LM120QML Series 3-Terminal Negative Regulators

Check for Samples: LM120QML

FEATURES

- **Preset Output Voltage Error Less Than ±3%**
- **Preset Current Limit**
- **Internal Thermal Shutdown**
- **Operates with Input-Output Voltage Differential Down to 1V**
- **Excellent Ripple Rejection**
- **Low Temperature Drift**
- **Easily Adjustable to Higher Output Voltage**

DESCRIPTION

The LM120 series are three-terminal negative regulators with a fixed output voltage of −5V, −12V, and −15V, and up to 1.5A load current capability. Where other voltages are required, the LM137 and LM137HV series provide an output voltage range of −1.2V to −47V.

The LM120 needs only one external component—a compensation capacitor at the output, making them easy to apply. Worst case specifies on output voltage deviation due to any combination of line, load or temperature variation assure satisfactory system operation.

Exceptional effort has been made to make the LM120 Series immune to overload conditions. The regulators have current limiting which is independent of temperature, combined with thermal overload protection. Internal current limiting protects against momentary faults while thermal shutdown prevents junction temperatures from exceeding safe limits during prolonged overloads.

Although primarily intended for fixed output voltage applications, the LM120 Series may be programmed for higher output voltages with a simple resistive divider. The low quiescent drain current of the devices allows this technique to be used with good regulation.

Table 1. LM120 Series Packages and Power Capability

Package	Rated Power Dissipation	Design Load Current
TO (K)	20W	1.5A
PFM (H)	2W	0.5A

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

All trademarks are the property of their respective owners.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Copyright © 2010–2013, Texas Instruments Incorporated

Connection Diagram

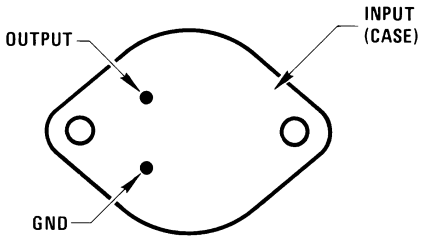


Figure 1. Bottom View
2-Pin TO Steel Metal Can
See K Package

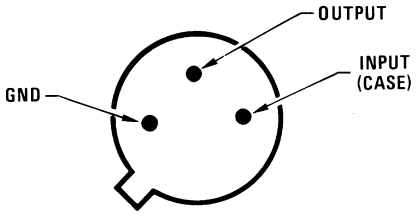
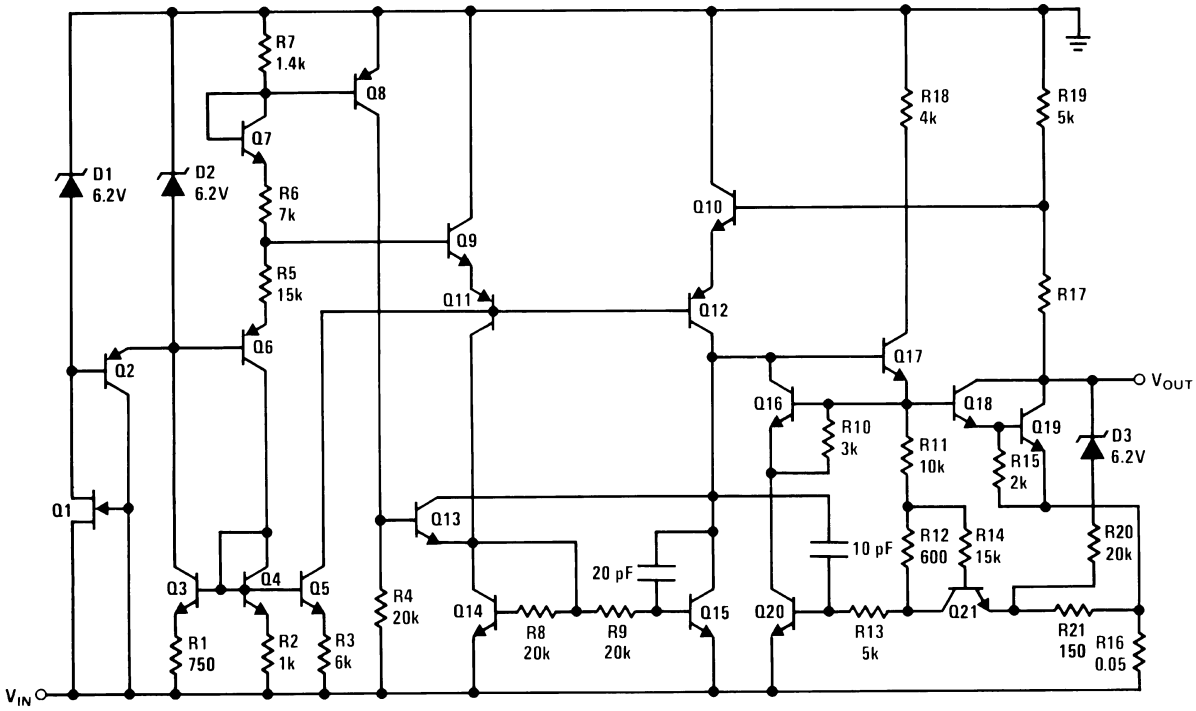


