SECTION 7—LINEAR INTEGRATED CIRCUITS

®C-QUAM (Compatible Quadrature Amplitude Modulation) is a registered trademark of Motorola, Inc.

Continued

SECTION 7—LINEAR INTEGRATED CIRCUITS (Continued)

See Also:

Application Notes:

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*Complete information is provided in Data Book CN-250, Discrete Semiconductors.
†Complete information is provided in Data Book SN-500, IC Sensors.

SELECTION GUIDE TO AM AND FM RADIO CIRCUITS

Device Type	RF Mixer	FM IF	FM Det.	Mute/ Squelch	Δf Mute	Stereo Decode	AM Radio	Audio Amp	Supply Voltage Range
NE564N/F	—	—	X	—	—	—	—	—	4.5-5.5 V
ULN-2111A	—	X	X	—	—	—	—	—	8.0-14 V
ULN-2204A	—	X	X	—	—	—	X	X	2.0-12 V
ULN-2241A	—	X	X	—	—	—	X	—	10-16 V
ULN-2243A	X	X	—	—	—	—	—	—	8.0-12 V
ULN-3803A	—	X	X	—	—	—	X	—	3.0-12 V
ULN-3809A	—	—	—	—	—	X	—	—	9.0-16 V
ULN-3820A	—	—	—	—	—	X†	—	—	6.0-12 V
ULN-3821A	—	—	—	—	—	—	XX††	—	6.0-12 V
ULN-3823A	—	—	—	—	—	X	—	—	1.8-9.0 V
ULN-3839A	—	—	—	—	—	—	X	X	1.8-9.0 V
ULN-3840A	—	X	X	X	X	—	X	—	8.5-16 V
ULN-3841A	—	—	—	—	—	—	X	—	6.5-16 V
ULN-3842A	X	X	X	X	X	—	X	—	8.5-16 V
ULN-3859A	X	X	X	X	—	—	—	—	4.0-9.0 V
ULN-3862A	X	X	X	X	—	—	—	—	2.0-8.0 V
ULN-3869M	X	—	—	—	—	—	—	—	1.5-6.0 V
ULN-3883A	X	X	X	X	—	—	—	X	3.0-9.0 V

Detailed technical information is available from any Sprague sales office or sales representative.

†C-QUAM® AM stereo decoder (®Motorola, Inc.).

††Tuning stabilizer for AM radio.

SELECTION GUIDE TO AUDIO POWER AMPLIFIERS

Device Type	Monophonic	Stereo	P_{OUT} @	R_L and	V_{CC}	Supply Voltage Range
ULN-2280B	X	—	2.5 W	8Ω	18 V	8.0-26 V
			2.5 W	16Ω	24 V	
ULN-3718M†	X	—	80 mW	8Ω	3.0 V	1.8-9.0 V
			125 mW	32Ω	6.0 V	
			430 mW	8Ω	6.0 V	
ULN-3725M†	X	—	0.9 W	4Ω	6.0 V	3.0-14 V
			1.3 W	8Ω	9.0 V	
			2.3 W	8Ω	12 V	
ULN-3750B	—	X	0.9 W	4Ω	6.0 V	3.0-14 V
			1.3 W	8Ω	9.0 V	
			2.3 W	8Ω	12 V	
ULN-3782M†	—	X	220 mW	8Ω	3.0 V	1.8-9.0 V
			430 mW	8Ω	6.0 V	
ULN-3784B	X	—	5.0 W	8Ω	24 V	9.0-28 V
			4.8 W	16Ω	28 V	
ULN-3793/94W	X	—	18 W	4Ω	13.2 V	8.0-16 V
			11 W	8Ω	13.2 V	

Detailed technical information is available from any Sprague sales office or sales representative.
†New product. Contact factory for information.

