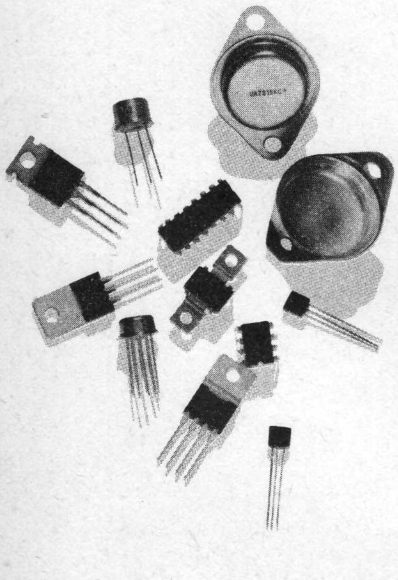


NOTES:
Leads are tin-plated Kovar or Alloy 42 nickel
Leads are intended for insertion in hole rows on .300" (7.62) centers
Leads purposely have a "positive" misalignment to facilitate insertion
Board-drilling dimensions should equal your practice for .020 inch (0.51) diameter lead

Package weight is 0.9 gram

*Package material varies depending on the product line
**Notch or ejector hold varies depending on the product line
***The .037-.027 (0.94-0.69) dimension does not apply to the corner leads

Dimensions nominal, in inches. Parentheses indicate metric dimensions.



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