Figure 2. Bottom View
3-Pin PFM Metal Can
See NDT0003A Package

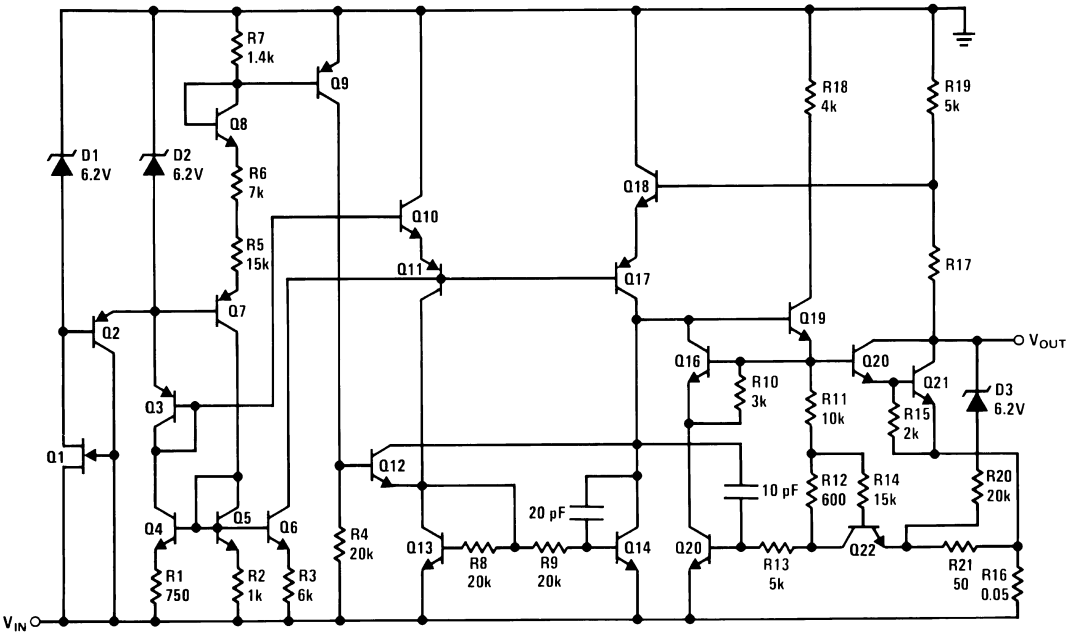
Schematic Diagrams

Figure 3. −5V



Copyright © 2010–2013, Texas Instruments Incorporated

Figure 4. −12V and −15V



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ABSOLUTE MAXIMUM RATINGS(1)

			LM120−5	LM120−12	LM120−15
Power Dissipation			Internally Limited		
Input Voltage			−25V	−35V	−40V
Input-Output Voltage Differential			25V	30V	30V
Junction Temperatures			150°C		
Storage Temperature Range			−65°C ≤ T_A ≤ +150°C		
Operating Temperature Range			−55°C ≤ T_A ≤ +125°C		
Lead Temperature (Soldering, 10 sec.)			300°C		
Thermal Resistance	θ_{JA}	PFM-Pkg (Still Air @ 0.5W)	191°C/W		
		PFM-Pkg (500LF/Min Air flow @ 0.5W)	70°C/W		
		TO-Pkg (Still Air @ 0.5W)	35°C/W		
		TO-Pkg (500LF/Min Air flow @ 0.5W)	TBD		
	θ_{JC}	PFM-Pkg	29°C/W		
		TO-Pkg	3°C/W		
ESD Tolerance(2)			4000V		

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

(2) Human body model, 1.5 kΩ in seriew with 100 pF.

Copyright © 2010–2013, Texas Instruments Incorporated

Table 2. QUALITY CONFORMANCE INSPECTION

Mil-Std-883, Method 5005 - Group A		
Subgroup	**Description**	**Temp (°C)**
1	Static tests at	+25
2	Static tests at	+125
3	Static tests at	-55
4	Dynamic tests at	+25
5	Dynamic tests at	+125
6	Dynamic tests at	-55
7	Functional tests at	+25
8A	Functional tests at	+125
8B	Functional tests at	-55
9	Switching tests at	+25
10	Switching tests at	+125
11	Switching tests at	-55
12	Settling time at	+25
13	Settling time at	+125
14	Settling time at	-55

LM120H-5.0 DC PARAMETERS

The following conditions apply, unless otherwise specified. V_{IN} = −10V, I_L = 5mA

Symbol	Parameter	Conditions	Notes	Min	Max	Unit	Sub-groups
I_Q	Quiescent Current	V_{IN} = -7V			2.0	mA	1, 2, 3
		V_{IN} = -25V			2.0	mA	1, 2, 3
ΔI_Q	Quiescent Current Change	5mA ≤ I_L ≤ 0.5A		-0.4	0.4	mA	1
				-0.5	0.5	mA	2, 3
		-25V ≤ V_{IN} ≤ -7V		-0.4	0.4	mA	1
				-0.5	0.5	mA	2, 3
V_{OUT}	Output Voltage			-5.1	-4.9	V	1
		V_{IN} = -7.5V		-5.2	-4.8	V	1, 2, 3
		V_{IN} = -7.5V, I_L = 0.5A		-5.2	-4.8	V	1, 2, 3
		V_{IN} = -25V		-5.2	-4.8	V	1, 2, 3
		V_{IN} = -25V, I_L = 100mA		-5.2	-4.8	V	1, 2, 3
R_{Line}	Line Regulation	-25V ≤ V_{IN} ≤ -7V		-25	25	mV	1
				-50	50	mV	2, 3
R_{Load}	Load Regulation	5mA ≤ I_L ≤ 0.5A		-50	50	mV	1
				-100	100	mV	2, 3
I_{OS}	Short Circuit Current	V_{IN} = -25V		0.1	1.5	A	1
RR	Ripple Rejection	f = 120Hz, I_L = 125mA, e_I = $1V_{RMS}$		54		dB	4

Copyright © 2010–2013, Texas Instruments Incorporated

LM120K-5.0 DC PARAMETERS

The following conditions apply, unless otherwise specified. V_{IN} = −10V, I_L = 5mA

Symbol	Parameter	Conditions	Notes	Min	Max	Unit	Sub-groups
I_Q	Quiescent Current	V_{IN} = -7V			2.0	mA	1, 2, 3
		V_{IN} = -25V			2.0	mA	1, 2, 3
ΔI_Q	Quiescent Current Change	5mA ≤ I_L ≤ 1.5A		-0.4	0.4	mA	1
				-0.5	0.5	mA	2, 3
		-25V ≤ V_{IN} ≤ -7V		-0.4	0.4	mA	1
				-0.5	0.5	mA	2, 3
V_{OUT}	Output Voltage			-5.1	-4.9	V	1
		V_{IN} = -7.5V		-5.2	-4.8	V	1, 2, 3
		V_{IN} = -7.5V, I_L = 1.5A		-5.2	-4.8	V	1, 2, 3
		V_{IN} = -25V		-5.2	-4.8	V	1, 2, 3
		V_{IN} = -25V, I_L = 1A		-5.2	-4.8	V	1, 2, 3
R_{Line}	Line Regulation	-25V ≤ V_{IN} ≤ -7V		-25	25	mV	1
				-50	50	mV	2, 3
R_{Load}	Load Regulation	5mA ≤ I_L ≤ 1.5A		-75	75	mV	1
				-100	100	mV	2, 3
I_{OS}	Short Circuit Current	V_{IN} = -25V		0.4	3.0	A	1
RR	Ripple Rejection	f = 120Hz, I_L = 350mA, e_I = $1V_{RMS}$		54		dB	4

