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LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

Single Supply Quad Operational Amplifiers

The LM324 series are low-cost, quad operational amplifiers with true differential inputs. They have several distinct advantages over standard operational amplifier types in single supply applications. The quad amplifier can operate at supply voltages as low as 3.0 V or as high as 32 V with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

Features

- Short Circuited Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents: 100 nA Maximum (LM324A)
- Four Amplifiers Per Package
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Industry Standard Pinouts
- ESD Clamps on the Inputs Increase Ruggedness without Affecting Device Operation
- NCV Prefix for Automotive and Other Applications Requiring Site and Control Changes
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant



ON Semiconductor®

<http://onsemi.com>



PDIP-14
N SUFFIX
CASE 646

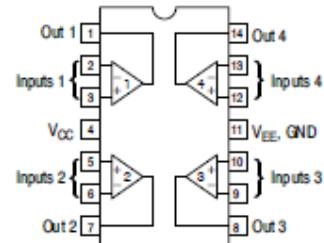


SOIC-14
D SUFFIX
CASE 751A



TSSOP-14
DTB SUFFIX
CASE 948G

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 10 of this data sheet.

DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 11 of this data sheet.

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

MAXIMUM RATINGS ($T_A = +25^\circ\text{C}$, unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltages Single Supply Split Supplies	V_{CC} V_{CC}, V_{EE}	32 ± 16	Vdc
Input Differential Voltage Range (Note 1)	V_{IDR}	± 32	Vdc
Input Common Mode Voltage Range (Note 2)	V_{ICR}	-0.3 to 32	Vdc
Output Short Circuit Duration	t_{sc}	Continuous	
Junction Temperature	T_J	150	$^\circ\text{C}$
Thermal Resistance, Junction-to-Air (Note 3) Case 646 Case 751A Case 948G	R_{thJA}	118 156 190	$^\circ\text{C}/\text{W}$
Storage Temperature Range	T_{stg}	-65 to +150	$^\circ\text{C}$
ESD Protection at any Pin Human Body Model Machine Model	V_{esd}	2000 200	V
Operating Ambient Temperature Range LM224 LM324, 324A LM2902 LM2902V, NCV2902 (Note 4)	T_A	-25 to +85 0 to +70 -40 to +105 -40 to +125	$^\circ\text{C}$

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. Split Power Supplies.
2. For supply voltages less than 32 V, the absolute maximum input voltage is equal to the supply voltage.
3. All R_{thJA} measurements made on evaluation board with 1 oz. copper traces of minimum pad size. All device outputs were active.
4. *NCV2902 is qualified for automotive use.*

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

ELECTRICAL CHARACTERISTICS ($V_{CC} = 5.0$ V, $V_{EE} = GND$, $T_A = 25^\circ C$, unless otherwise noted.)

Characteristic	Symbol	LM224			LM324A			LM324			LM2902			LM2902V/NCV2902			Unit
		Min	Typ	Max	Min	Typ	Max										
Input Offset Voltage $V_{CC} = 5.0$ V to 30 V $V_{ICR} = 0$ V to $V_{CC} - 1.7$ V, $V_O = 1.4$ V, $R_B = 0 \Omega$ $T_A = 25^\circ C$ $T_A = T_{high}$ (Note 5) $T_A = T_{low}$ (Note 5)	V_{IO}	-	2.0	5.0	-	2.0	3.0	-	2.0	7.0	-	2.0	7.0	-	2.0	7.0	mV
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{high}$ to T_{low} (Notes 5 and 7)	$\Delta V_{IO}/\Delta T$	-	7.0	-	-	7.0	30	-	7.0	-	-	7.0	-	-	7.0	-	$\mu V/^\circ C$
Input Offset Current $T_A = T_{high}$ to T_{low} (Note 5)	I_{IO}	-	3.0	30	-	5.0	30	-	5.0	30	-	5.0	50	-	5.0	50	nA
Average Temperature Coefficient of Input Offset Current $T_A = T_{high}$ to T_{low} (Notes 5 and 7)	$\Delta I_{IO}/\Delta T$	-	10	-	-	10	300	-	10	-	-	10	-	-	10	-	pA/°C
Input Bias Current $T_A = T_{high}$ to T_{low} (Note 5)	I_B	-	-90	-150	-	-45	-100	-	-90	-250	-	-90	-250	-	-90	-250	nA
Input Common Mode Voltage Range (Note 6) $V_{CC} = 30$ V $T_A = +25^\circ C$ $T_A = T_{high}$ to T_{low} (Note 5)	V_{ICR}	0 0	-	26.3 28	0 0	-	26.3 28	V									
Differential Input Voltage Range	V_{IDR}	-	-	V_{CC}	-	-	V_{CC}	V									
Large Signal Open Loop Voltage Gain $R_L = 2.0 \text{ k}\Omega$, $V_{CC} = 15$ V, for Large V_O Swing $T_A = T_{high}$ to T_{low} (Note 5)	A_{VOL}	50 25	100 -	-	25 15	100 -	V/mV										
Channel Separation 10 kHz $\leq f \leq$ 20 kHz, Input Referenced	CS	-	-120	-	-	-120	-	-	-120	-	-	-120	-	-	-120	-	dB
Common Mode Rejection, $R_B \leq 10 \text{ k}\Omega$	CMR	70	85	-	65	70	-	65	70	-	50	70	-	50	70	-	dB
Power Supply Rejection	PSR	65	100	-	65	100	-	65	100	-	50	100	-	50	100	-	dB

5. LM224: $T_{low} = -25^\circ C$, $T_{high} = +85^\circ C$
 LM324/LM324A: $T_{low} = 0^\circ C$, $T_{high} = +70^\circ C$
 LM2902: $T_{low} = -40^\circ C$, $T_{high} = +105^\circ C$
 LM2902V & NCV2902: $T_{low} = -40^\circ C$, $T_{high} = +125^\circ C$
NCV2902 is qualified for automotive use.
6. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is $V_{CC} - 1.7$ V, but either or both inputs can go to +32 V without damage, independent of the magnitude of V_{CC} .
7. Guaranteed by design.

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

ELECTRICAL CHARACTERISTICS ($V_{CC} = 5.0$ V, $V_{EE} = GND$, $T_A = 25^\circ C$, unless otherwise noted.)

Characteristics	Symbol	LM224			LM324A			LM324			LM2902			LM2902V/NCV2902			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Output Voltage - High Limit $V_{CC} = 5.0$ V, $R_L = 2.0$ k Ω , $T_A = 25^\circ C$ $V_{CC} = 30$ V $R_L = 2.0$ k Ω ($T_A = T_{High}$ to T_{Low}) (Note 8)	V_{OH}	3.3	3.5	-	3.3	3.5	-	3.3	3.5	-	3.3	3.5	-	3.3	3.5	-	V
$V_{CC} = 30$ V $R_L = 2.0$ k Ω ($T_A = T_{High}$ to T_{Low}) (Note 8)		28	-	-	28	-	-	28	-	-	28	-	-	28	-	-	
$V_{CC} = 30$ V $R_L = 10$ k Ω ($T_A = T_{High}$ to T_{Low}) (Note 8)		27	28	-	27	28	-	27	28	-	27	28	-	27	28	-	
Output Voltage - Low Limit, $V_{CC} = 5.0$ V, $R_L = 10$ k Ω , $T_A = T_{High}$ to T_{Low} (Note 8)	V_{OL}	-	5.0	20	-	5.0	20	-	5.0	20	-	5.0	100	-	5.0	100	mV
Output Source Current ($V_D = +1.0$ V, $V_{CC} = 15$ V) $T_A = 25^\circ C$ $T_A = T_{High}$ to T_{Low} (Note 8)	I_{O+}	20	40	-	20	40	-	20	40	-	20	40	-	20	40	-	mA
		10	20	-	10	20	-	10	20	-	10	20	-	10	20	-	
Output Sink Current ($V_D = -1.0$ V, $V_{CC} = 15$ V) $T_A = 25^\circ C$ $T_A = T_{High}$ to T_{Low} (Note 8) ($V_D = -1.0$ V, $V_O = 200$ mV, $T_A = 25^\circ C$)	I_{O-}	10	20	-	10	20	-	10	20	-	10	20	-	10	20	-	mA
		5.0	8.0	-	5.0	8.0	-	5.0	8.0	-	5.0	8.0	-	5.0	8.0	-	
		12	50	-	12	50	-	12	50	-	12	50	-	12	50	-	μA
Output Short Circuit to Ground (Note 9)	I_{SC}	-	40	60	-	40	60	-	40	60	-	40	60	-	40	60	mA
Power Supply Current ($T_A = T_{High}$ to T_{Low}) (Note 8)	I_{OC}	-	-	3.0	-	1.4	3.0	-	-	3.0	-	-	3.0	-	-	3.0	mA
$V_{CC} = 30$ V $V_O = 0$ V, $R_L = \infty$ $V_{CC} = 5.0$ V, $V_O = 0$ V, $R_L = \infty$		-	-	1.2	-	0.7	1.2	-	-	1.2	-	-	1.2	-	-	1.2	

8. LM224: $T_{low} = -25^\circ C$, $T_{high} = +85^\circ C$
 LM324/LM324A: $T_{low} = 0^\circ C$, $T_{high} = +70^\circ C$
 LM2902: $T_{low} = -40^\circ C$, $T_{high} = +105^\circ C$
 LM2902V & NCV2902: $T_{low} = -40^\circ C$, $T_{high} = +125^\circ C$
NCV2902 is qualified for automotive use.
9. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is $V_{CC} - 1.7$ V, but either or both inputs can go to +32 V without damage, independent of the magnitude of V_{CC} .

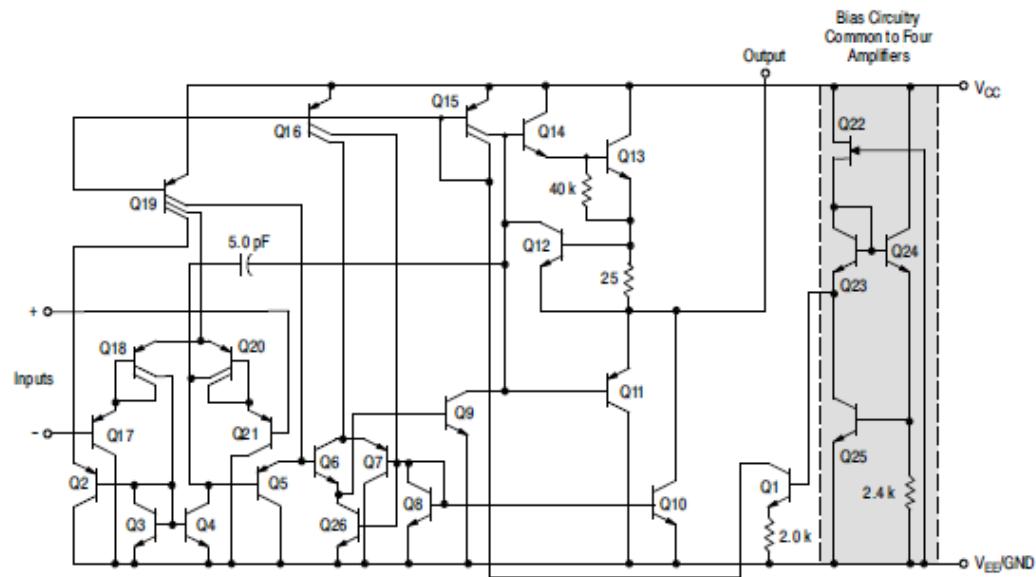
LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

Figure 1. Representative Circuit Diagram
(One-Fourth of Circuit Shown)

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

CIRCUIT DESCRIPTION

The LM324 series is made using four internally compensated, two-stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance, a smaller compensation capacitor (only 5.0 pF) can be employed, thus saving chip area. The transconductance reduction is accomplished by splitting the collectors of Q20 and Q18. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single-ended converter. The second stage consists of a standard current source load amplifier stage.



Figure 3.

