

## Low-Power, High-Speed CMOS Analog Switches

### DESCRIPTION

The DG401, DG403, DG405 monolithic analog switches were designed to provide precision, high performance switching of analog signals. Combining low power (0.35  $\mu$ W, typ.) with high speed ( $t_{ON}$ : 75 ns, typ.), the DG401 series is ideally suited for portable and battery powered industrial and military applications.

Built on the Vishay Siliconix proprietary high-voltage silicon-gate process to achieve high voltage rating and superior switch on/off performance, break-before-make is guaranteed for the SPDT configurations. An epitaxial layer prevents latchup.

Each switch conducts equally well in both directions when on, and blocks up to 30 V peak-to-peak when off. On-resistance is very flat over the full  $\pm 15$  V analog range, rivaling JFET performance without the inherent dynamic range limitations.

The three devices in this series are differentiated by the type of switch action as shown in the functional block diagrams.

### FEATURES

- 44 V supply max. rating
- $\pm 15$  V analog signal range
- On-resistance -  $R_{DS(on)}$ : 30  $\Omega$
- Low leakage -  $I_{D(on)}$ : 40 pA
- Fast switching -  $t_{ON}$ : 75 ns
- Ultra low power requirements -  $P_D$ : 0.35  $\mu$ W
- TTL, CMOS compatible
- Single supply capability
- **Compliant to RoHS directive 2002/95/EC**



**RoHS\***  
COMPLIANT

### BENEFITS

- Wide dynamic range
- Break-before-make switching action
- Simple interfacing

### APPLICATIONS

- Audio and video switching
- Sample-and-hold circuits
- Battery operation
- Test equipment
- Communications systems
- PBX, PABX

### FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION



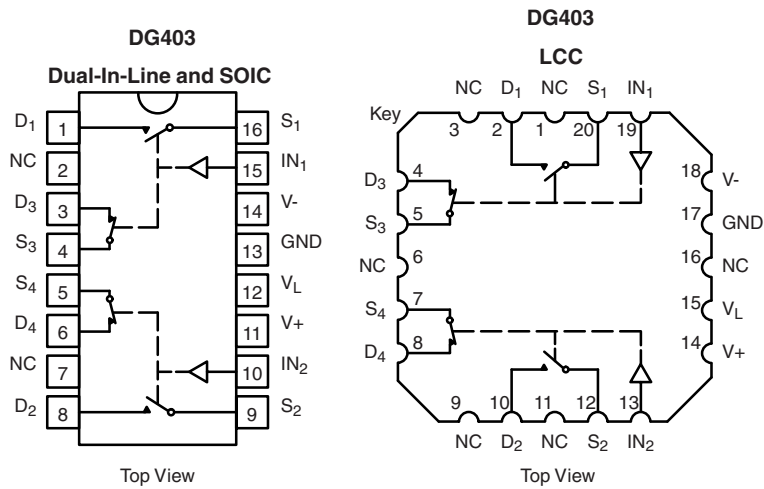
Two SPST Switches per Package

TRUTH TABLE	
Logic	Switch
0	OFF
1	ON

Logic "0"  $\leq 0.8$  V  
Logic "1"  $\geq 2.4$  V

\* Pb containing terminations are not RoHS compliant, exemptions may apply

## FUNCTIONAL BLOCK DIAGRAM AND PIN CONFIGURATION



Two SPDT Switches per Package

TRUTH TABLE		
Logic	SW <sub>1</sub> , SW <sub>2</sub>	SW <sub>3</sub> , SW <sub>4</sub>
0	OFF	ON
1	ON	OFF

Logic "0" ≤ 0.8 V  
 Logic "1" ≥ 2.4 V



Two DPST Switches per Package

TRUTH TABLE	
Logic	Switch
0	OFF
1	ON

Logic "0" ≤ 0.8 V  
 Logic "1" ≥ 2.4 V



<b>ORDERING INFORMATION</b>		
Temp. Range	Package	Part Number
<b>DG401</b>		
- 40 °C to 85 °C	16-Pin Plastic DIP	DG401DJ DG401DJ-E3
	16-Pin Narrow SOIC	DG401DY DG401DY-T1 DG401DY-E3 DG401DY-T1-E3
<b>DG403</b>		
- 40 °C to 85 °C	16-Pin Plastic DIP	DG403DJ DG403DJ-E3
	16-Pin Narrow SOIC	DG403DY DG403DY-E3 DG403DY-T1 DG403DY-T1-E3
<b>DG405</b>		
- 40 °C to 85 °C	16-Pin Plastic DIP	DG405DJ DG405DJ-E3
	16-Pin Narrow SOIC	DG405DY DG405DY-E3 DG405DY-T1 DG405DY-T1-E3