SELECTION GUIDE TO POWER SUPPLY CIRCUITS

Device Type	Description	Page
NE5560N/F	General-purpose, full-feature, primary side PWM controller with feed-forward control for single-ended power converter applications	§
NE5561N	Low-cost, basic PWM controller for dc-to-dc systems	§
NE5568N	Similar to NE5561N with trimmed ±2% reference	§
SG3525AJ/AN	High-frequency PWM controller with dual NOR outputs for single- or double-ended systems	§
SG3526J/N	High-frequency full-feature PWM controller for single- or double-ended systems	§
SG3527AJ/AN	Similar to SG3525AJ/AN with dual OR outputs	§
TL594CN	Universal PWM controller featuring dual analog inputs and pin-programmable dual outputs	§
TL594IN	Similar to TL594C for operation over temperature range of −40°C to +85°C	§
TL595CN	Similar to TL594CN with added 39 V shunt regulator and output logic steering input	§
TL595IN	Similar to TL595CN for operation over temperature range of −40°C to +85°C	§
ULN-8130A	Versatile precision voltage monitoring system featuring a ±1% trimmed reference. Monitors four positive *or* two positive and two negative power supply outputs and power line	7-23
ULN-8131A	Similar to ULN-8130A. Can also monitor three positive outputs and one negative power supply output and power line	7-28
ULN-8163A/R	Full-feature, precision (trimmed to ±1%), low-voltage primary-side controller with pulse-by-pulse current limiting for single-ended applications	7-33

§Detailed technical information is available from any Sprague sales office or sales representative.

SELECTION GUIDE TO MISCELLANEOUS LINEAR ICs

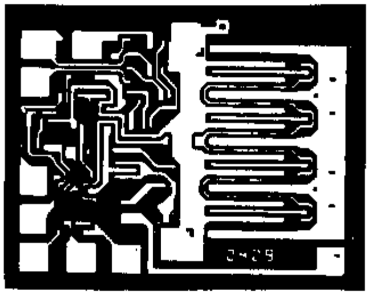
Description	Page
Telecommunications	
NE564F/N and SE564F High-Frequency Phase-Locked Loops	§
UDN-2522A Quad Bus Transmitter/Receiver	3-25
Series ULN-3800A FM Radio Systems	7-3
Automotive/Transportation	
Series ULN-2240A FM and AM/FM Radio Systems	7-3
ULN-2429A Fluid Detector (Impedance Comparator)	7-7
ULN-2430M Timer	7-10
ULN-2435A and 2445A Automotive Lamp Monitors	7-13
ULN-2436M Dual-Mode (10 min./5 min.) Countdown Timer	†
ULN-2455A General-Purpose Quad Comparator	7-13
ULN-2457A/L Quad Lamp Monitor for 24 V Systems	7-19
Series ULN-3700 Audio Power Amplifiers	7-4
Series ULN-3800A AM and AM/FM Radio Systems	7-3
Hall Effect and Optoelectronic Sensors	*
Linear Power Control	
ULN-3751Z Power Operational Amplifier	4-93
ULN-3735B/W Dual Power Operational Amplifiers	4-98
ULN-3755B/W Dual Power Operational Amplifiers	4-107
Sensors	
Series UGN-3500 Linear Output Hall Effect Sensors	*
ULN-3310D/T Precision Light Sensors	*
ULN-8130A Precision Supervisory Systems Monitor	7-23
ULN-8131A Precision Supervisory Systems Monitor	7-28

§Detailed technical information is available from any Sprague sales office or sales representative.
†New product. Contact factory for information.
*Refer to Data Book SN-500, Integrated Sensors.