LM120H-12 DC PARAMETERS

The following conditions apply, unless otherwise specified. V_{IN} = −17V, I_L = 5mA

Symbol	Parameter	Conditions	Notes	Min	Max	Unit	Sub-groups
I_Q	Quiescent Current	V_{IN} = -14V			4.0	mA	1, 2, 3
		V_{IN} = -32V			4.0	mA	1, 2, 3
ΔI_Q	Quiescent Current Change	V_{IN} = -17V, 5mA ≤ I_L ≤ 200mA			0.4	mA	1
					0.5	mA	2, 3
		-32V ≤ V_{IN} ≤ -14V			0.4	mA	1
					0.5	mA	2, 3
R_{Load}	Load Regulation	V_{IN} = -17V, 5mA ≤ I_L ≤ 200mA		-25	25	mV	1
				-50	50		2, 3
R_{Line}	Line Regulation	-32V ≤ V_{IN} ≤ -14V		-10	10	mV	1
				-20	20	mV	2, 3
I_{OS}	Short Circuit Current	V_{IN} = -32V		0.1	1.5	A	1
V_{OUT}	Output Voltage	V_{IN} = -17V		-12.3	-11.7	V	1
		V_{IN} = -32V		-12.5	-11.5	V	1, 2, 3
		V_{IN} = -32V, I_L = 100mA		-12.5	-11.5	V	1, 2, 3
		V_{IN} = -14.5V		-12.5	-11.5	V	1, 2, 3
		V_{IN} = -14.5V, I_L = 200mA		-12.5	-11.5	V	1, 2, 3
RR	Ripple Rejection	f = 120Hz, I_L = 125mA, e_i = $1V_{RMS}$		56		dB	4

Copyright © 2010–2013, Texas Instruments Incorporated

LM120K-12 DC PARAMETERS

The following conditions apply to all the following parameters, unless otherwise specified. V_{IN} = −17V, I_L = 5mA

Symbol	Parameter	Conditions	Notes	Min	Max	Unit	Sub-groups
I_Q	Quiescent Current	V_{IN} = -14V			4.0	mA	1, 2, 3
		V_{IN} = -32V			4.0	mA	1, 2, 3
ΔI_Q	Quiescent Current Change	V_{IN} = -17V, 5mA ≤ I_L ≤ 1A			0.4	mA	1
					0.5	mA	2, 3
		-32V ≤ V_{IN} ≤ -14V			0.4	mA	1
					0.5	mA	2, 3
R_{Load}	Load Regulation	V_{IN} = -17V, 5mA ≤ I_L ≤ 1A		-80	80	mV	1, 2, 3
R_{Line}	Line Regulation	-32V ≤ V_{IN} ≤ -14V		-10	10	mV	1
				-20	20	mV	2, 3
I_{OS}	Short Circuit Current	V_{IN} = -32V		0.4	3.0	A	1
V_{OUT}	Output Voltage	V_{IN} = -17V		-12.3	-11.7	V	1
		V_{IN} = -32V		-12.5	-11.5	V	1, 2, 3
		V_{IN} = -32V, I_L = 1A		-12.5	-11.5	V	1, 2, 3
		V_{IN} = -14.5V		-12.5	-11.5	V	1, 2, 3
		V_{IN} = -14.5V, I_L = 1A		-12.5	-11.5	V	1, 2, 3
RR	Ripple Rejection	f = 120Hz, I_L = 350mA, e_i = $1V_{RMS}$		56		dB	4

LM120H-15 DC PARAMETERS

The following conditions apply to all the following parameters, unless otherwise specified. V_{IN} = 20V, I_L = 5mA

Symbol	Parameter	Conditions	Notes	Min	Max	Unit	Sub-groups
I_Q	Quiescent Current	V_{IN} = -17V			4.0	mA	1, 2, 3
		V_{IN} = -35V			4.0	mA	1, 2, 3
ΔI_Q	Quiescent Current Change	V_{IN} = -17V, 5mA ≤ I_L ≤ 200mA			0.4	mA	1
					0.5	mA	2, 3
		-35V ≤ V_{IN} ≤ -17V			0.4	mA	1
					0.5	mA	2, 3
R_{Load}	Load Regulation	V_{IN} = -20V, 5mA ≤ I_L ≤ 200mA		-25	25	mV	1
				−50	50	mV	2, 3
R_{Line}	Line Regulation	-35V ≤ V_{IN} ≤ -17V		-10	10	mV	1
				-20	20	mV	2, 3
I_{OS}	Short Circuit Current	V_{IN} = -35V		0.1	1.5	A	1
V_{OUT}	Output Voltage	V_{IN} = -20V		-15.3	-14.7	V	1
		V_{IN} = -35V		-15.5	-14.5	V	1, 2, 3
		V_{IN} = -35V, I_L = 100mA		-15.5	-14.5	V	1, 2, 3
		V_{IN} = -17.5V		-15.5	-14.5	V	1, 2, 3
		V_{IN} = -17.5V, I_L = 200mA		-15.5	-14.5	V	1, 2, 3
RR	Ripple Rejection	f = 120Hz, I_L = 125mA, e_i = $1V_{RMS}$		56		dB	4

Copyright © 2010–2013, Texas Instruments Incorporated

LM120K-15 DC PARAMETERS

The following conditions apply, unless otherwise specified. V_{IN} = 20V, I_L = 5mA