<b>ABSOLUTE MAXIMUM RATINGS</b>			
Parameter	Limit	Unit	
V+ to V-	44	V	
GND to V-	25		
V <sub>L</sub>	(GND - 0.3) to (V+) + 0.3		
Digital Inputs <sup>a</sup> , V <sub>S</sub> , V <sub>D</sub>	(V-) - 2 to (V+) + 2 or 30 mA, whichever occurs first		
Current (Any Terminal) Continuous	30	mA	
Current, S or D (Pulsed 1 ms, 10 % Duty)	100		
Storage Temperature	(DJ, DY Suffix) - 65 to 125	°C	
Power Dissipation (Package) <sup>b</sup>	16-Pin Plastic DIP <sup>c</sup>	450	mW
	16-Pin SOIC <sup>d</sup>	600	

## Notes:

- Signals on S<sub>x</sub>, D<sub>x</sub>, or IN<sub>x</sub> exceeding V+ or V- will be clamped by internal diodes. Limit forward diode current to maximum current ratings.
- All leads welded or soldered to PC board.
- Derate 6 mW/°C above 75 °C.
- Derate 7.6 mW/°C above 75 °C.

SPECIFICATIONS <sup>a</sup>							
Parameter	Symbol	Test Conditions Unless Specified V <sub>+</sub> = 15 V, V <sub>-</sub> = - 15 V V <sub>L</sub> = 5 V, V <sub>IN</sub> = 2.4 V, 0.8 V <sup>f</sup>	Temp. <sup>b</sup>	Typ. <sup>c</sup>	D Suffix - 40 °C to 85 °C		Unit
					Min. <sup>d</sup>	Max. <sup>d</sup>	
<b>Analog Switch</b>							
Analog Signal Range <sup>e</sup>	V <sub>ANALOG</sub>		Full		- 15	15	V
Drain-Source On-Resistance	R <sub>DS(on)</sub>	I <sub>S</sub> = - 10 mA, V <sub>D</sub> = ± 10 V V <sub>+</sub> = 13.5 V, V <sub>-</sub> = - 13.5 V	Room Full	30		45 55	Ω
Δ Drain-Source On-Resistance	ΔR <sub>DS(on)</sub>	I <sub>S</sub> = - 10 mA, V <sub>D</sub> = ± 5 V, 0 V V <sub>+</sub> = 16.5 V, V <sub>-</sub> = - 16.5 V	Room Full	3		3 5	
Switch Off Leakage Current	I <sub>S(off)</sub>	V <sub>+</sub> = 16.5 V, V <sub>-</sub> = - 16.5 V V <sub>D</sub> = ± 15.5 V, V <sub>S</sub> = ± 15.5 V	Room Hot	- 0.01	- 0.5 - 5	0.5 5	nA
	I <sub>D(off)</sub>		Room Hot	- 0.01	- 0.5 - 5	0.5 5	
Channel On Leakage Current	I <sub>D(on)</sub>	V <sub>+</sub> = 16.5 V, V <sub>-</sub> = - 16.5 V V <sub>S</sub> = V <sub>D</sub> = ± 15.5 V	Room Hot	- 0.04	- 1 - 10	1 10	
<b>Digital Control</b>							
Input Current V <sub>IN</sub> Low	I <sub>IL</sub>	V <sub>IN</sub> under test = 0.8 V All Other = 2.4 V	Full	0.005	- 1	1	μA
Input Current V <sub>IN</sub> High	I <sub>IH</sub>	V <sub>IN</sub> under test = 2.4 V All Other = 0.8 V	Full	0.005	- 1	1	
<b>Dynamic Characteristics</b>							
Turn-On Time	t <sub>ON</sub>	R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF See Figure 2	Room	75		150	ns
Turn-Off Time	t <sub>OFF</sub>		Room	30		100	
Break-Before-Make Time Delay (DG403)	t <sub>D</sub>	R <sub>L</sub> = 300 Ω, C <sub>L</sub> = 35 pF	Room	35	5		
Charge Injection	Q	C <sub>L</sub> = 10 nF V <sub>gen</sub> = 0 V, R <sub>gen</sub> = 0 Ω	Room	60			pC
Off Isolation Reject Ratio	OIRR	R <sub>L</sub> = 100 Ω, C <sub>L</sub> = 5 pF f = 1 MHz	Room	72			dB
Channel-to-Channel Crosstalk	X <sub>TALK</sub>		Room	90			
Source Off Capacitance	C <sub>S(off)</sub>	f = 1 MHz, V <sub>S</sub> = 0 V	Room	12			pF
Drain Off Capacitance	C <sub>D(off)</sub>		Room	12			
Channel On Capacitance	C <sub>D</sub> , C <sub>S(on)</sub>		Room	39			
<b>Power Supplies</b>							
Positive Supply Current	I <sub>+</sub>	V <sub>+</sub> = 16.5 V, V <sub>-</sub> = - 16.5 V V <sub>IN</sub> = 0 or 5 V	Room Full	0.01		1 5	μA
Negative Supply Current	I <sub>-</sub>		Room Full	- 0.01	- 1 - 5		
Logic Supply Current	I <sub>L</sub>		Room Full	0.01		1 5	
Ground Current	I <sub>GND</sub>		Room Full	- 0.01	- 1 - 5		