ULN-2429A FLUID DETECTOR

FEATURES

- High Output Current
- A-C or D-C Output
- Single-Wire Probe
- Low External Parts Count
- Internal Voltage Regulator
- Reverse Voltage Protection
- 14-Pin Dual In-Line Plastic Package



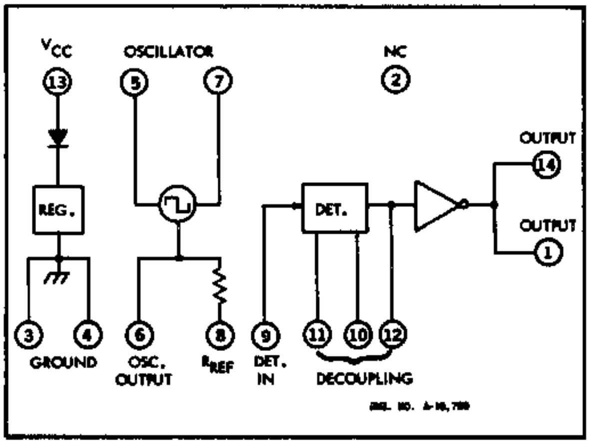
PRIMARILY DESIGNED for use as an automotive low coolant detector, the ULN-2429A monolithic bipolar integrated circuit is ideal for detecting the presence or absence of many different types of liquids in automotive, home, or industrial applictions. Especially useful in harsh environments, reverse voltage protection, internal voltage regulation, temperature compensation, and high-frequency noise immunity are all incorporated in the design.

A simple probe, immersed in the fluid being monitored, is driven with an a-c signal to prevent plating problems. The presence, absence, or condition of the fluid is determined by comparing the loaded probe resistance with an internal (pin 8) or external (pin 6) resistance. Typical conductive fluids which can be sensed are tap water, sea water, weak acids and bases, wet soil, wine, beer, and coffee. Non-conductive fluids include most petroleum products, distilled water, dry soil, and vodka. The probe can be replaced with any variable-resistance element such as a photodiode or photoconductive cell, rotary or linear position sensor, or thermistor for detecting solids, non-conducting liquids, gases, etc.

The high-current output is typically a square wave signal for use with an LED, incandescent lamp, or loudspeaker. A capacitor can be connected (pin 12) to provide a d-c output for use with inductive loads such as relays and solenoids.

The ULN-2429A is rated for operation with a load voltage of up to 30 volts. Selected devices, for operation up to 50 V are available as the ULN-2429A-1. In all other respects, the ULN-2429A and the ULN-2429A-1 fluid detectors are identical.

These devices are furnished in an improved 14-lead dual in-line plastic package with a copper alloy lead frame for superior thermal characteristics. However, in order to realize the maximum current-handling capability of these devices, both of the output pins (1 and 14) and both ground pins (3 and 4) should be used.



FUNCTIONAL BLOCK DIAGRAM

ABSOLUTE MAXIMUM RATINGS

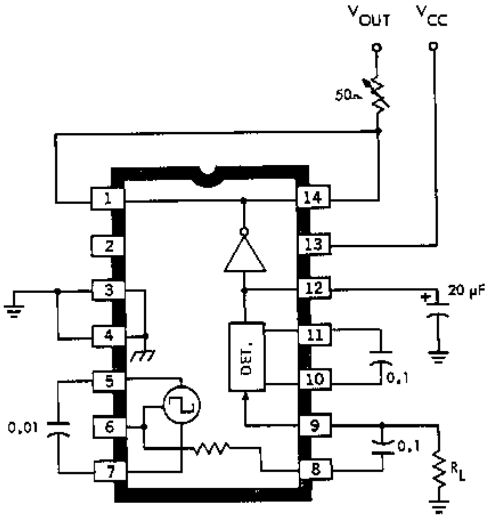
Supply Voltage, V_{CC} (continuous) . . . . +16 V, −50 V
(1 hr. at +25°C) . . . . +24 V
(10 μs) . . . . +50 V
Output Voltage, V_{OUT} (ULN-2429A) . . . . +30 V
(ULN-2429A-1) . . . . +50 V
Output Current, I_{OUT} (continuous) . . . . 700 mA
(1 hr. at +25°C) . . . . 1.0 A
Package Power Dissipation, P_D . . . . 1.33 W*
Operating Temperature Range, T_A . . . . −40°C to +85°C
Storage Temperature Range, T_S . . . . −65°C to +150°C

*Derate at the rate of 16.67 mW/°C above T_A = +70°C.