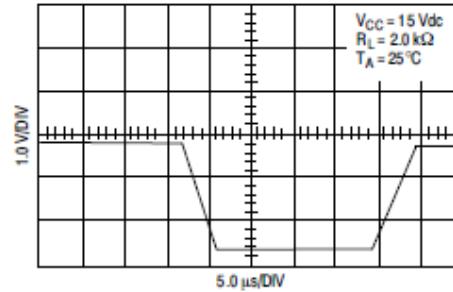


Figure 2. Large Signal Voltage Follower Response

Each amplifier is biased from an internal-voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.

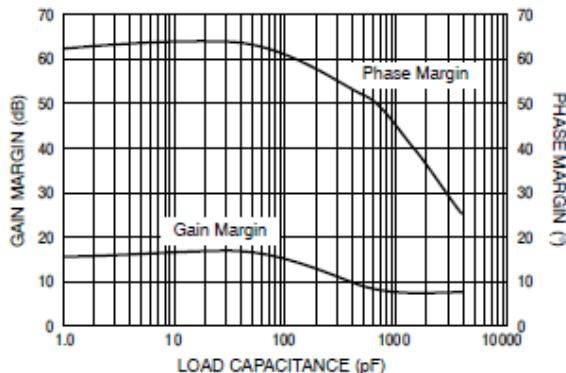


Figure 4. Gain and Phase Margin

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

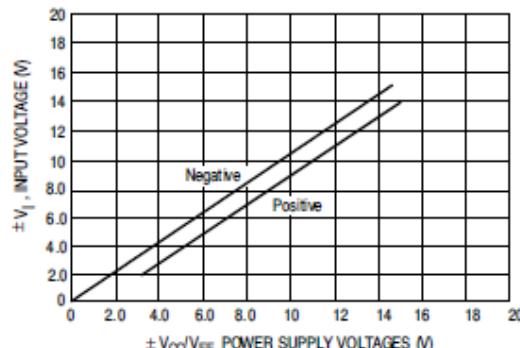


Figure 5. Input Voltage Range

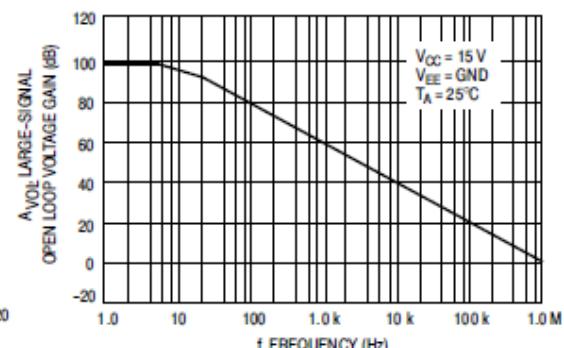


Figure 6. Open Loop Frequency

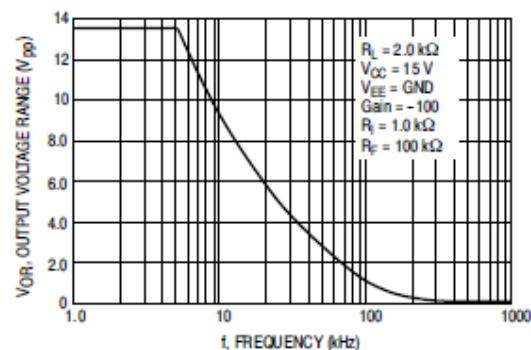


Figure 7. Large-Signal Frequency Response

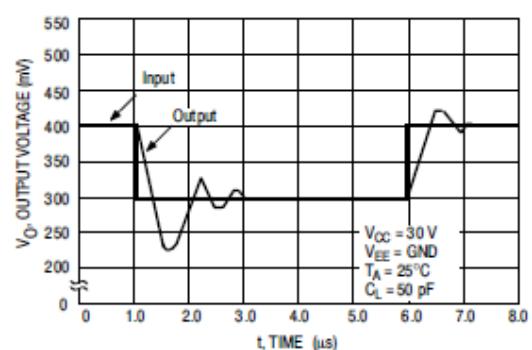


Figure 8. Small-Signal Voltage Follower Pulse Response (Noninverting)

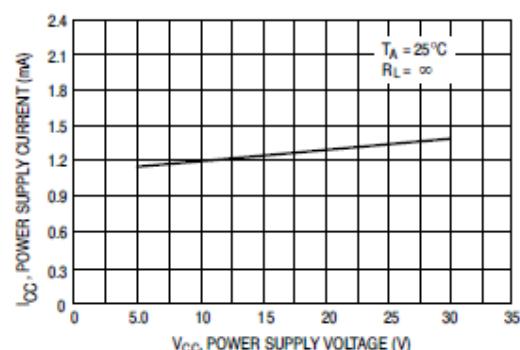


Figure 9. Power Supply Current versus Power Supply Voltage

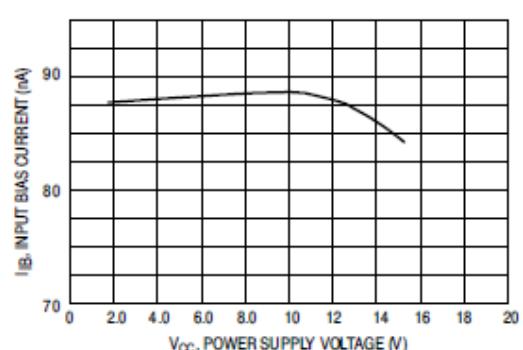


Figure 10. Input Bias Current versus Power Supply Voltage

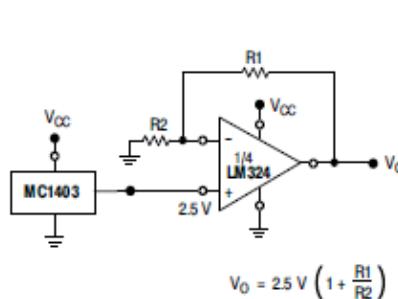
LM324, LM324A, LM224, LM2902, LM2902V, NCV2902


Figure 11. Voltage Reference

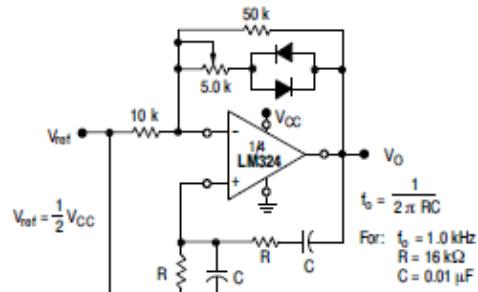


Figure 12. Wien Bridge Oscillator

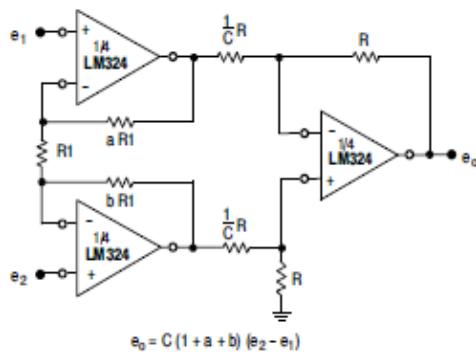


Figure 13. High Impedance Differential Amplifier

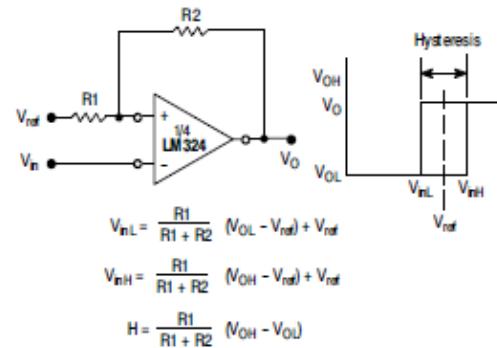


Figure 14. Comparator with Hysteresis

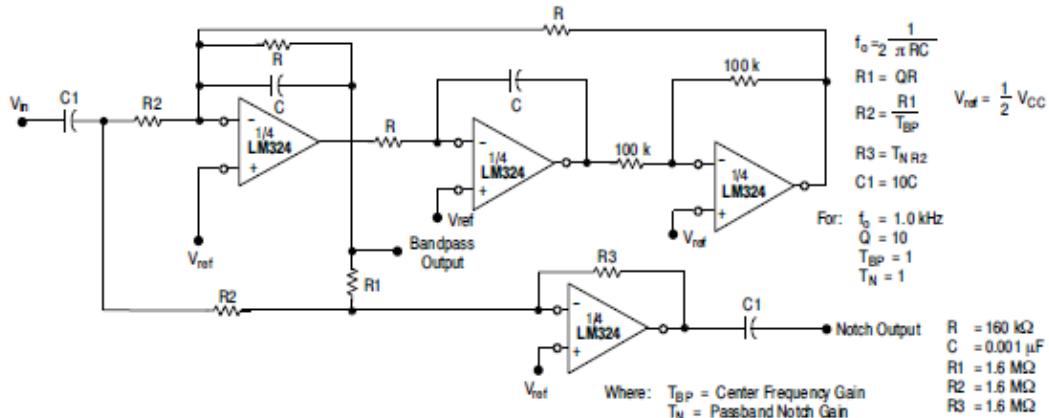


Figure 15. Bi-Quad Filter

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

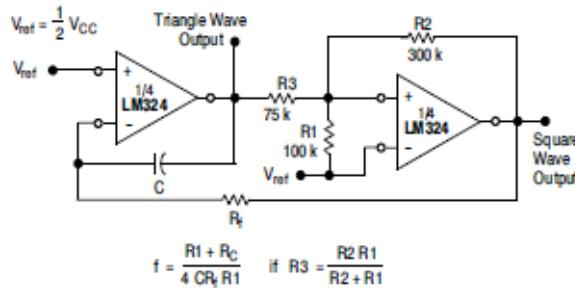


Figure 16. Function Generator

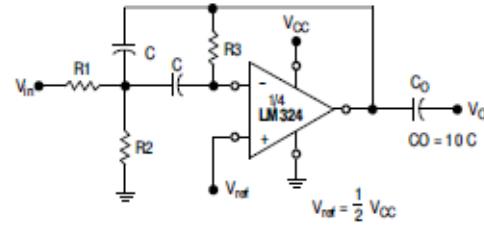


Figure 17. Multiple Feedback Bandpass Filter

Given: f_0 = center frequency
 $A(f_0)$ = gain at center frequency

Choose value f_0, C

$$\begin{aligned} \text{Then: } R_3 &= \frac{Q}{\pi f_0 C} \\ R_1 &= \frac{R_3}{2 A(f_0)} \\ R_2 &= \frac{R_1 R_3}{4 Q^2 R_1 - R_3} \end{aligned}$$

For less than 10% error from operational amplifier, $\frac{Q_0 f_0}{BW} < 0.1$
where f_0 and BW are expressed in Hz.

If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

ORDERING INFORMATION

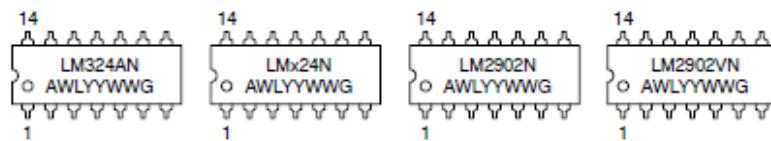
Device	Operating Temperature Range	Package	Shipping [†]
LM224DG	-25°C to +85°C	SOIC-14	55 Units/Rail
LM224DR2G		SOIC-14	2500/Tape & Reel
LM224DTBG		TSSOP-14	96 Units/Tube
LM224DTBR2G		TSSOP-14	2500/Tape & Reel
LM224NG		PDIP-14	25 Units/Rail
LM324DG	0°C to +70°C	SOIC-14	55 Units/Rail
LM324DR2G		SOIC-14	2500/Tape & Reel
LM324DTBG		TSSOP-14	96 Units/Tube
LM324DTBR2G		TSSOP-14	2500/Tape & Reel
LM324NG		PDIP-14	25 Units/Rail
LM324ADG		SOIC-14	55 Units/Rail
LM324ADR2G		SOIC-14	2500/Tape & Reel
LM324ADTBG		TSSOP-14	96 Units/Tube
LM324ADTBR2G		TSSOP-14	2500/Tape & Reel
LM324ANG		PDIP-14	25 Units/Rail
LM2902DG	-40°C to +105°C	SOIC-14	55 Units/Rail
LM2902DR2G		SOIC-14	2500/Tape & Reel
LM2902DTBG		TSSOP-14	96 Units/Tube
LM2902DTBR2G		TSSOP-14	2500/Tape & Reel
LM2902NG		PDIP-14	25 Units/Rail
LM2902VDG	-40°C to +125°C	SOIC-14	55 Units/Rail
LM2902VDR2G		SOIC-14	2500/Tape & Reel
LM2902VDTBG		TSSOP-14	96 Units/Tube
LM2902VDTBR2G		TSSOP-14	2500/Tape & Reel
LM2902VNG		PDIP-14	25 Units/Rail
NCV2902DR2G		SOIC-14	2500/Tape & Reel
NCV2902DTBR2G		TSSOP-14	

[†]For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD6011/D.