Notes:

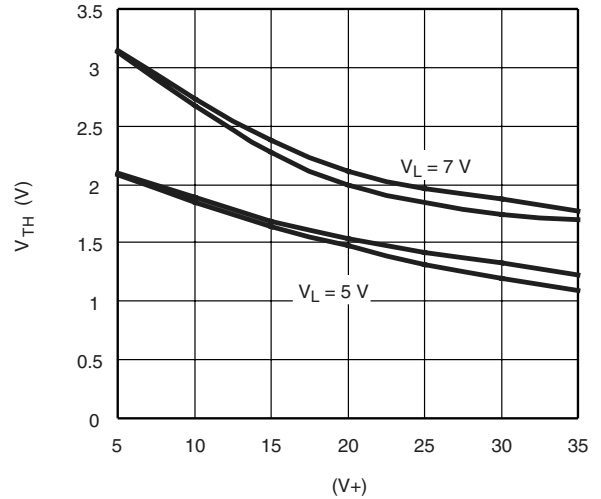
- Refer to PROCESS OPTION FLOWCHART.
- Room = 25 °C, Full = as determined by the operating temperature suffix.
- Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.
- The algebraic convention whereby the most negative value is a minimum and the most positive a maximum, is used in this datasheet.
- Guaranteed by design, not subject to production test.
- V<sub>IN</sub> = input voltage to perform proper function.

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

## TYPICAL CHARACTERISTICS 25 °C, unless otherwise noted



Input Switching Threshold vs. Logic Supply Voltage



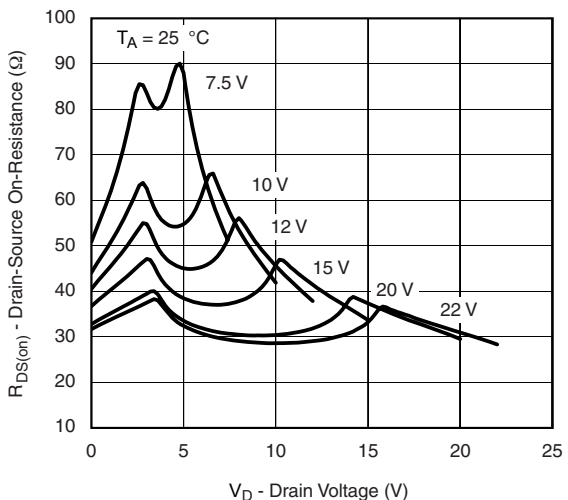
Input Switching Threshold vs. Supply Voltages