ELECTRICAL CHARACTERISTICS at $T_A = -25°C$, $V_{CC} = V_{OUT} = +12$ V (unless otherwise specified)

Characteristic	Symbol	Test Pin	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Supply Voltage Range	V_{CC}	13	—	10	—	16	V
Supply Current	I_{CC}	13	$V_{CC} = +16$V	—	—	10	mA
Oscillator Output Voltage	V_{osc}	6	R_L = 18 kΩ	—	3.0	—	V_{PP}
Output ON Voltage	V_{OUT}	1,14	$R_L \geq 30$ kΩ, I_{OUT} = 500 mA	—	0.9	1.5	V
Output OFF Current	I_{OUT}	1,14	$R_L \leq 10$ kΩ, $V_{OUT} = V_{OUT}$(max)	—	—	100	μA
Oscillator Frequency	f_{osc}	6	R_L = 18 kΩ	—	2.4	—	kHz

TEST CIRCUIT



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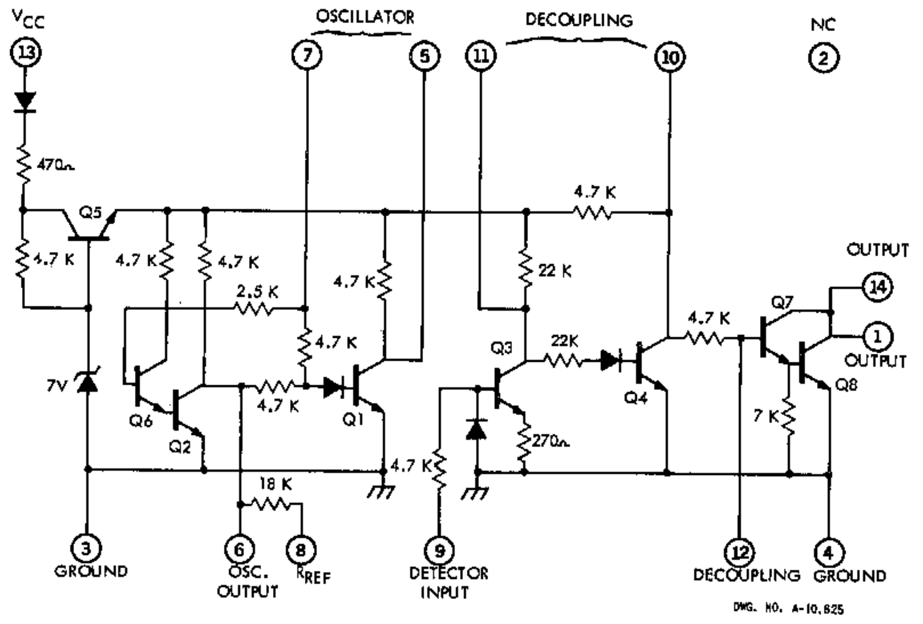
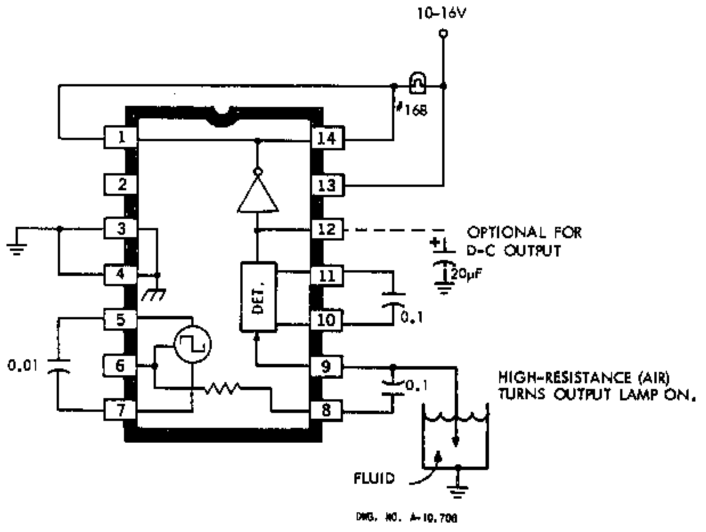
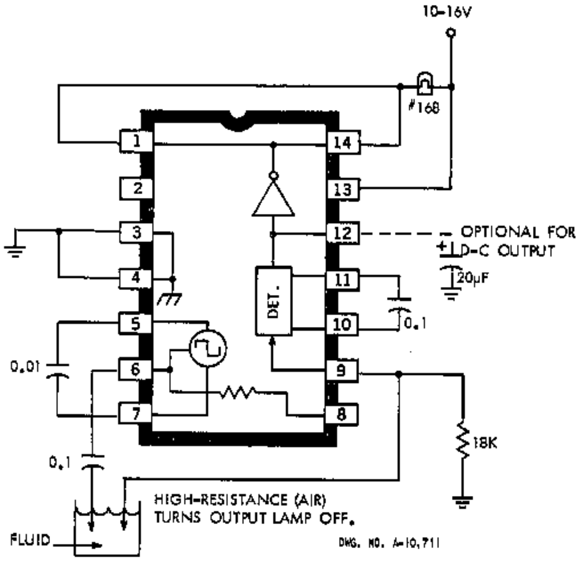
CIRCUIT SCHEMATIC