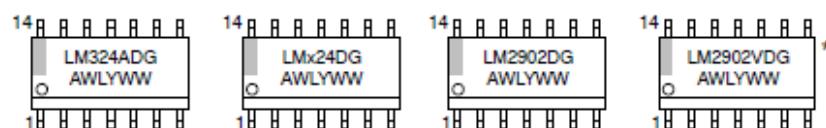
LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

MARKING DIAGRAMS

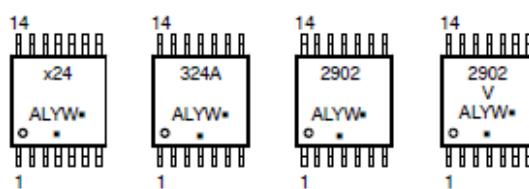
PDIP-14
N SUFFIX
CASE 646



SOIC-14
D SUFFIX
CASE 751A



TSSOP-14
DTB SUFFIX
CASE 948G



x = 2 or 3
 A = Assembly Location
 WL, L = Wafer Lot
 YY, Y = Year
 WW, W = Work Week
 G or * = Pb-Free Package

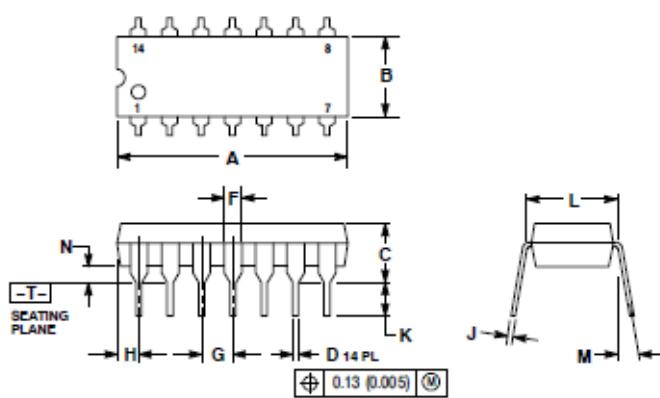
(Note: Microdot may be in either location)

*This marking diagram also applies to NCV2902.

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

PACKAGE DIMENSIONS

PDIP-14
CASE 646-06
ISSUE P



NOTES:

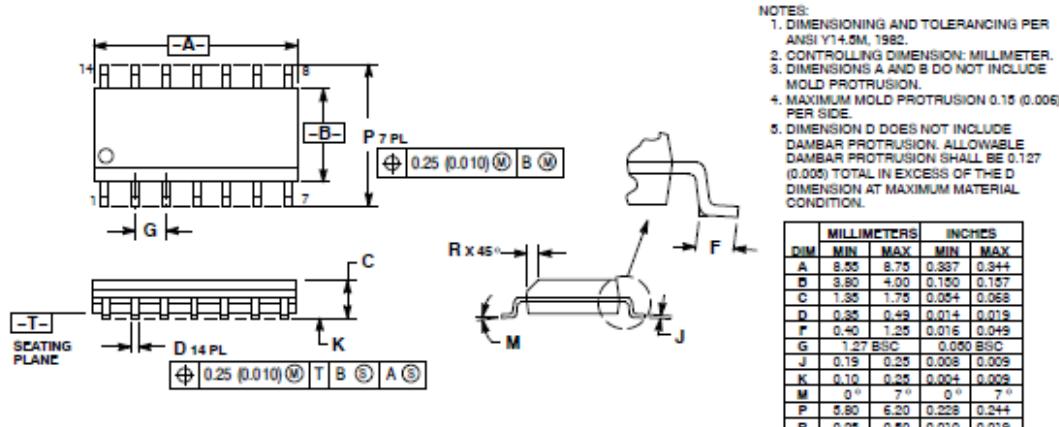
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
4. DIMENSION B DOES NOT INCLUDE MOLD FLASH.
5. ROUNDED CORNERS OPTIONAL.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.715	0.770	18.16	19.56
B	0.240	0.260	6.10	6.60
C	0.145	0.185	3.69	4.69
D	0.015	0.021	0.38	0.53
F	0.040	0.070	1.02	1.78
G	0.100 BSC	0.154 BSC	2.54 BSC	3.92 BSC
H	0.052	0.095	1.32	2.41
J	0.008	0.015	0.20	0.38
K	0.115	0.185	2.92	4.69
L	0.290	0.310	7.37	7.87
M	—	10"	—	10"
N	0.015	0.039	0.38	1.01

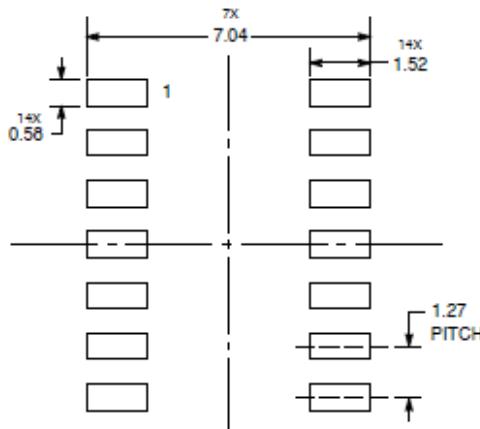
LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

PACKAGE DIMENSIONS

SOIC-14
CASE 751A-03
ISSUE H



SOLDERING FOOTPRINT*



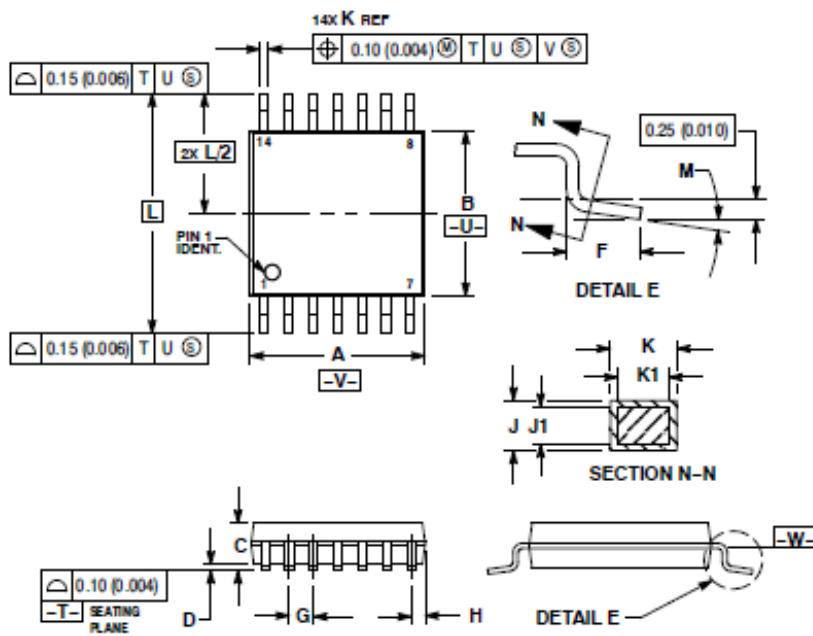
DIMENSIONS: MILLIMETERS

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

LM324, LM324A, LM224, LM2902, LM2902V, NCV2902

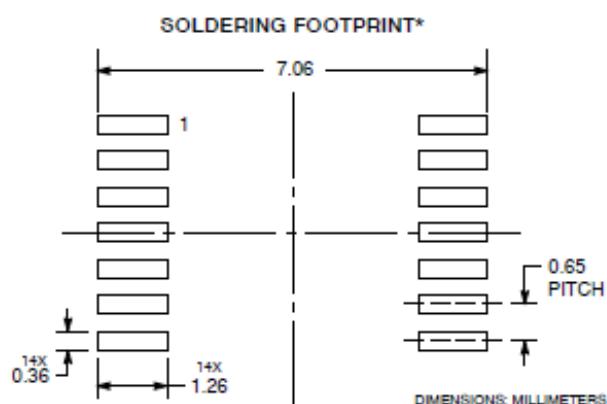
PACKAGE DIMENSIONS

TSSOP-14
CASE 948G-01
ISSUE B



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
 2. CONTROLLING DIMENSION: MILLIMETER.
 3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
 4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
 5. DIMENSION K DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.06 (0.002) TOTAL IN EXCESS OF THE K DIMENSION AT MAXIMUM MATERIAL CONDITION.
 6. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.
 7. DIMENSION A AND B ARE TO BE DETERMINED AT DATUM PLANE -W-.

	MILLIMETERS	INCHES		
DIM	MIN	MAX	MIN	MAX
A	4.90	5.10	0.193	0.200
B	4.30	4.50	0.169	0.177
C	—	1.20	—	0.047
D	0.05	0.15	0.002	0.006
F	0.30	0.75	0.020	0.030
G	0.55 BSC	0.60 BSC	—	—
H	0.50	0.60	0.020	0.024
J	0.09	0.20	0.004	0.008
J1	0.09	0.16	0.004	0.006
K	0.13	0.30	0.007	0.012
K1	0.19	0.25	0.007	0.010
L	6.40 BSC	6.50 BSC	0.252 BSC	0.256 BSC
M	0 "	8 "	0 "	8 "



*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.



ACS714

**Automotive Grade, Fully Integrated, Hall Effect-Based Linear Current Sensor IC
with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor**

Features and Benefits

- Low-noise analog signal path
- Device bandwidth is set via the FILTER pin
- 5 μ s output rise time in response to step input current
- 80 kHz bandwidth
- Total output error 1.5% typical, at $T_A = 25^\circ\text{C}$
- Small footprint, low-profile SOIC8 package
- 1.2 m Ω internal conductor resistance
- 2.1 kVRMS minimum isolation voltage from pins 1-4 to pins 5-8
- 5.0 V, single supply operation
- 66 to 185 mV/A output sensitivity
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis
- Ratiometric output from supply voltage
- Operating temperature range, -40°C to 150°C



TÜV America
Certificate Number:
UV 06 05 54214 010



Package: 8 pin SOIC (suffix LC)



Approximate Scale 1:1



Description

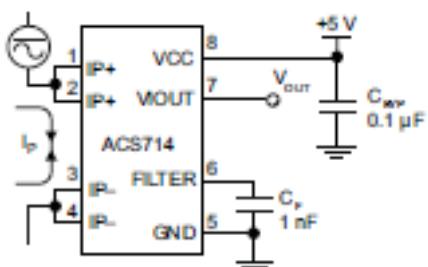
The Allegro® ACS714 provides economical and precise solutions for AC or DC current sensing in automotive systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switch-mode power supplies, and overcurrent fault protection.

The device consists of a precise, low-offset, linear Hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging.

The output of the device has a positive slope ($>V_{OUT/I_p}$) when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sampling. The internal resistance of this conductive path is 1.2 m Ω typical, providing low power loss. The thickness of the copper conductor allows survival of the device at up to 5 \times overcurrent conditions. The terminals of

Continued on the next page...

Typical Application



Application 1. The ACS714 outputs an analog signal, V_{OUT} , that varies linearly with the uni- or bi-directional AC or DC primary sampled current, I_p , within the range specified. C_v is recommended for noise management, with values that depend on the application.

ACS714

*Automotive Grade, Fully Integrated, Hall Effect-Based Linear Current Sensor IC
with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor*

Description (continued)

the conductive path are electrically isolated from the signal leads (pins 5 through 8). This allows the ACS714 to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

The ACS714 is provided in a small, surface mount SOIC8 package.