Symbol	Parameter	Conditions	Notes	Min	Max	Unit	Sub-groups
I_Q	Quiescent Current	V_{IN} = -17V			4.0	mA	1, 2, 3
		V_{IN} = -35V			4.0	mA	1, 2, 3
ΔI_Q	Quiescent Current Change	V_{IN} = -17V, 5mA ≤ I_L ≤ 1A			0.4	mA	1
					0.5	mA	2, 3
		-35V ≤ V_{IN} ≤ -17V			0.4	mA	1
					0.5	mA	2, 3
R_{Load}	Load Regulation	V_{IN} = -20V, 5mA ≤ I_L ≤ 1A		-80	80	mV	1, 2, 3
R_{Line}	Line Regulation	-35V ≤ V_{IN} ≤ -17V		-10	10	mV	1
				-20	20	mV	2, 3
I_{OS}	Short Circuit Current	V_{IN} = -35V		0.4	3.0	A	1
V_{OUT}	Output Voltage	V_{IN} = -20V		-15.3	-14.7	V	1
		V_{IN} = -35V		-15.5	-14.5	V	1, 2, 3
		V_{IN} = -35V, I_L = 1A		-15.5	-14.5	V	1, 2, 3
		V_{IN} = -17.5V		-15.5	-14.5	V	1, 2, 3
		V_{IN} = -17.5V, I_L = 1.5A		-15.5	-14.5	V	1, 2, 3
ΔV_O / Δt	Long Term Stability		See (1)		150	mV	1
RR	Ripple Rejection	f = 120Hz, I_L = 350mA, e_I = 1V_{RMS}		56		dB	4

(1) Specified parameter, not tested

Copyright © 2010–2013, Texas Instruments Incorporated

TYPICAL PERFORMANCE CHARACTERISTICS

Output Voltage vs Temperature

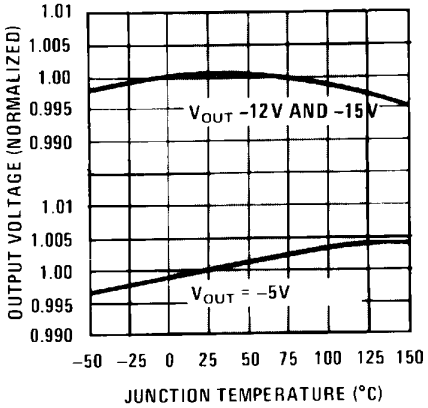


Figure 5.

Ripple Rejection (All Types)

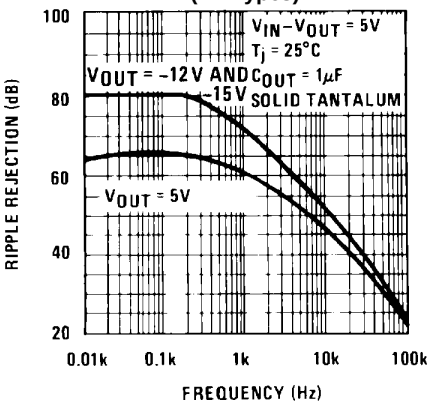


Figure 6.

Output Impedance TO-3

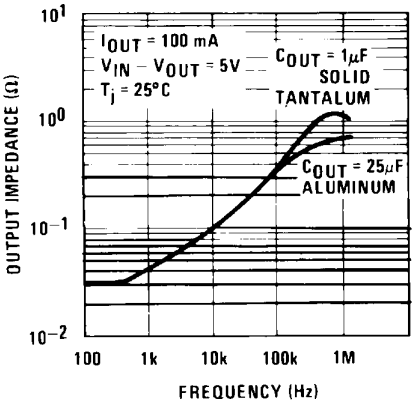


Figure 7.

Output Impedance TO-5

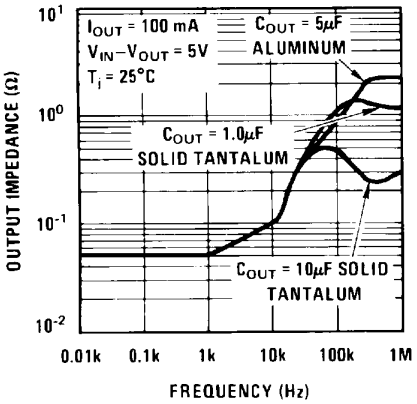


Figure 8.

Minimum Input-Output Differential TO-3

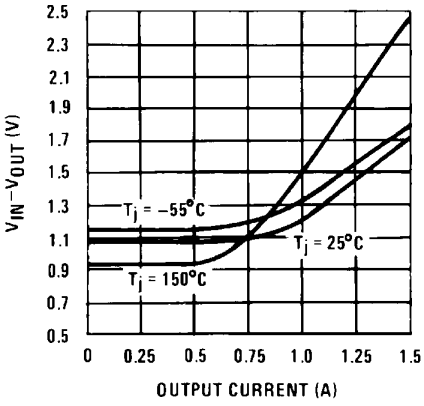


Figure 9.

Minimum Input-Output Differential TO-5

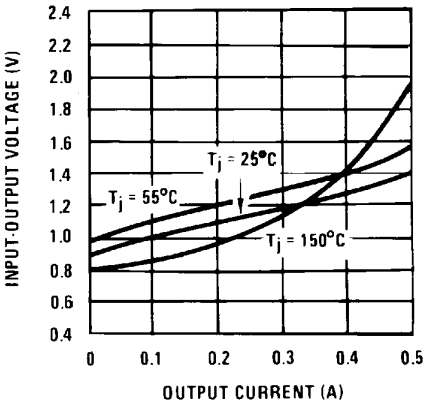


Figure 10.

Copyright © 2010–2013, Texas Instruments Incorporated

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Quiescent Current vs Input Voltage

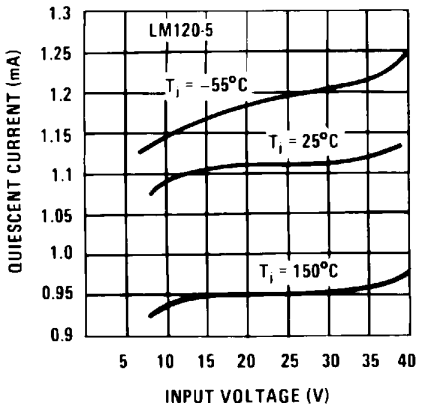


Figure 11.