TYPICAL APPLICATIONS

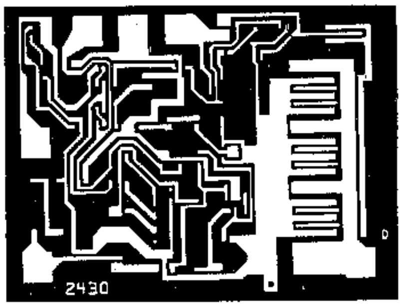




ULN-2430M TIMER

FEATURES

- Microseconds to Minutes
- Temperature Compensated
- 400 mA Output
- 8-Pin Dual In-Line Plastic Package



PROVIDING time delays from several microseconds to approximately 10 minutes, the ULN-2430M timer was originally designed for use as a rear window heater timer in automotive applications. In typical system designs, this device will meet all of the stringent automotive environmental and transient requirements, including "load dump". The rugged design, the high output current rating, and an internal voltage regulator and reference allow the ULN-2430M timer to be used in many industrial applications.

ABSOLUTE MAXIMUM RATINGS

Regulator Current, I_{REG}	15 mA
Latch Current, I_4	3 mA
Output Current, I_{OUT}	400 mA
Package Power Dissipation, P_D	330 mW*
Operating Temperature Range, T_A	−40°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

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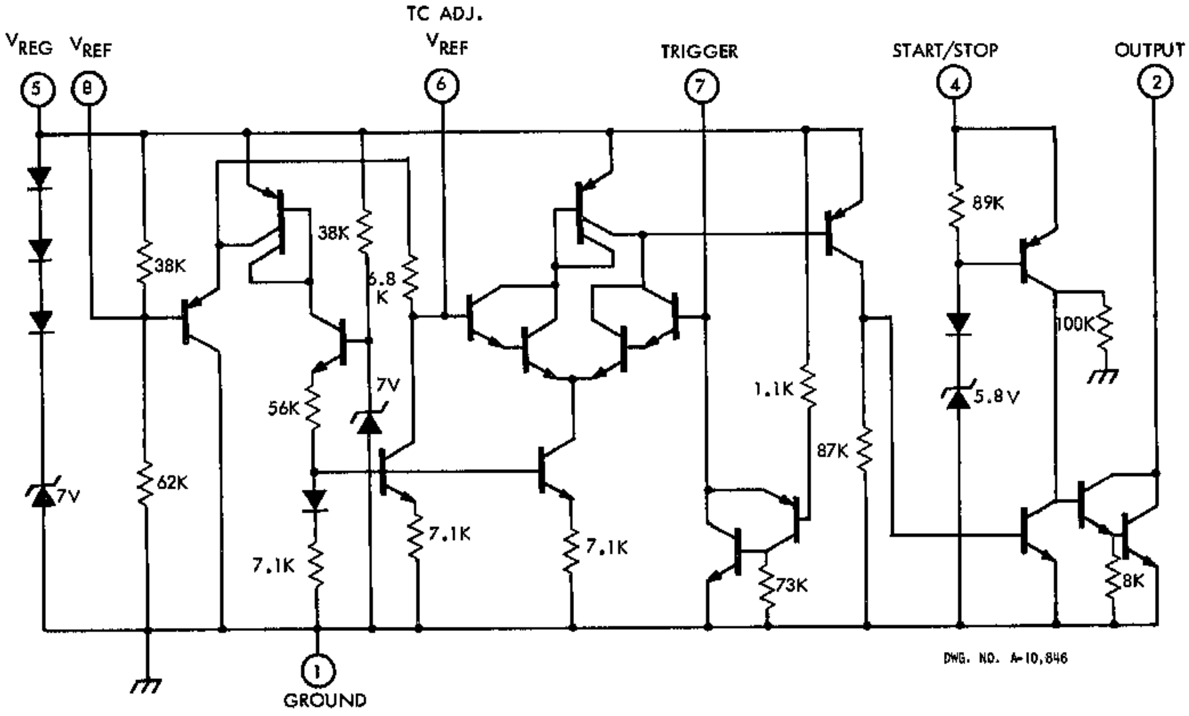
*Derate at the rate of 4.2 mW/°C above T_A = +70°C.