The leadframe is plated with 100% matte tin, which is compatible with standard lead (Pb) free printed circuit board assembly processes. Internally, the device is Pb-free, except for flip-chip high-temperature Pb-based solder balls, currently exempt from RoHS. The device is fully calibrated prior to shipment from the factory.

Selection Guide

Part Number	Optimized Range, I_p (A)	Sensitivity, Sens (Typ) (mV/A)	T_A (°C)	Packing*
AC8714ELCTR-05B-T	±5	185	-40 to 85	Tape and reel, 3000 pieces/reel
AC8714ELCTR-20A-T	±20	100		
AC8714ELCTR-30A-T	±30	66		
AC8714LLCTR-05B-T	±5	185		
AC8714LLCTR-20A-T	±20	100		
AC8714LLCTR-30A-T	±30	66		

*Contact Allegro for additional packing options.

Absolute Maximum Ratings

Characteristic	Symbol	Notes	Rating	Units
Supply Voltage	V_{DD}		8	V
Reverse Supply Voltage	V_{RDO}		-0.1	V
Output Voltage	V_{OUT}		8	V
Reverse Output Voltage	V_{REOUT}		-0.1	V
Reinforced Isolation Voltage	V_{ISO}	Pins 1-4 and 5-8; 60 Hz, 1 minute, $T_A=25^\circ\text{C}$	2100	VAC
		Maximum working voltage according to UL60950-1	184	V_{peak}
Basic Isolation Voltage	$V_{ISO(BAS)}$	Pins 1-4 and 5-8; 60 Hz, 1 minute, $T_A=25^\circ\text{C}$	1500	VAC
		Maximum working voltage according to UL60950-1	354	V_{peak}
Output Current Source	$I_{OUT(SOURCE)}$		3	mA
Output Current Sink	$I_{OUT(SINK)}$		10	mA
Overcurrent Transient Tolerance	I_p	1 pulse, 100 ms	100	A
Nominal Operating Ambient Temperature	T_A	Range E	-40 to 85	°C
		Range L	-40 to 150	°C
Maximum Junction Temperature	$T_J(max)$		165	°C
Storage Temperature	T_{STG}		-65 to 170	°C



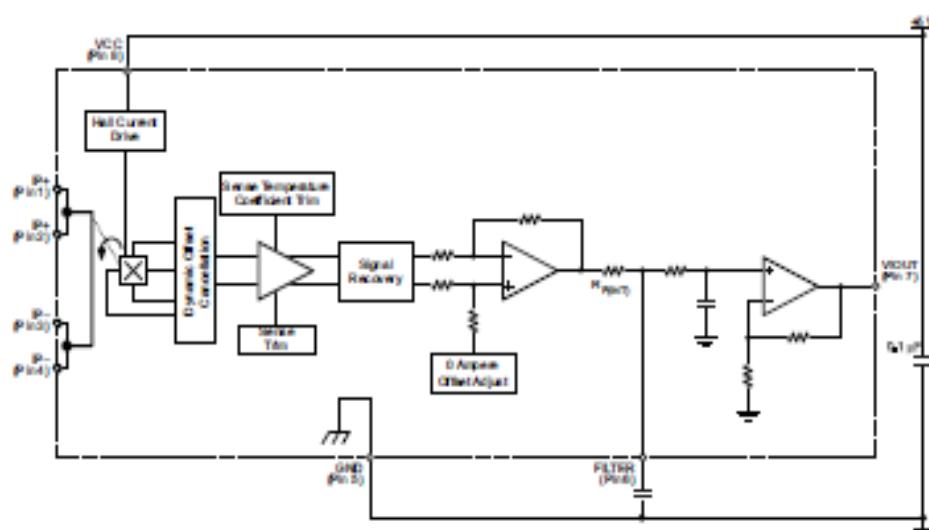
TÜV America
Certificate Number:
UBV 06 05 54214 010

Parameter	Specification
Fire and Electric Shock	CAN/CSA-C22.2 No. 60950-1-03 UL 60950-1:2003 EN 60950-1:2001

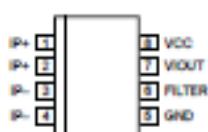
ACS714

*Automotive Grade, Fully Integrated, Hall Effect-Based Linear Current Sensor IC
with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor*

Functional Block Diagram



Pin-out Diagram



Terminal List Table

Number	Name	Description
1 and 2	IP+	Terminals for current being sampled; fused internally
3 and 4	IP-	Terminals for current being sampled; fused internally
5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

ACS714

*Automotive Grade, Fully Integrated, Hall Effect-Based Linear Current Sensor IC
with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor*

x30A PERFORMANCE CHARACTERISTICS over Range E: $T_A = -40^\circ\text{C}$ to 85°C ¹, $C_F = 1 \text{ nF}$, and $V_{DD} = 5 \text{ V}$, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_p		-30	-	30	A
Sensitivity	Sens	Over full range of I_p , $T_A = 25^\circ\text{C}$	64	66	68	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, $T_A = 25^\circ\text{C}$, 66 mV/A programmed Sensitivity, $C_F = 47 \text{ nF}$, C_{OUT} = open, 2 kHz bandwidth	-	7	-	mV
Zero Current Output Slope	$\Delta I_{OUT(0)}$	$T_A = -40^\circ\text{C}$ to 25°C	-	-0.35	-	mV/C
		$T_A = 25^\circ\text{C}$ to 150°C	-	-0.08	-	mV/C
Sensitivity Slope	ΔSens	$T_A = -40^\circ\text{C}$ to 25°C	-	0.007	-	mV/A/C
		$T_A = 25^\circ\text{C}$ to 150°C	-	-0.002	-	mV/A/C
Electrical Output Voltage	V_{OE}	$I_p = 0 \text{ A}$	-30	-	30	mV
Total Output Error ²	E_{TOT}	$I_p = \pm 30 \text{ A}$, $T_A = 25^\circ\text{C}$	-	± 1.5	-	%

¹Device may be operated at higher primary current levels, I_p , and ambient temperatures, T_A , provided that the Maximum Junction Temperature, $T_J(\text{max})$, is not exceeded.

²Percentage of I_p , with $I_p = 30 \text{ A}$. Output filtered.

x30A PERFORMANCE CHARACTERISTICS over Range L: $T_A = -40^\circ\text{C}$ to 150°C ¹, $C_F = 1 \text{ nF}$, and $V_{DD} = 5 \text{ V}$, unless otherwise specified

Characteristic	Symbol	Test Conditions	Min.	Typ.	Max.	Units
Optimized Accuracy Range	I_p		-30	-	30	A
Sensitivity	Sens	Over full range of I_p , $T_A = 25^\circ\text{C}$	-	66	-	mV/A
		Over full range of I_p , $T_A = -40^\circ\text{C}$ to 150°C	63	-	69	mV/A
Noise	$V_{NOISE(PP)}$	Peak-to-peak, $T_A = 25^\circ\text{C}$, 66 mV/A programmed Sensitivity, $C_F = 47 \text{ nF}$, C_{OUT} = open, 2 kHz bandwidth	-	7	-	mV
Zero Current Output Slope	$\Delta I_{OUT(0)}$	$T_A = -40^\circ\text{C}$ to 25°C	-	-0.35	-	mV/C
		$T_A = 25^\circ\text{C}$ to 150°C	-	-0.08	-	mV/C
Sensitivity Slope	ΔSens	$T_A = -40^\circ\text{C}$ to 25°C	-	0.007	-	mV/A/C
		$T_A = 25^\circ\text{C}$ to 150°C	-	-0.002	-	mV/A/C
Electrical Output Voltage	V_{OE}	$I_p = 0 \text{ A}$	-40	-	40	mV
Total Output Error ²	E_{TOT}	$I_p = \pm 30 \text{ A}$, $T_A = 25^\circ\text{C}$	-	± 1.5	-	%
		$I_p = \pm 30 \text{ A}$, $T_A = -40^\circ\text{C}$ to 150°C	-5	-	5	%

¹Device may be operated at higher primary current levels, I_p , and ambient temperatures, T_A , provided that the Maximum Junction Temperature, $T_J(\text{max})$, is not exceeded.

²Percentage of I_p , with $I_p = 30 \text{ A}$. Output filtered.

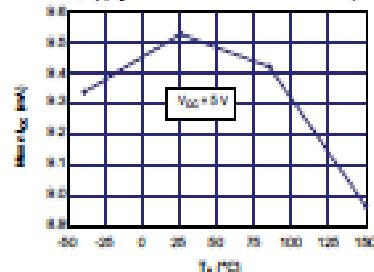
ACS714

*Automotive Grade, Fully Integrated, Hall Effect-Based Linear Current Sensor IC
with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor*

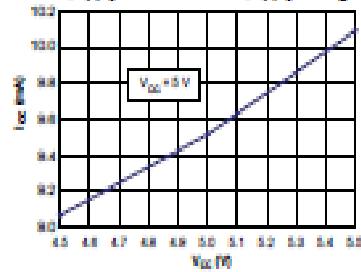
Characteristic Performance

$I_p = 30\text{ A}$, unless otherwise specified

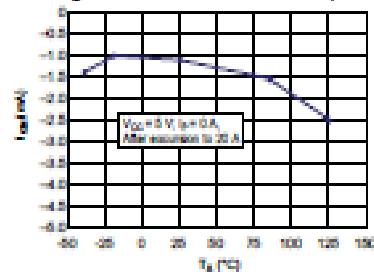
Mean Supply Current versus Ambient Temperature



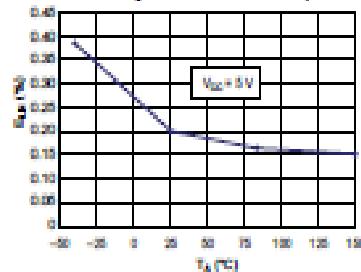
Supply Current versus Supply Voltage



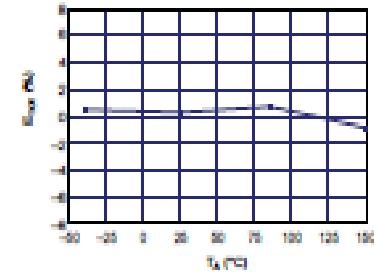
Magnetic Offset versus Ambient Temperature



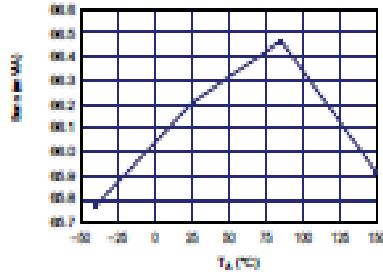
Nonlinearity versus Ambient Temperature



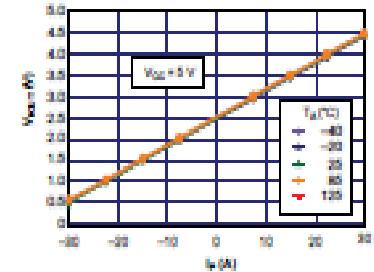
Mean Total Output Error versus Ambient Temperature



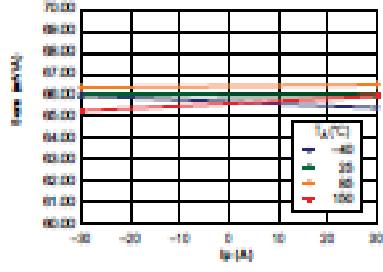
Sensitivity versus Ambient Temperature



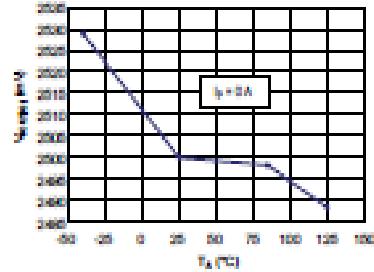
Output Voltage versus Sensed Current



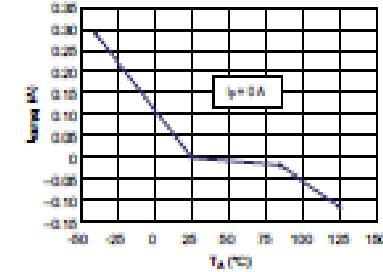
Sensitivity versus Sensed Current



0 A Output Voltage versus Ambient Temperature



0 A Output Voltage Current versus Ambient Temperature



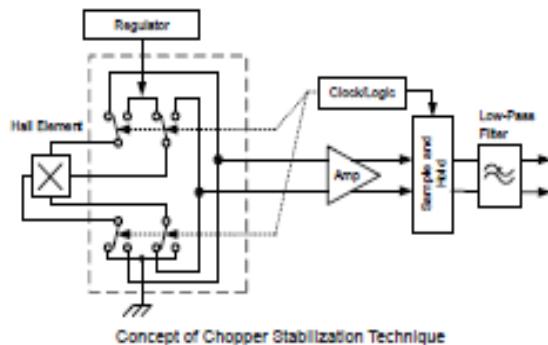
ACS714

Automotive Grade, Fully Integrated, Hall Effect-Based Linear Current Sensor IC with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor