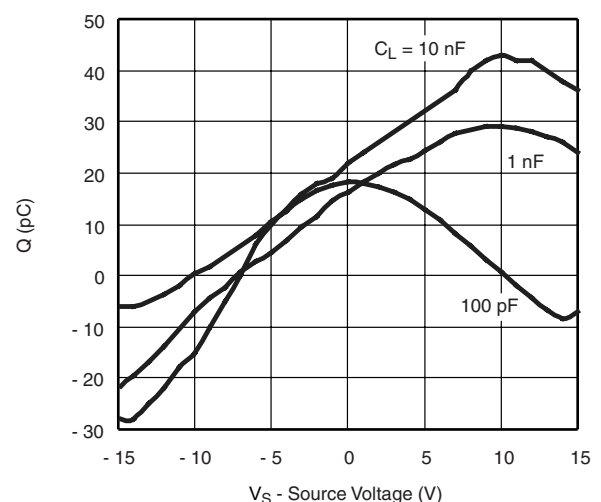
$R_{DS(on)}$  vs.  $V_D$  and Temperature



$R_{DS(on)}$  vs.  $V_D$  and Power Supply Voltage



$R_{DS(on)}$  vs.  $V_D$  and Power Supply Voltage ( $V_- = 0$  V)



Charge Injection vs. Analog Voltage

### TYPICAL CHARACTERISTICS 25 °C, unless otherwise noted



**Leakage Current vs. Temperature**



**Leakage Current vs. Analog Voltage**



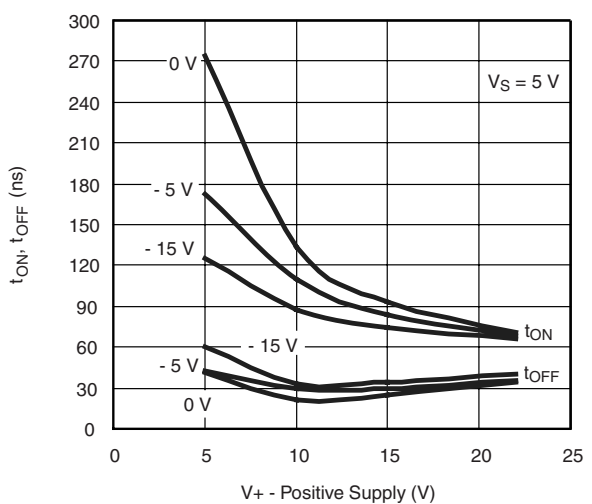
**Supply Current vs. Temperature**



**Switching Time vs. Temperature\***



**Switching Time vs. Power Supply Voltage\***



**Switching Time vs. Positive Supply Voltage\***

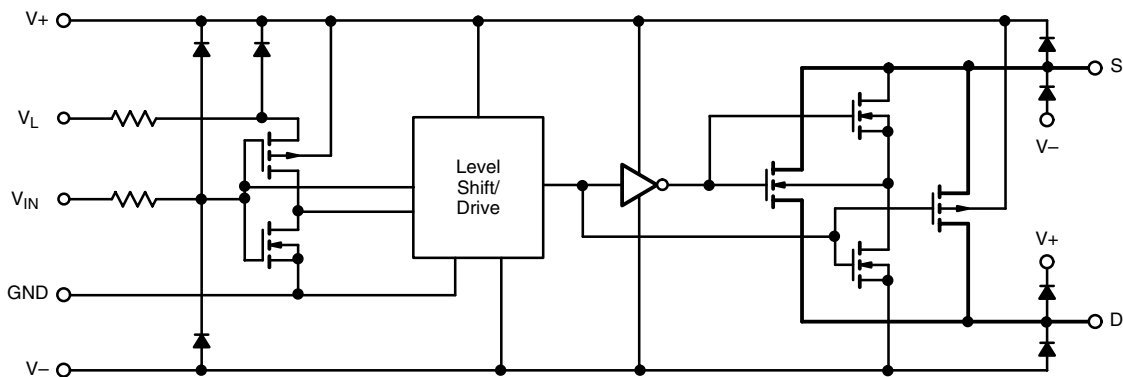
\* Refer to Figure 2 for test conditions.