ELECTRICAL CHARACTERISTICS at T_A = +25°C (unless otherwise noted), Fig. 1

Characteristic	Test Pin	Test Conditions	Limits			Units
			Min.	Typ.	Max.	
Operating Voltage Range			10	—	16	V
Regulator Voltage	5		8.4	9.0	10.1	V
Output Breakdown Voltage	2	I_{LEAK} = 100 μA	30	—	—	V
Output Saturation Voltage	2	I_{OUT} = 400 mA	—	—	2.5	V
		I_{OUT} = 250 mA	—	—	1.3	V
Latch Voltage	4	Over Op. Temp. Range	5.5	7.0	8.0	V
Trigger Threshold	7	V_7/V_5	0.60	0.63	0.67	
Reference	8	V_8/V_5	0.58	0.63	0.68	
Temp. Coeff. of Trigger Threshold	7		−2.0	—	−4.0	mV/°C
Trigger Input Current	7		—	20	200	nA
Capacitor Discharge Time	7	C_1 = 220 μF, ±10%	—	—	2.0	s
Supply Current	5	V_{CC} = 16 V	—	—	10	mA

CIRCUIT OPERATION

The basic system shown in Figure 1 provides power for the timer after the momentary closure of the "rear window heater switch" S_1. Momentary closure provides an input to pin 4 which turns ON the output driver, energizes the relay, and (through the relay contacts) provides power to the timer and the heater element. Waveforms are shown in Figure 2.