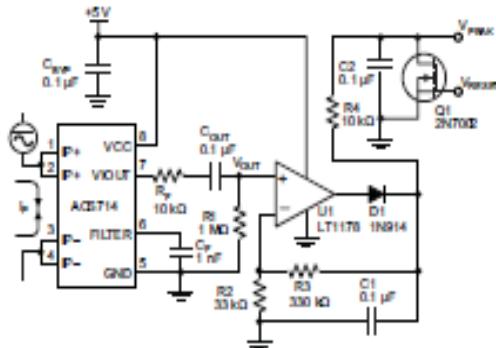
Chopper Stabilization Technique

Chopper Stabilization is an innovative circuit technique that is used to minimize the offset voltage of a Hall element and an associated on-chip amplifier. Allegro patented a Chopper Stabilization technique that nearly eliminates Hall IC output drift induced by temperature or package stress effects. This offset reduction technique is based on a signal modulation-demodulation process. Modulation is used to separate the undesired DC offset signal from the magnetically induced signal in the frequency domain. Then, using a low-pass filter, the modulated DC offset is suppressed while the magnetically induced signal passes through the filter. As a result of this chopper stabilization approach, the output voltage from the Hall IC is desensitized to the effects of temperature and mechanical stress. This technique produces devices that have an extremely stable Electrical Offset Voltage, are immune to thermal stress, and have precise recoverability after temperature cycling.

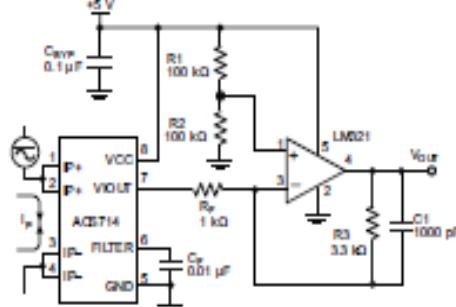
This technique is made possible through the use of a BiCMOS process that allows the use of low-offset and low-noise amplifiers in combination with high-density logic integration and sample and hold circuits.



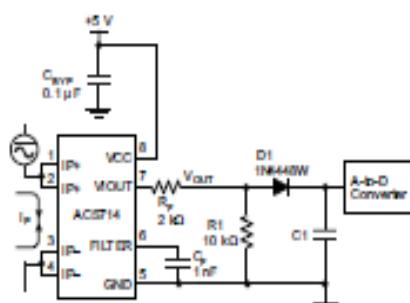
Typical Applications



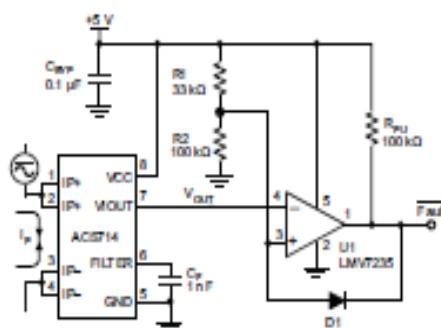
Application 2. Peak Detecting Circuit



Application 3. This configuration Increases gain to 610 mV/A (tested using the ACS714ELC-05A).



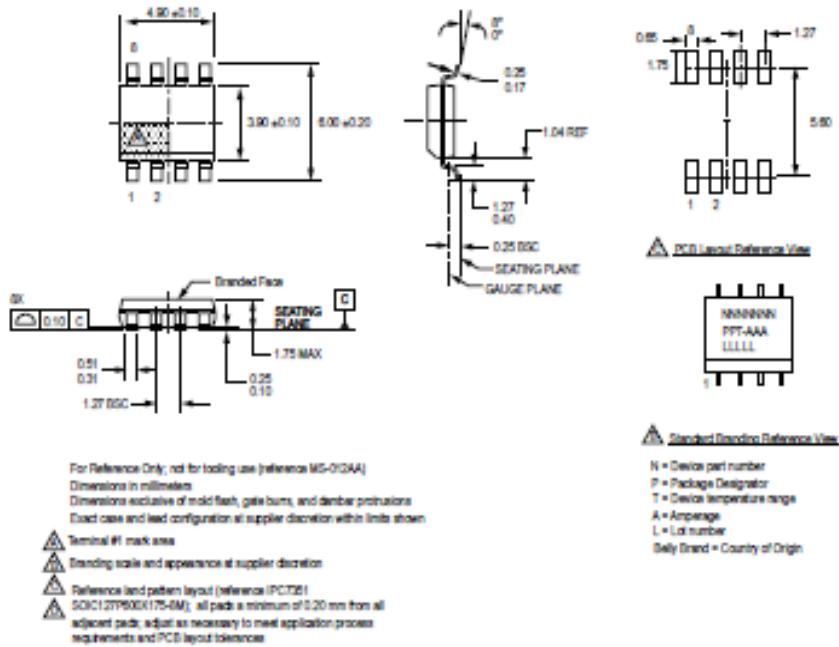
Application 4. Rectified Output. 3.3 V scaling and rectification application for A-to-D converters. Replaces current transformer solutions with simpler ACS circuit. C1 is a function of the load resistance and filtering desired. R1 can be omitted if the full range is desired.



Application 5. 10 A Overcurrent Fault Latch. Fault threshold set by R1 and R2. This circuit latches an overcurrent fault and holds it until the 5 V rail is powered down.

ACS714

*Automotive Grade, Fully Integrated, Hall Effect-Based Linear Current Sensor IC
with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor*

Package LC, 8-pin SOIC

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April 2007

LM1575/LM2575/LM2575HV SIMPLE SWITCHER® 1A Step-Down Voltage Regulator

General Description

The LM2575 series of regulators are monolithic integrated circuits that provide all the active functions for a step-down (buck) switching regulator, capable of driving a 1A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3V, 5V, 12V, 15V, and an adjustable output version.

Requiring a minimum number of external components, these regulators are simple to use and include internal frequency compensation and a fixed-frequency oscillator.

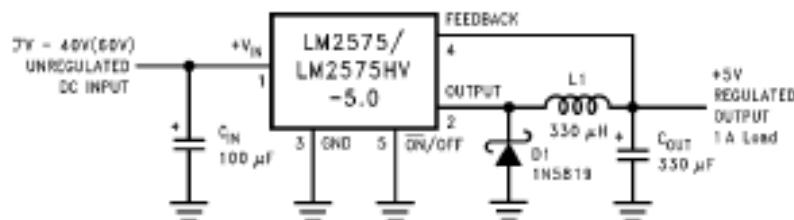
The LM2575 series offers a high-efficiency replacement for popular three-terminal linear regulators. It substantially reduces the size of the heat sink, and in many cases no heat sink is required.

A standard series of inductors optimized for use with the LM2575 are available from several different manufacturers. This feature greatly simplifies the design of switch-mode power supplies.

Other features include a guaranteed $\pm 4\%$ tolerance on output voltage within specified input voltage and output load conditions, and $\pm 10\%$ on the oscillator frequency. External shutdown is included, featuring 50 μ A (typical) standby current. The output switch includes cycle-by-cycle current limiting, as well as thermal shutdown for full protection under fault conditions.

Typical Application

(Fixed Output Voltage Versions)



Note: Pin numbers are for the TO-220 package.

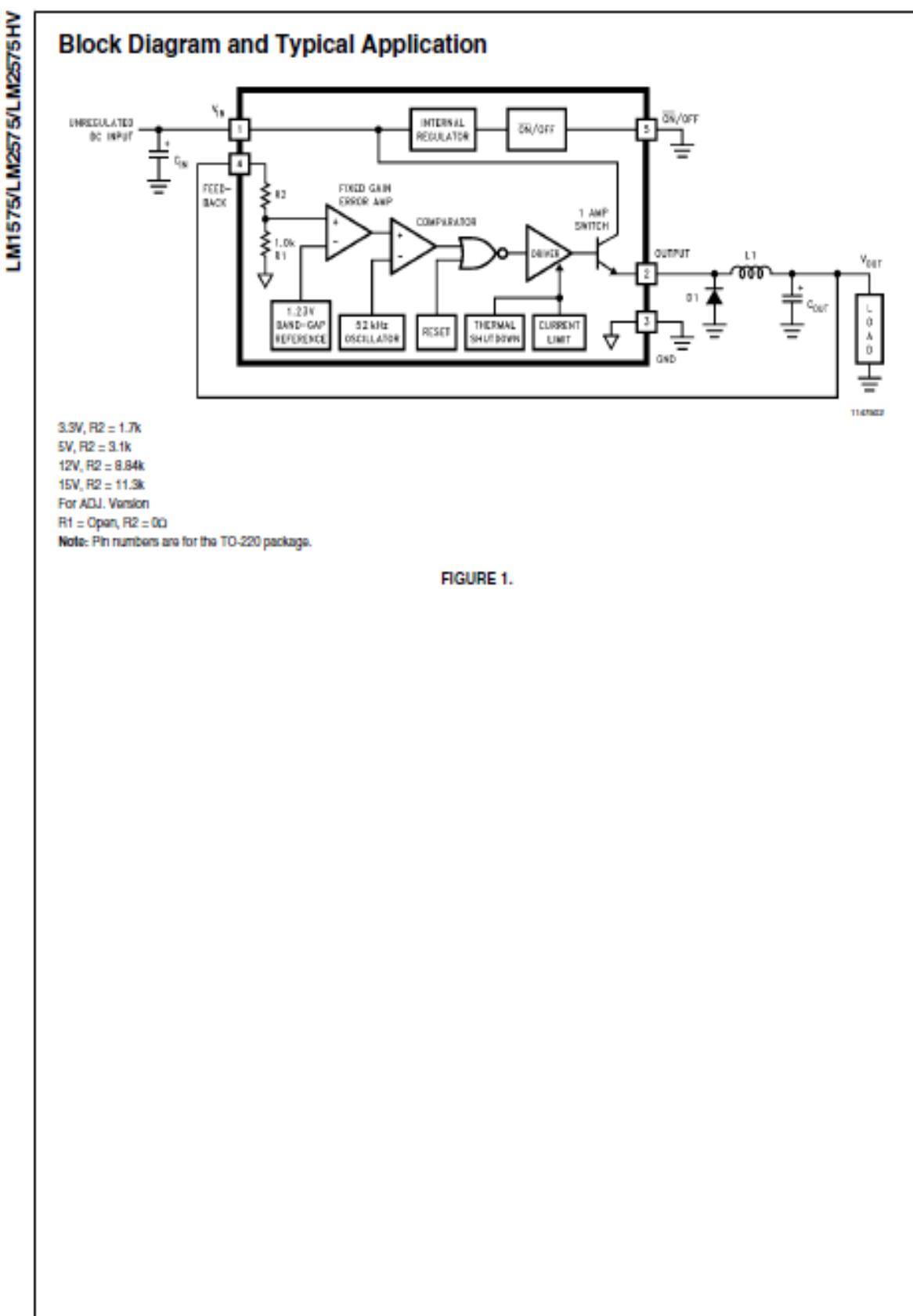
Features

- 3.3V, 5V, 12V, 15V, and adjustable output versions
- Adjustable version output voltage range, 1.23V to 37V (57V for HV version) $\pm 4\%$ max over line and load conditions
- Guaranteed 1A output current
- Wide input voltage range, 40V up to 60V for HV version
- Requires only 4 external components
- 52 kHz fixed frequency internal oscillator
- TTL shutdown capability, low power standby mode
- High efficiency
- Uses readily available standard inductors
- Thermal shutdown and current limit protection
- P+ Product Enhancement tested

Applications

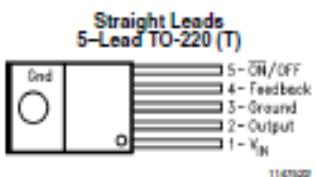
- Simple high-efficiency step-down (buck) regulator
- Efficient pre-regulator for linear regulators
- On-card switching regulators
- Positive to negative converter (Buck-Boost)

SIMPLE SWITCHER® is a registered trademark of National Semiconductor Corporation.