**TYPICAL CHARACTERISTICS** 25 °C, unless otherwise noted



**Supply Current vs. Switching Frequency**

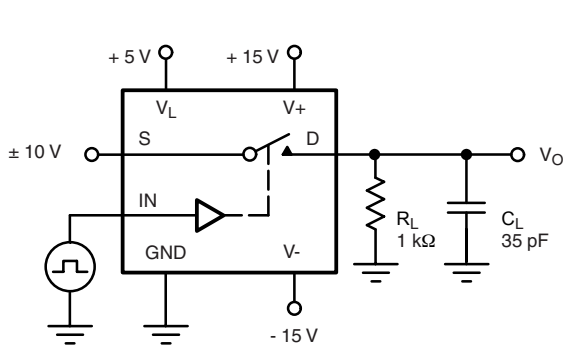
**SCHEMATIC DIAGRAM** Typical Channel



**Figure 1.**

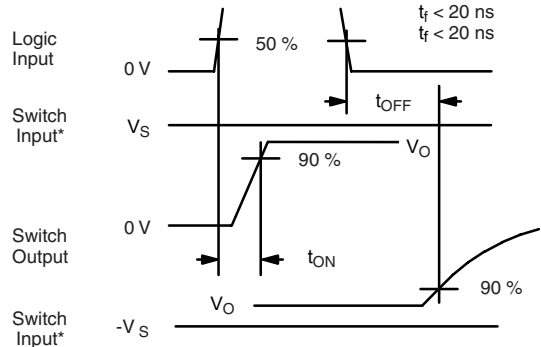
### TEST CIRCUITS

$V_O$  is the steady state output with the switch on. Feedthrough via switch capacitance may result in spikes at the leading and trailing edge of the output waveform.



$C_L$  (includes fixture and stray capacitance)

$$V_O = V_S \frac{R_L}{R_L + r_{DS(on)}}$$



\*  $V_S = 10\text{ V}$  for  $t_{ON}$ ,  $V_S = -10\text{ V}$  for  $t_{OFF}$

Note: Logic input waveform is inverted for switches that have the opposite logic sense control

Figure 2. Switching Time



$C_L$  (includes fixture and stray capacitance)

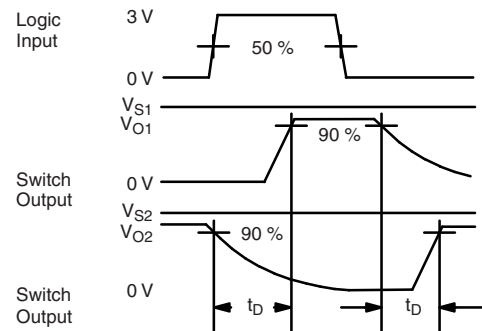


Figure 3. Break-Before-Make



Figure 4. Charge Injection



**TEST CIRCUITS**



**Figure 5. Off Isolation**



**Figure 7. Crosstalk**



**Figure 6. Insertion Loss**



**Figure 8. Capacitances**

## APPLICATIONS



Figure 9. Stereo Source Selector



Figure 10. Dual Slope Integrator

### Dual Slope Integrators:

The DG403 is well suited to configure a selectable slope integrator. One control signal selects the timing capacitor  $C_1$  or  $C_2$ . Another one selects  $e_{in}$  or discharges the capacitor in preparation for the next integration cycle.

### Band-Pass Switched Capacitor Filter:

Single-pole double-throw switches are a common element for switched capacitor networks and filters. The fast switching times and low leakage of the DG403 allow for higher clock rates and consequently higher filter operating frequencies.

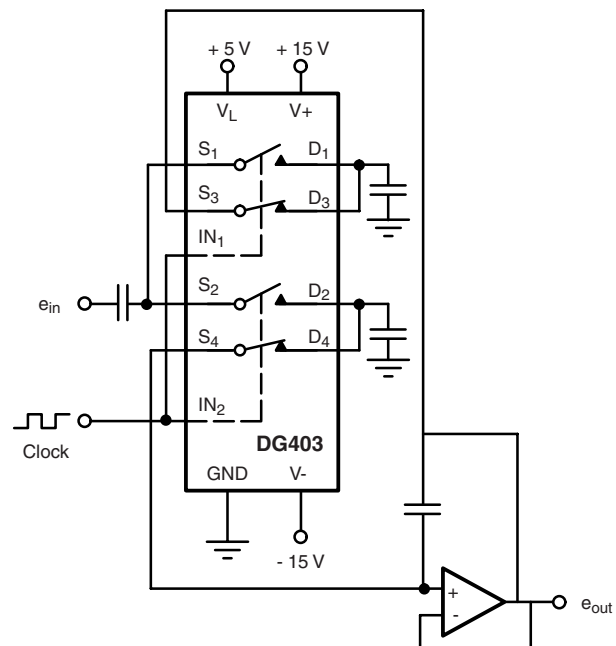


Figure 11. Band-Pass Switched Capacitor Filter

**APPLICATIONS**
**Peak Detector:**

$A_3$  acting as a comparator provides the logic drive for operating  $SW_1$ . The output of  $A_2$  is fed back to  $A_3$  and compared to the analog input  $e_{in}$ . If  $e_{in} > e_{out}$  the output of  $A_3$  is high keeping  $SW_1$  closed. This allows  $C_1$  to charge up to

the analog input voltage. When  $e_{in}$  goes below  $e_{out}$   $A_3$  goes negative, turning  $SW_1$  off. The system will therefore store the most positive analog input experienced.