Quiescent Current vs Load Current

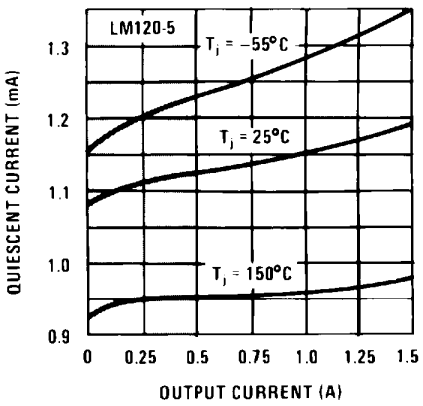
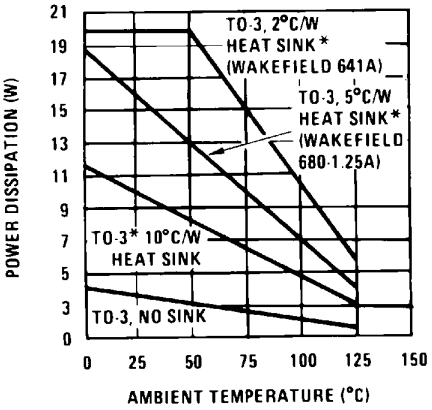


Figure 12.

Maximum Average Power Dissipation (TO-3)



*These curves for LM120. Derate 25°C further for LM320.

Figure 13.

Maximum Average Power Dissipation (TO-5)

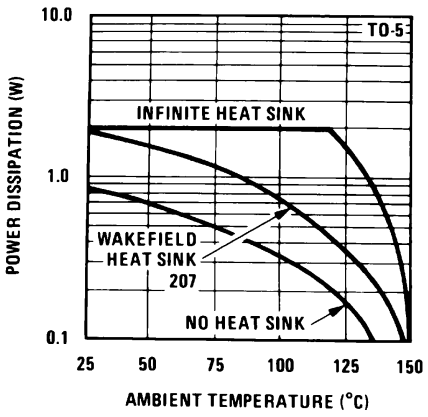


Figure 14.

Short Circuit Current

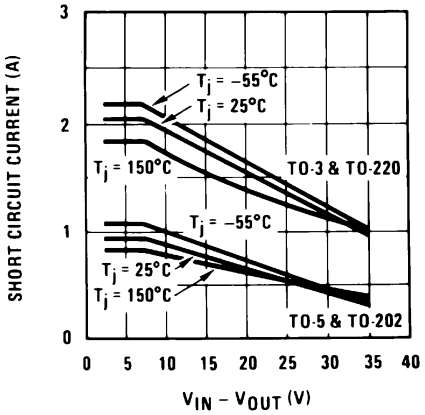
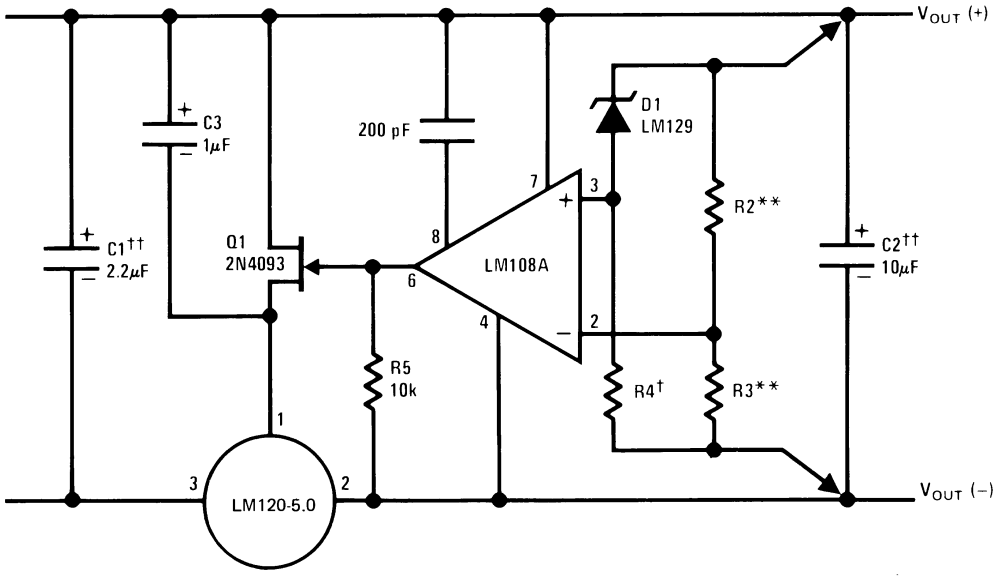


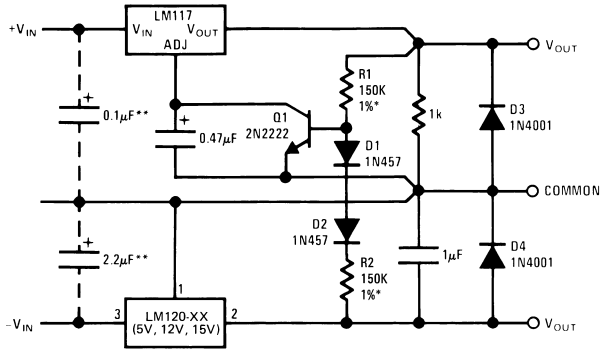
Figure 15.

TYPICAL APPLICATIONS



Lead and line regulation — 0.01% temperature stability — 0.2%
†Determines Zener current.
††Solid tantalum.
An LM120-12 or LM120-15 may be used to permit higher input voltages, but the regulated output voltage must be at least −15V when using the LM120-12 and −18V for the LM120-15.
**Select resistors to set output voltage. 2 ppm/°C tracking suggested.

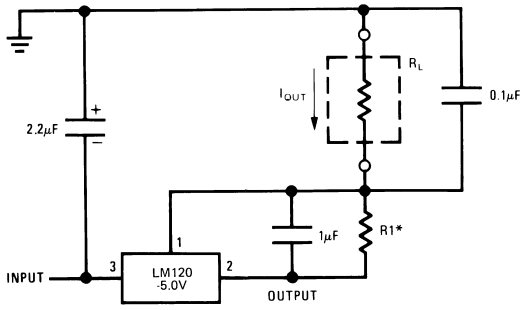
Figure 16. High Stability 1 Amp Regulator



* Resistor tolerance of R1 and R2 determine matching of (+) and (−) inputs.
**Necessary only if raw supply capacitors are more than 3″ from regulators
An LM3086N array may substitute for Q1, D1 and D2 for better stability and tracking. In the array diode transistors Q5 and Q4 (in parallel) make up D2; similarly, Q1 and Q2 become D1 and Q3 replaces the 2N2222.