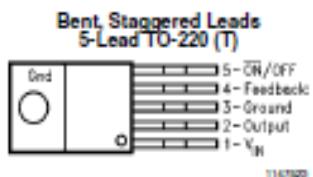


Connection Diagrams

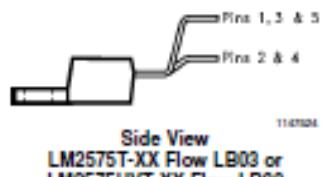
(XX indicates output voltage option. See Ordering Information table for complete part number.)



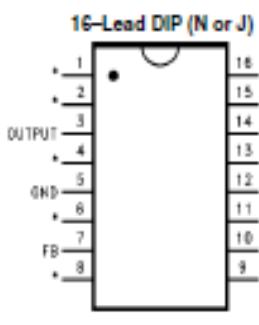
Top View
LM2575T-XX or LM2575HVT-XX
See NS Package Number T05A



Top View

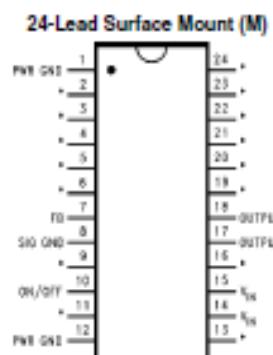


Side View
LM2575T-XX Flow LB03 or
LM2575HVT-XX Flow LB03
See NS Package Number T05D



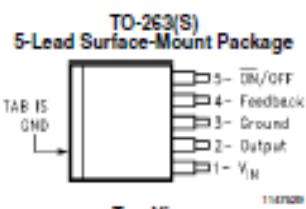
*No Internal Connection

Top View
LM2575N-XX or LM2575HVN-XX
See NS Package Number N16A
LM1575J-XX-OML
See NS Package Number J16A



*No Internal Connection

Top View
LM2575M-XX or LM2575HVM-XX
See NS Package Number M24B



Top View



Side View
LM2575S-XX or LM2575HVS-XX
See NS Package Number TS5B

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Maximum Supply Voltage LM1575/LM2575	45V
LM2575HV	63V
ON/OFF Pin Input Voltage	$-0.3V \leq V \leq +V_{IN}$
Output Voltage to Ground (Steady State)	-1V
Power Dissipation	Internally Limited
Storage Temperature Range	-65°C to +150°C
Maximum Junction Temperature	150°C

Minimum ESD Rating

(C = 100 pF, R = 1.5 kΩ) 2 kV

Load Temperature 260°C

(Soldering, 10 sec.)

Operating Ratings

Temperature Range	LM1575	$-55^{\circ}\text{C} \leq T_J \leq +150^{\circ}\text{C}$
LM2575/LM2575HV		$-40^{\circ}\text{C} \leq T_J \leq +125^{\circ}\text{C}$
Supply Voltage	LM1575/LM2575	40V
LM2575HV		60V

LM1575-3.3, LM2575-3.3, LM2575HV-3.3 Electrical Characteristics

Specifications with standard type face are for $T_J = 25^{\circ}\text{C}$, and those with boldface type apply over full Operating Temperature Range.

Symbol	Parameter	Conditions	Typ	LM1575-3.3	LM2575-3.3	Units (Limits)
				Limit (Note 2)	Limit (Note 3)	

SYSTEM PARAMETERS (Note 4) Test Circuit Figure 2

V_{OUT}	Output Voltage	$V_{IN} = 12\text{V}$, $I_{LOAD} = 0.2\text{A}$ Circuit of Figure 2	3.3	3.267 3.333	3.234 3.366	V V(Min) V(Max)
V_{OUT}	Output Voltage LM1575/LM2575	$4.75\text{V} \leq V_{IN} \leq 40\text{V}$, $0.2\text{A} \leq I_{LOAD} \leq 1\text{A}$ Circuit of Figure 2	3.3	3.200/3.168 3.400/3.432	3.168/3.135 3.432/3.465	V V(Min) V(Max)
V_{OUT}	Output Voltage LM2575HV	$4.75\text{V} \leq V_{IN} \leq 60\text{V}$, $0.2\text{A} \leq I_{LOAD} \leq 1\text{A}$ Circuit of Figure 2	3.3	3.200/3.168 3.416/3.450	3.168/3.135 3.450/3.482	V V(Min) V(Max)
η	Efficiency	$V_{IN} = 12\text{V}$, $I_{LOAD} = 1\text{A}$	75			%

LM1575-5.0, LM2575-5.0, LM2575HV-5.0 Electrical Characteristics

Specifications with standard type face are for $T_J = 25^{\circ}\text{C}$, and those with boldface type apply over full Operating Temperature Range.

Symbol	Parameter	Conditions	Typ	LM1575-5.0	LM2575-5.0	Units (Limits)
				Limit (Note 2)	Limit (Note 3)	

SYSTEM PARAMETERS (Note 4) Test Circuit Figure 2

V_{OUT}	Output Voltage	$V_{IN} = 12\text{V}$, $I_{LOAD} = 0.2\text{A}$ Circuit of Figure 2	5.0	4.950 5.050	4.900 5.100	V V(Min) V(Max)
V_{OUT}	Output Voltage LM1575/LM2575	$0.2\text{A} \leq I_{LOAD} \leq 1\text{A}$, $8\text{V} \leq V_{IN} \leq 40\text{V}$ Circuit of Figure 2	5.0	4.850/4.800 5.150/5.200	4.800/4.750 5.200/5.250	V V(Min) V(Max)

LM1575/LM2575/LM2575HV

Symbol	Parameter	Conditions	Typ	LM1575-5.0	LM2575-5.0 LM2575HV-5.0	Units (Limits)
				Limit (Note 2)	Limit (Note 3)	
V_{out}	Output Voltage LM2575HV	$0.2A \leq I_{LOAD} \leq 1A$, $8V \leq V_{IN} \leq 60V$ Circuit of Figure 2	5.0	4.850/4.800 5.175/5.225	4.800/4.750 5.225/5.275	V V(Min) V(Max)
η	Efficiency	$V_{IN} = 12V$, $I_{LOAD} = 1A$	77			%

LM1575-12, LM2575-12, LM2575HV-12
Electrical Characteristics

Specifications with standard type face are for $T_J = 25^\circ C$, and those with boldface type apply over full Operating Temperature Range.

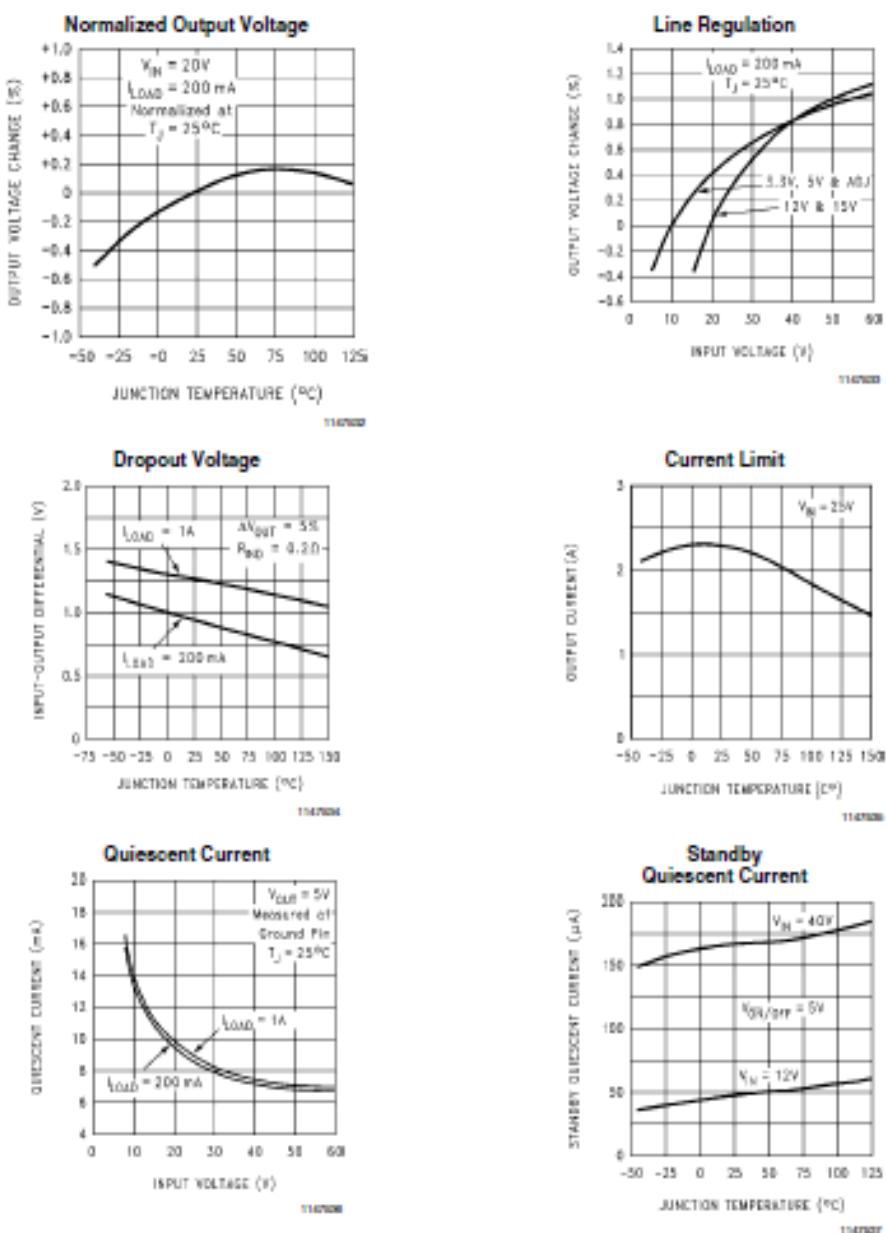
Symbol	Parameter	Conditions	Typ	LM1575-12	LM2575-12 LM2575HV-12	Units (Limits)
				Limit (Note 2)	Limit (Note 3)	
SYSTEM PARAMETERS (Note 4) Test Circuit Figure 2						
V_{out}	Output Voltage	$V_{IN} = 25V$, $I_{LOAD} = 0.2A$ Circuit of Figure 2	12	11.88 12.12	11.76 12.24	V V(Min) V(Max)
V_{out}	Output Voltage LM1575/LM2575	$0.2A \leq I_{LOAD} \leq 1A$, $15V \leq V_{IN} \leq 40V$ Circuit of Figure 2	12	11.64/11.52 12.36/12.48	11.52/11.40 12.48/12.60	V V(Min) V(Max)
V_{out}	Output Voltage LM2575HV	$0.2A \leq I_{LOAD} \leq 1A$, $15V \leq V_{IN} \leq 60V$ Circuit of Figure 2	12	11.64/11.52 12.42/12.54	11.52/11.40 12.54/12.66	V V(Min) V(Max)
η	Efficiency	$V_{IN} = 15V$, $I_{LOAD} = 1A$	88			%