Figure 12. Positive Peak Detector

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**SOIC (NARROW): 16-LEAD**  
JEDEC Part Number: MS-012



Dim	MILLIMETERS		INCHES	
	Min	Max	Min	Max
A	1.35	1.75	0.053	0.069
A <sub>1</sub>	0.10	0.20	0.004	0.008
B	0.38	0.51	0.015	0.020
C	0.18	0.23	0.007	0.009
D	9.80	10.00	0.385	0.393
E	3.80	4.00	0.149	0.157
e	1.27 BSC		0.050 BSC	
H	5.80	6.20	0.228	0.244
L	0.50	0.93	0.020	0.037
∅	0°	8°	0°	8°

ECN: S-03946—Rev. F, 09-Jul-01  
DWG: 5300



### PDIP: 16-LEAD



Dim	MILLIMETERS		INCHES	
	Min	Max	Min	Max
<b>A</b>	3.81	5.08	0.150	0.200
<b>A<sub>1</sub></b>	0.38	1.27	0.015	0.050
<b>B</b>	0.38	0.51	0.015	0.020
<b>B<sub>1</sub></b>	0.89	1.65	0.035	0.065
<b>C</b>	0.20	0.30	0.008	0.012
<b>D</b>	18.93	21.33	0.745	0.840
<b>E</b>	7.62	8.26	0.300	0.325
<b>E<sub>1</sub></b>	5.59	7.11	0.220	0.280
<b>e<sub>1</sub></b>	2.29	2.79	0.090	0.110
<b>e<sub>A</sub></b>	7.37	7.87	0.290	0.310
<b>L</b>	2.79	3.81	0.110	0.150
<b>Q<sub>1</sub></b>	1.27	2.03	0.050	0.080
<b>S</b>	0.38	1.52	.015	0.060

ECN: S-03946—Rev. D, 09-Jul-01  
DWG: 5482



**CERDIP: 16-LEAD**



Dim	MILLIMETERS		INCHES	
	Min	Max	Min	Max
A	4.06	5.08	0.160	0.200
A <sub>1</sub>	0.51	1.14	0.020	0.045
B	0.38	0.51	0.015	0.020
B <sub>1</sub>	1.14	1.65	0.045	0.065
C	0.20	0.30	0.008	0.012
D	19.05	19.56	0.750	0.770
E	7.62	8.26	0.300	0.325
E <sub>1</sub>	6.60	7.62	0.260	0.300
e <sub>1</sub>	2.54 BSC		0.100 BSC	
e <sub>A</sub>	7.62 BSC		0.300 BSC	
L	3.18	3.81	0.125	0.150
L <sub>1</sub>	3.81	5.08	0.150	0.200
Q <sub>1</sub>	1.27	2.16	0.050	0.085
S	0.38	1.14	0.015	0.045
∞	0°	15°	0°	15°

ECN: S-03946—Rev. G, 09-Jul-01  
DWG: 5403



**20-LEAD LCC**



Dim	MILLIMETERS		INCHES	
	Min	Max	Min	Max
<b>A</b>	1.37	2.24	0.054	0.088
<b>A<sub>1</sub></b>	1.63	2.54	0.064	0.100
<b>B</b>	0.56	0.71	0.022	0.028
<b>D</b>	8.69	9.09	0.342	0.358
<b>E</b>	8.69	9.09	0.442	0.358
<b>e</b>	1.27 BSC		0.050 BSC	
<b>L</b>	1.14	1.40	0.045	0.055
<b>L<sub>1</sub></b>	1.96	2.36	0.077	0.093

ECN: S-03946—Rev. B, 09-Jul-01  
DWG: 5321

## RECOMMENDED MINIMUM PADS FOR SO-16



Recommended Minimum Pads  
Dimensions in Inches/(mm)

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