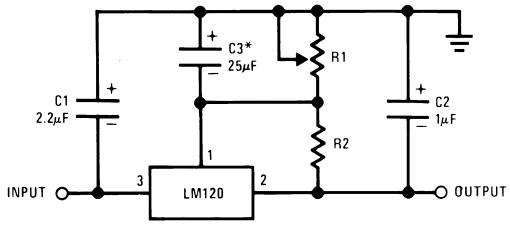
Figure 17. Wide Range Tracking Regulator

Copyright © 2010–2013, Texas Instruments Incorporated



$$*I_{OUT} = 1\ mA + \frac{5.0V}{R1}$$

Figure 18. Current Source



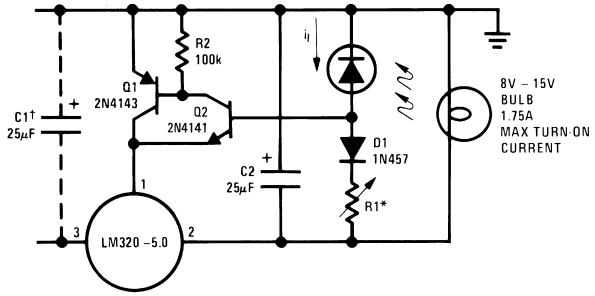
*Optional. Improves transient response and ripple rejection.

$$V_{OUT} = V_{SET}\frac{R1 + R2}{R2}$$

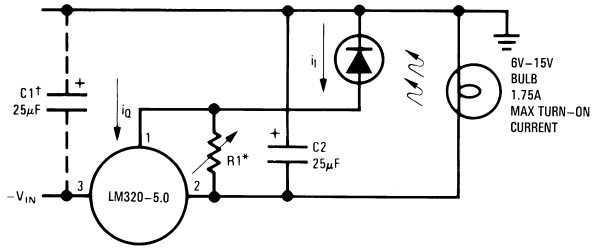
SELECT R2 AS FOLLOWS:
LM120-5 −300Ω
LM120-12 −750Ω
LM120-15 −1k

Figure 19. Variable Output

Copyright © 2010–2013, Texas Instruments Incorporated



*Lamp brightness increases until i_I = 5V/R1 (i_I can be set as low as 1 μA).
†Necessary only if raw supply filter capacitor is more than 2″ from LM320MP.



*Lamp brightness increases until $i_I = i_Q$ (1 mA) + 5V/R1.
†Necessary only if raw supply filter capacitor is more than 2″ from LM320.

Figure 20. Light Controllers Using Silicon Photo Cells

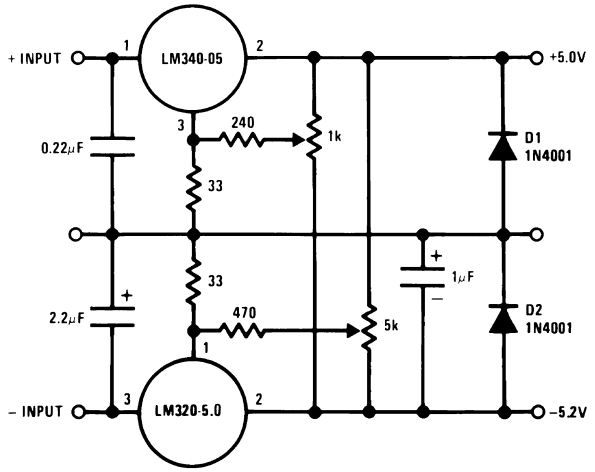
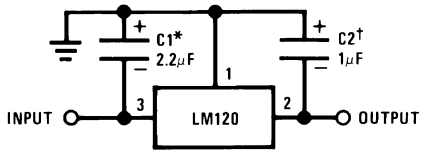


Figure 21. Dual Trimmed Supply



*Required if regulator is separated from filter capacitor by more than 3″. For value given, capacitor must be solid tantalum. 25 μF aluminum electrolytic may be substituted.
†Required for stability. For value given, capacitor must be solid tantalum. 25 μF aluminum electrolytic may be substituted. Values given may be increased without limit.
For output capacitance in excess of 100 μF, a high current diode from input to output (1N4001, etc.) will protect the regulator from momentary input shorts.

Figure 22. Fixed Regulator

Copyright © 2010–2013, Texas Instruments Incorporated

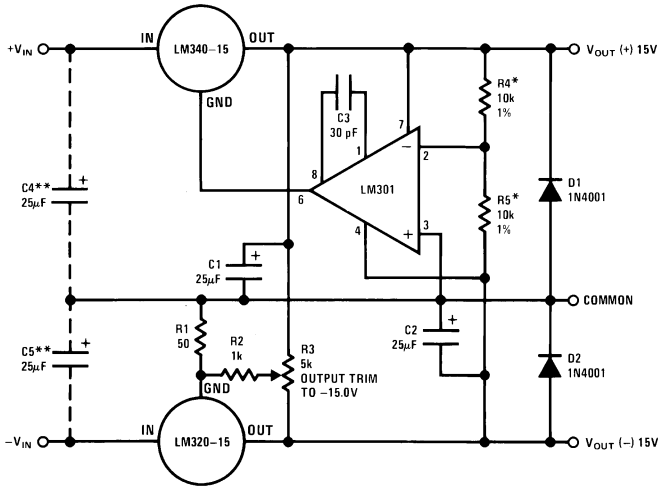


Figure 23. ±15V, 1 Amp Tracking Regulators

Table 3. Performance (Typical)(1)

Load Regulation at ΔI_L = 1A	10 mV	1 mV
Output Ripple, C_{IN} = 3000 µF, I_L = 1A	100 µVRMS	100 µVRMS
Temperature Stability	+50 mV	+50 mV
Output Noise 10 Hz ≤ f ≤ 10 kHz	150 µVRMS	150 µVRMS

(1) *Resistor tolerance of R4 and R5 determine matching of (+) and (−) outputs.
**Necessary only if raw supply filter capacitors are more than 2″ from regulators.

Copyright © 2010–2013, Texas Instruments Incorporated

REVISION HISTORY

Date Released	Revision	Section	Changes
12/15/2010	A	New release to the corporate format	6 MDS datasheets were converted and merged into one datasheet compliant to corporate format. Drift endpoints removed since note used on 883 product. MDS MNLM120-5.0-K Rev OBL, MNLM120-5.0-H Rev 0BL, MNLM120-12-K Rev OBL, MNLM120-12-H Rev 0BL, MNLM120-15-K Rev OBL, & MNLM120-15-H Rev 0BL will be archived.
4/22/2013	A	All	Changed layout of National Data Sheet to TI format.