LM1575-15, LM2575-15, LM2575HV-15
Electrical Characteristics

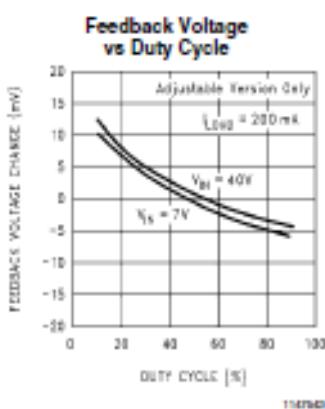
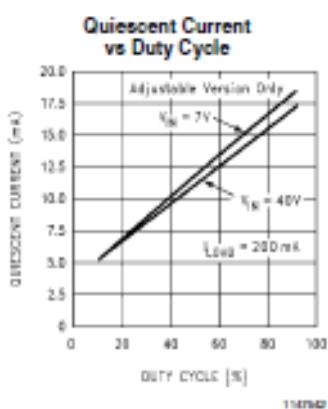
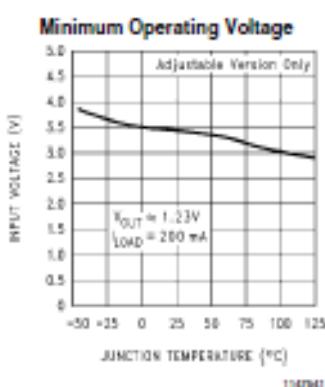
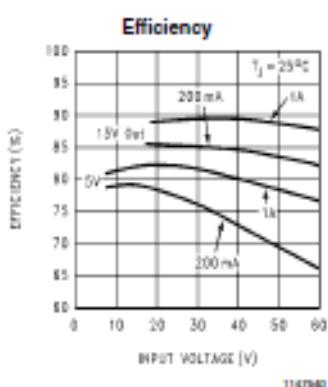
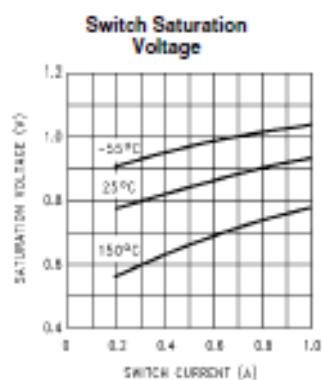
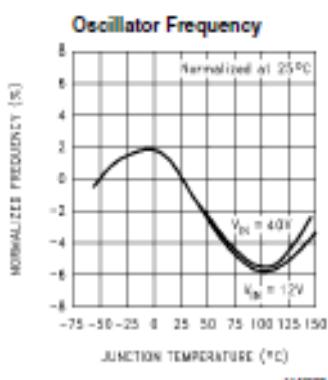
Specifications with standard type face are for $T_J = 25^\circ C$, and those with boldface type apply over full Operating Temperature Range.

Symbol	Parameter	Conditions	Typ	LM1575-15	LM2575-15 LM2575HV-15	Units (Limits)
				Limit (Note 2)	Limit (Note 3)	
SYSTEM PARAMETERS (Note 4) Test Circuit Figure 2						
V_{out}	Output Voltage	$V_{IN} = 30V$, $I_{LOAD} = 0.2A$ Circuit of Figure 2	15	14.85 15.15	14.70 15.30	V V(Min) V(Max)
V_{out}	Output Voltage LM1575/LM2575	$0.2A \leq I_{LOAD} \leq 1A$, $18V \leq V_{IN} \leq 40V$ Circuit of Figure 2	15	14.55/14.40 15.45/15.60	14.40/14.25 15.60/15.75	V V(Min) V(Max)
V_{out}	Output Voltage LM2575HV	$0.2A \leq I_{LOAD} \leq 1A$, $18V \leq V_{IN} \leq 60V$ Circuit of Figure 2	15	14.55/14.40 15.525/15.675	14.40/14.25 15.68/15.83	V V(Min) V(Max)
η	Efficiency	$V_{IN} = 18V$, $I_{LOAD} = 1A$	88			%

Typical Performance Characteristics (Circuit of Figure 2)

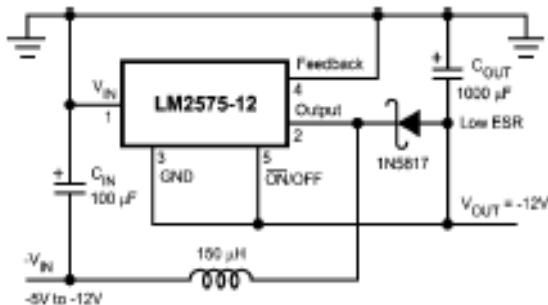


LM1575/LM2575/LM2575HV



NEGATIVE BOOST REGULATOR

Another variation on the buck-boost topology is the negative boost configuration. The circuit in Figure 11 accepts an input voltage ranging from -5V to -12V and provides a regulated -12V output. Input voltages greater than -12V will cause the output to rise above -12V, but will not damage the regulator. Because of the boosting function of this type of regulator, the switch current is relatively high, especially at low input voltages. Output load current limitations are a result of the maximum current rating of the switch. Also, boost regulators can not provide current limiting load protection in the event of a shorted load, so some other means (such as a fuse) may be necessary.



Typical Load Current
200 mA for $V_{IN} = -5.2V$
500 mA for $V_{IN} = -7V$
Note: Pin numbers are for TO-220 packages.

FIGURE 11. Negative Boost

UNDERVOLTAGE LOCKOUT

In some applications it is desirable to keep the regulator off until the input voltage reaches a certain threshold. An undervoltage lockout circuit which accomplishes this task is shown in Figure 12, while Figure 13 shows the same circuit applied to a buck-boost configuration. These circuits keep the regulator off until the input voltage reaches a predetermined level.

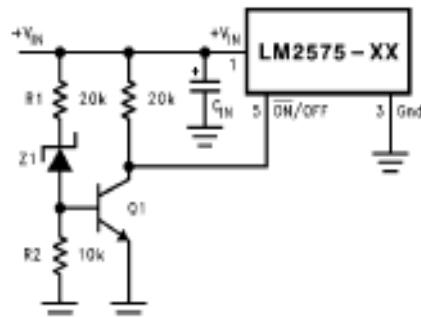
$$V_{TH} = V_{Z1} + 2V_{BE} (Q1)$$

DELAYED STARTUP

The ON/OFF pin can be used to provide a delayed startup feature as shown in Figure 14. With an input voltage of 20V and for the part values shown, the circuit provides approximately 10 ms of delay time before the circuit begins switching. Increasing the RC time constant can provide longer delay times. But excessively large RC time constants can cause problems with input voltages that are high in 60 Hz or 120 Hz ripple, by coupling the ripple into the ON/OFF pin.

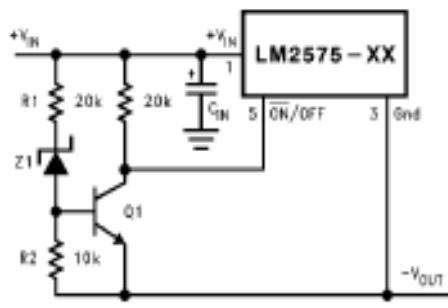
ADJUSTABLE OUTPUT, LOW-RIPPLE POWER SUPPLY

A 1A power supply that features an adjustable output voltage is shown in Figure 15. An additional L-C filter that reduces the output ripple by a factor of 10 or more is included in this circuit.



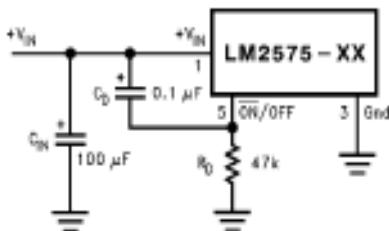
Note: Complete circuit not shown.
Note: Pin numbers are for the TO-220 package.

FIGURE 12. Undervoltage Lockout for Buck Circuit



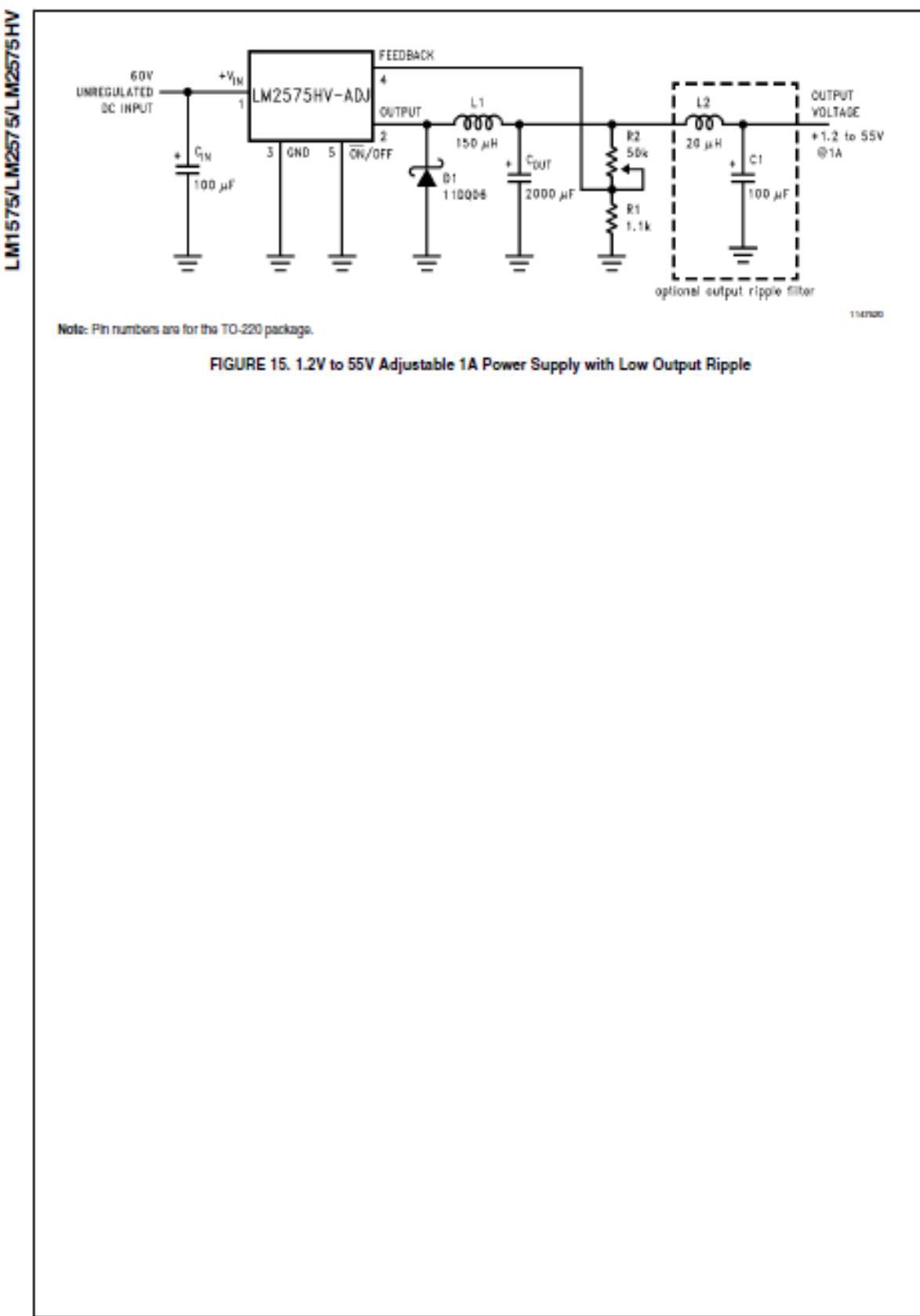
Note: Complete circuit not shown (see Figure 10).
Note: Pin numbers are for the TO-220 package.