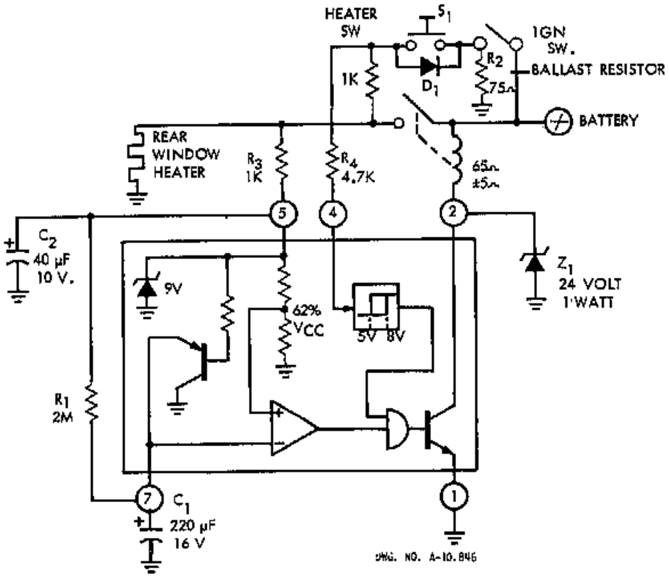
The output remains ON, supplying power to the heater until $V_7 = 62\%\ V_5$, which occurs at time $t = R_1 \times C_1$. The time delay can be adjusted from several microseconds to approximately 10 minutes by the choice of R_1 and C_1. When $t = R_1 \times C_1$, the comparator changes state and the relay de-energizes, returning the circuit to the quiescent condition.

Timing accuracy is primarily a function of capacitor leakage for long time delays. Hard switching of the comparator necessitates low input bias currents on the comparator and low capacitor leakage current. The worst case comparator input is 200 nA and the charge current at $V_7 = 62\%\ V_5$ is approximately 1.7 μA for R_1 = 2 MΩ. For these reasons, it is recommended that R_1 not exceed 2 MΩ and C_1 leakage be less than 500 nA.

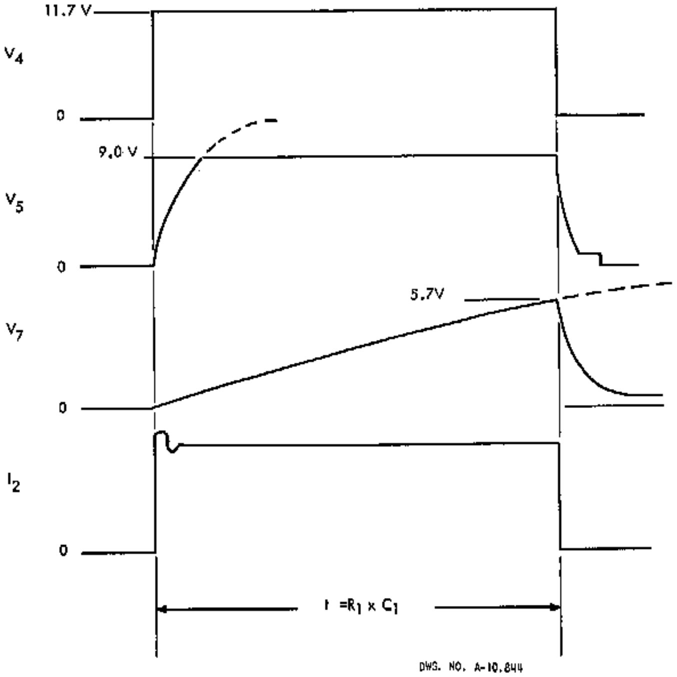
Diode D_1 and the circuitry associated with pin 4 provide start-stop capability for the timer. When the voltage at pin 4 is larger than 8 V timing is initiated. When less than 5.5 V, timing is stopped. Transient protection against load dump and other automotive environmental hazards is provided by the integrated circuit design and discrete components Z_1, C_2, R_3, R_4, and D_1.

TYPICAL APPLICATION

(Figure 1)



TIMER WAVEFORMS



ULN-2435A, ULN-2445A, AND ULN-2455A AUTOMOTIVE LAMP MONITORS

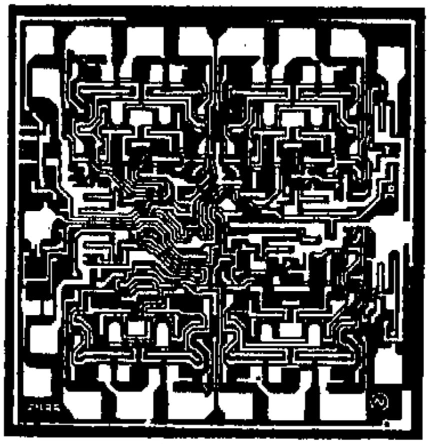
FEATURES

- No Standby Power
- Integral to Wiring Assembly
- Fail-Safe
- Reverse Voltage Protected
- Internal Transient Protection
- Dual In-Line Plastic Packages