Copyright © 2010–2013, Texas Instruments Incorporated

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LM120H-12/883	Active	Production	TO (NDT) | 3	20 | JEDEC TRAY (5+1)	No	Call TI	Level-1-NA-UNLIM	-55 to 150	LM120H-12/883 Q ACO LM120H-12/883 Q >T
LM120H-15/883	Active	Production	TO (NDT) | 3	20 | JEDEC TRAY (5+1)	No	Call TI	Level-1-NA-UNLIM	-55 to 150	LM120H-15P+ LM120H-15/883 Q ACO LM120H-15/883 Q >T
LM120H-5.0/883	Active	Production	TO (NDT) | 3	20 | JEDEC TRAY (5+1)	No	Call TI	Level-1-NA-UNLIM	-55 to 150	LM120H-5.0/883 Q ACO LM120H-5.0/883 Q >T
LM120K-12/883	Active	Production	TO (K) | 2	50 | TRAY NON-STD	Yes	Call TI	Level-1-NA-UNLIM	-55 to 150	LM120K-12 /883 Q ACO /883 Q >T
LM120K-15/883	Active	Production	TO (K) | 2	50 | TRAY NON-STD	Yes	Call TI	Level-1-NA-UNLIM	-55 to 150	(LM120H-15P+, LM120K-15) /883 Q ACO /883 Q >T
LM120KG-12 MD8	Active	Production	DIESALE (Y) | 0	221 | JEDEC TRAY (5+1)	Yes	Call TI	Level-1-NA-UNLIM	-55 to 125	
LM120KG-15 MD8	Active	Production	DIESALE (Y) | 0	221 | JEDEC TRAY (5+1)	Yes	Call TI	Level-1-NA-UNLIM	-55 to 125	
LM120KG-5 MD8	Active	Production	DIESALE (Y) | 0	221 | JEDEC TRAY (5+1)	Yes	Call TI	Level-1-NA-UNLIM	-55 to 125	

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

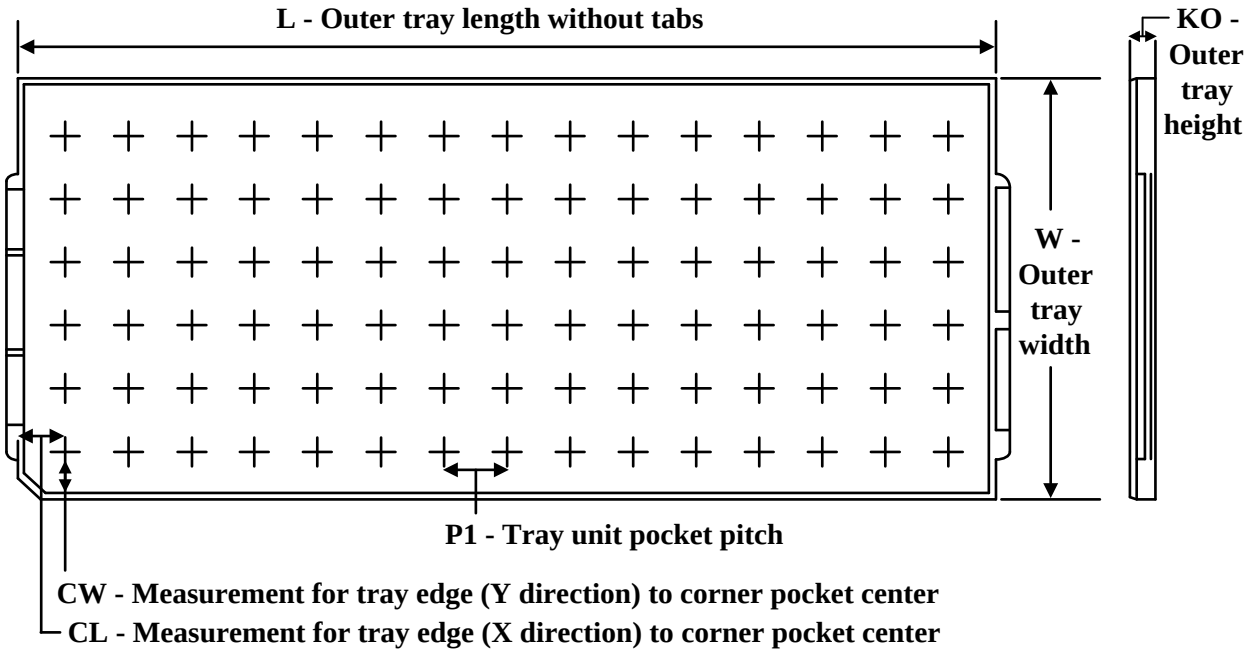
(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TRAY



Chamfer on Tray corner indicates Pin 1 orientation of packed units.

*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	Unit array matrix	Max temperature (°C)	L (mm)	W (mm)	K0 (µm)	P1 (mm)	CL (mm)	CW (mm)
LM120H-12/883	NDT	TO-CAN	3	20	2 X 10	150	126.49	61.98	8890	11.18	12.95	18.54
LM120H-15/883	NDT	TO-CAN	3	20	2 X 10	150	126.49	61.98	8890	11.18	12.95	18.54
LM120H-5.0/883	NDT	TO-CAN	3	20	2 X 10	150	126.49	61.98	8890	11.18	12.95	18.54
LM120K-12/883	K	TO-CAN	2	50	9 X 6	NA	292.1	215.9	25654	3.87	22.3	25.4
LM120K-15/883	K	TO-CAN	2	50	9 X 6	NA	292.1	215.9	25654	3.87	22.3	25.4