FIGURE 13. Undervoltage Lockout for Buck-Boost Circuit

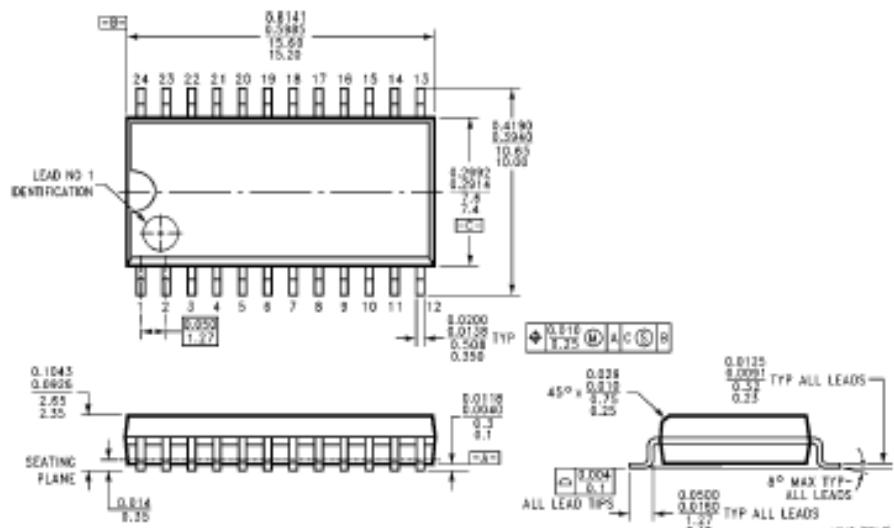
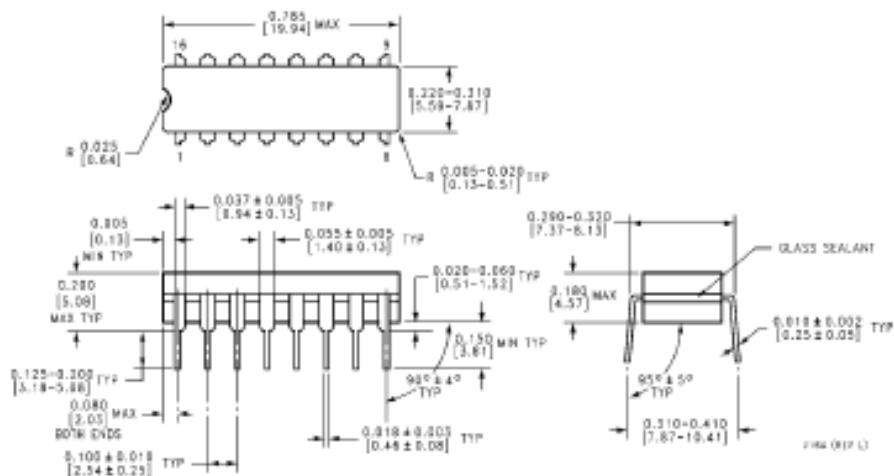


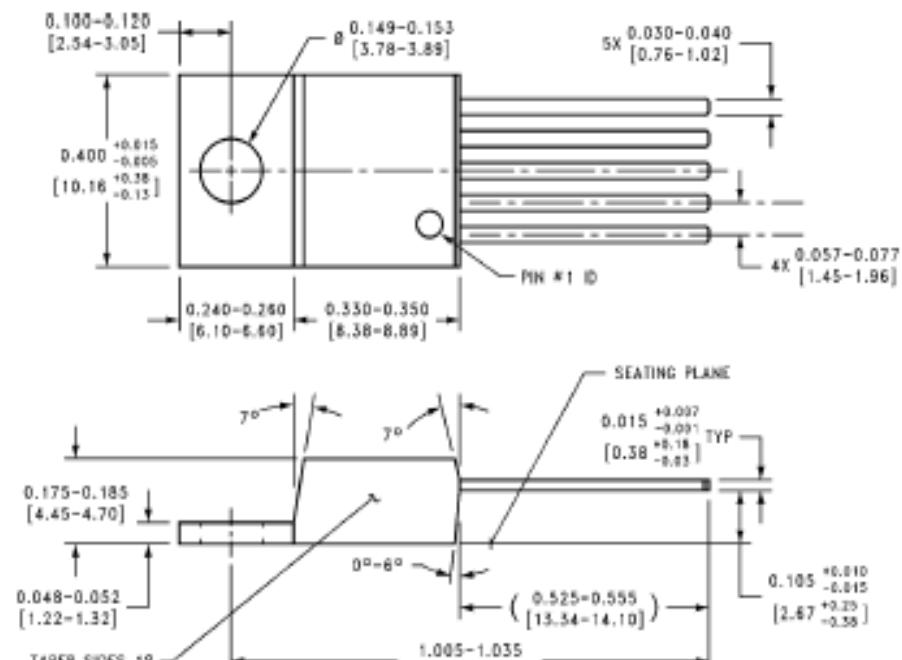
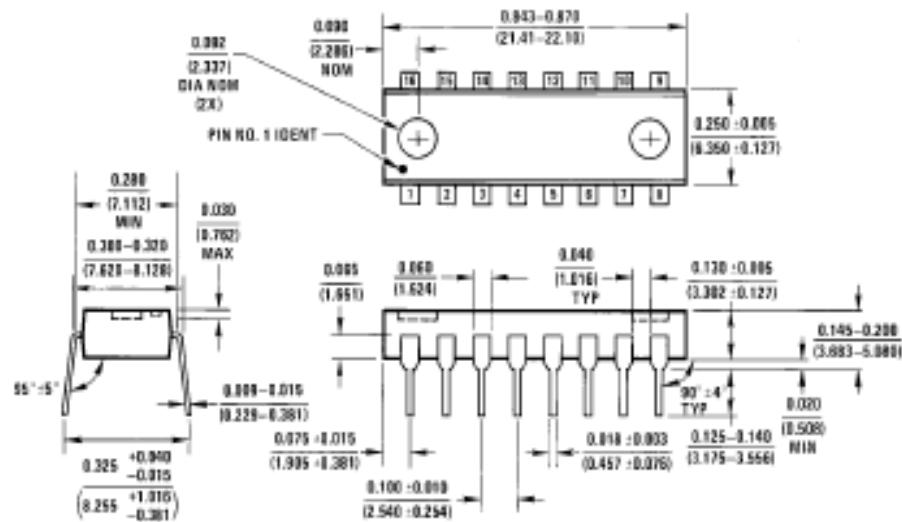
Note: Complete circuit not shown.
Note: Pin numbers are for the TO-220 package.

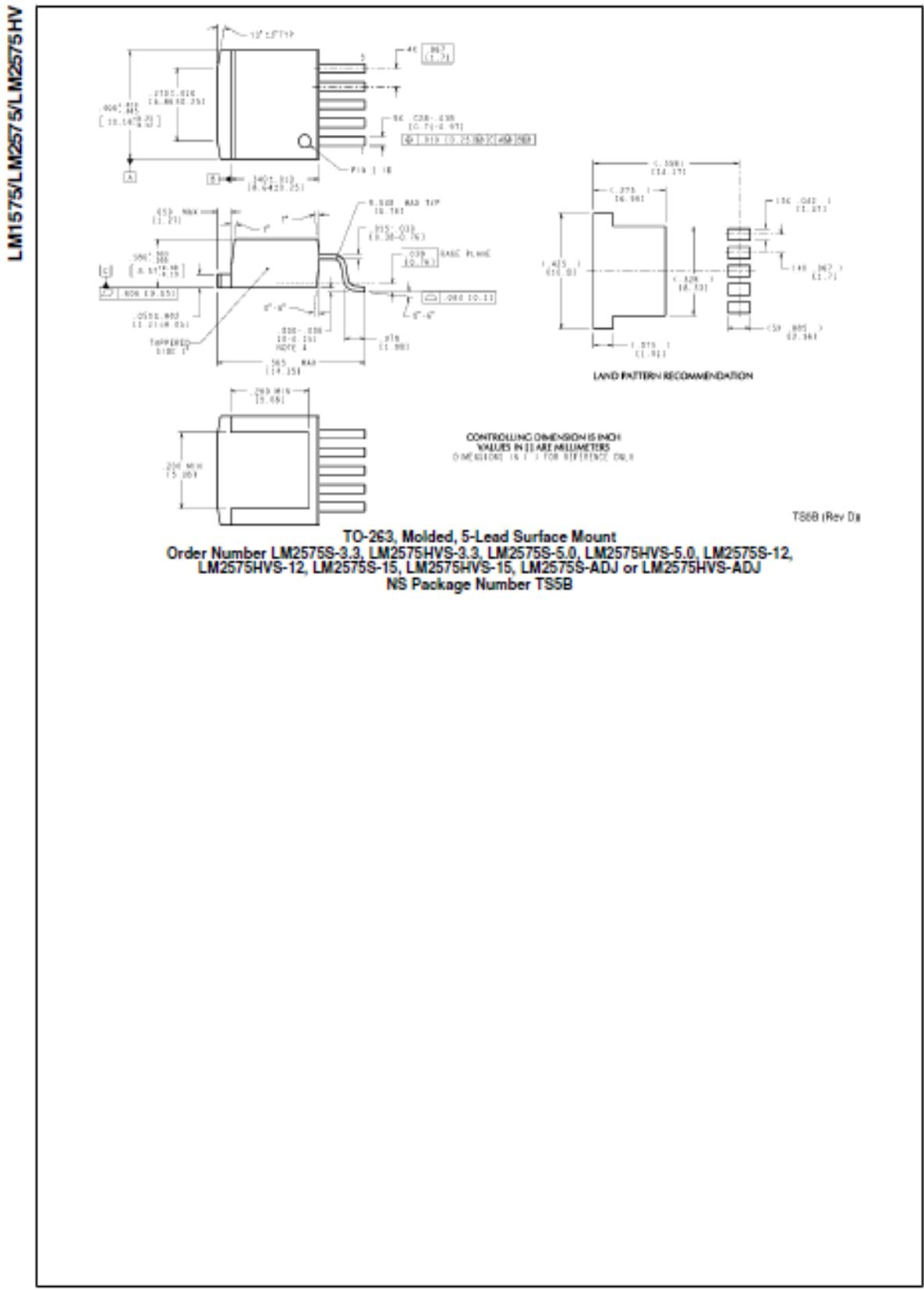
FIGURE 14. Delayed Startup

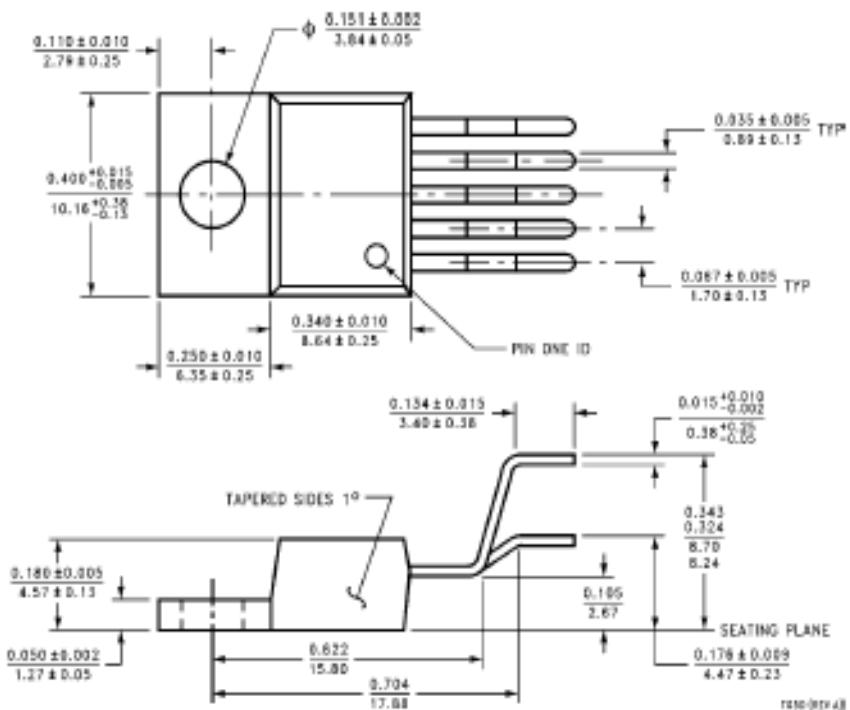


LM1575/LM2575/LM2575HV

Physical Dimensions inches (millimeters) unless otherwise noted







Bent, Staggered 5-Lead TO-220 (T)
Order Number LM2575T-3.3 Flow LB03, LM2575HVT-3.3 Flow LB03,
LM2575T-5.0 Flow LB03, LM2575HVT-5.0 Flow LB03,
LM2575T-12 Flow LB03, LM2575HVT-12 Flow LB03,
LM2575T-15 Flow LB03, LM2575HVT-15 Flow LB03,
LM2575T-ADJ Flow LB03 or LM2575HVT-ADJ Flow LB03
NS Package Number T05D