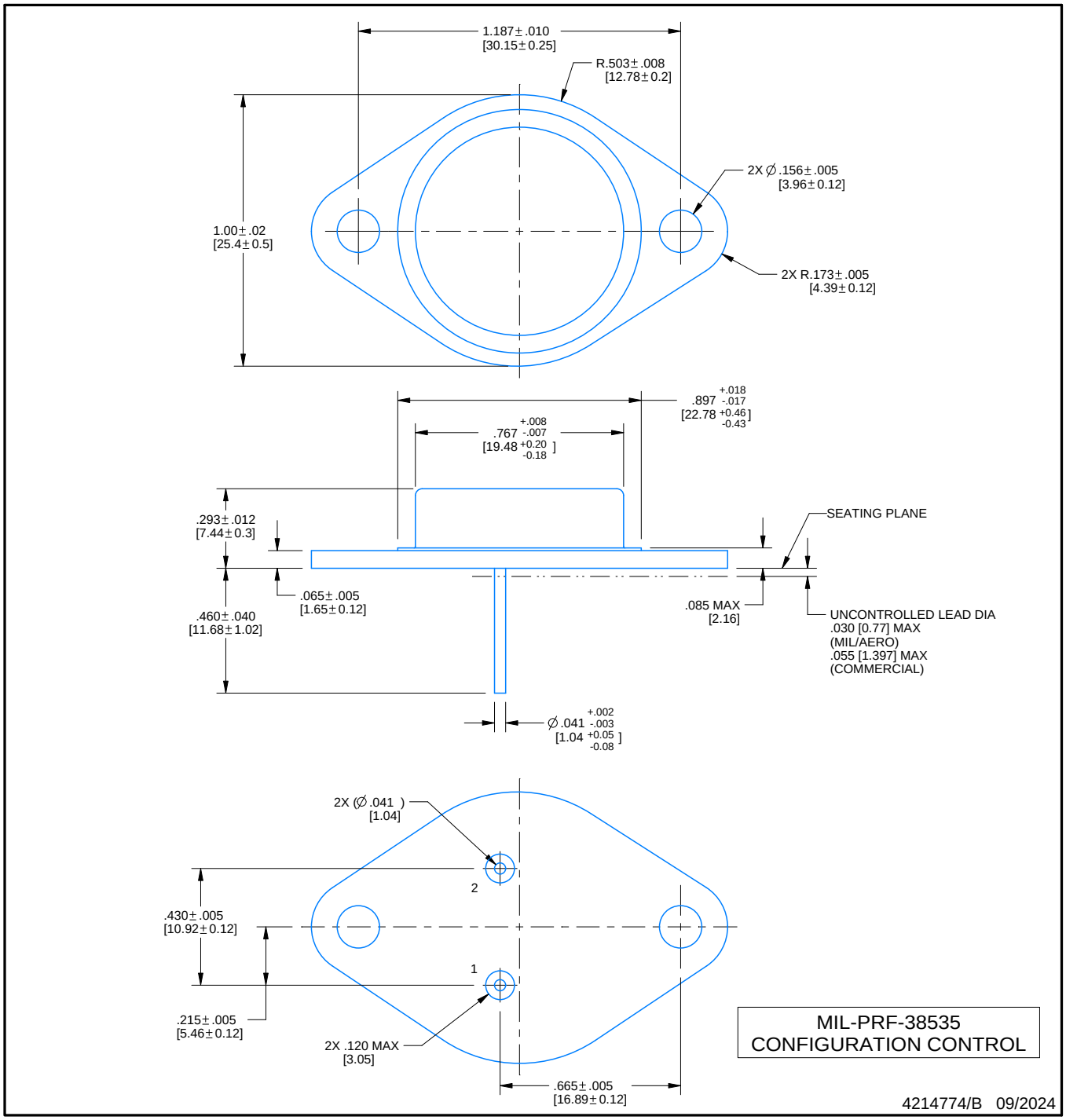
K0002A



PACKAGE OUTLINE

TO-CAN - 7.747 mm max height

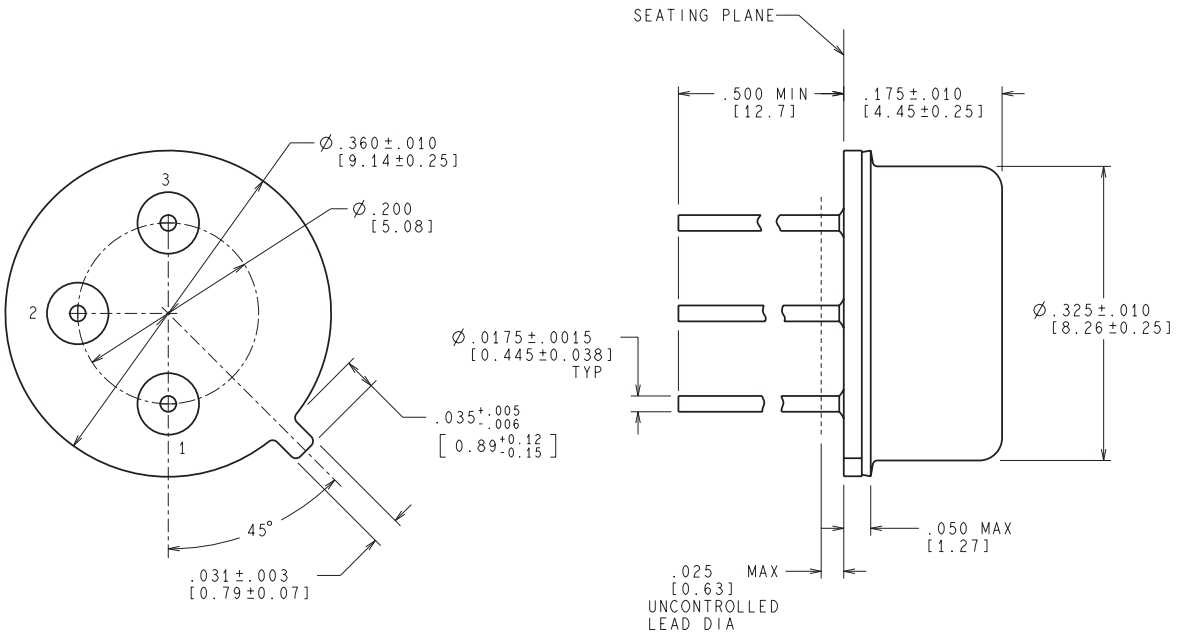
TRANSISTOR OUTLINE



NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Leads not to be bent greater than 15°.

NDT0003A



CONTROLLING DIMENSION IS INCH
VALUES IN [ ] ARE MILLIMETERS

MIL-PRF-38535
CONFIGURATION CONTROL

H03A (Rev D)

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale, TI’s General Quality Guidelines, or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025