CAPABLE of monitoring all types of automotive lamps, Type ULN-2435A, ULN-2445A, and ULN-2455A lamp monitors provide multiple LED outputs to pinpoint the area in which a lamp has failed. Types ULN-2435A and ULN-2445A feature an additional output that triggers an alarm if any of the comparators detects a lamp failure. This output can be used to drive an audible signaling device or centrally located warning indicator.

The Type ULN-2435A lamp monitor has interconnected comparator ouputs and logic to monitor the ignition circuit and fuses, making it uniquely applicable to automotive applications. Type ULN-2445A is similar, but has no interconnected comparators. Type ULN-2455A is a general-purpose quad comparator that can be used to monitor automotive lamps, multiple low-voltage power supplies, or, with appropriate sensors, industrial processes.

Installation and operation of these quad lamp monitors has no effect on normal lamp operation. Comparators sense the normal voltage drop in the lamp wiring (approximately 20 mV) for each of the monitored lamp circuits. Little additional wiring is necessary for installation because the system can be completely integral to the wiring assembly. No standby power is required: The operating voltage is obtained from the sense leads; the system is energized only when the lamps are turned ON.



All three integrated circuits are designed for use in the severe automotive environment. Lateral PNP transistors provide high-frequency noise immunity and differential transient-voltage protection. Reverse voltage protection, internal regulators, and temperature compensation are all embodied in the circuit design. A failure within the device will not affect lamp operation.

Types ULN-2435A and ULN-2445A are supplied in 18-pin dual in-line plastic packages. The Type ULN-2455A lamp monitor is supplied in a 14-pin dual in-line plastic package.

ABSOLUTE MAXIMUM RATINGS at +25°C Free-Air Temperature

Supply Voltage, V_{CC}	30 V
Peak Supply Voltage, V_{CC} (0.1 s)	80 V
Peak Reverse Voltage, V_R	30 V
Output Current, I_{OUT}	35 mA
Package Power Dissipation, P_D (ULN-2435/45A)	2.3 W*
(ULN-2455A)	2.0 W**
Operating Temperature Range, T_A	−40°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

---

*Derate at the rate of 18.18 mW/°C above T_A = +25°C.

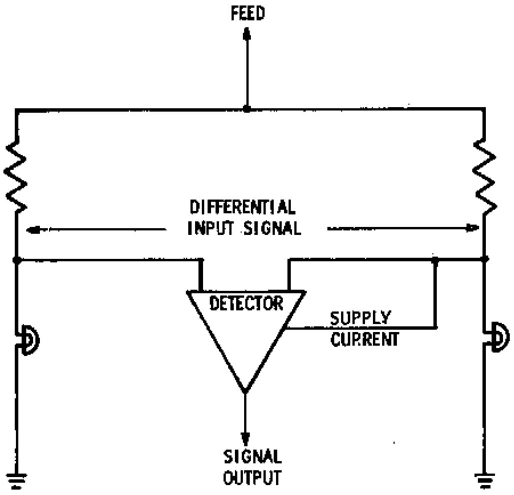
**Derate at the rate of 16.67 mW/°C above T_A = +25°C.

PRINCIPLE OF OPERATION

Operation of these lamp monitors is similar to that of a simple bridge circuit in which the top two legs of the bridge are formed by the wiring assembly resistance or discrete low-value resistors. The bottom legs of the bridge are the monitored lamps. Four differential amplifier circuits sense the voltage drops in the wiring assemblies (approximately 20 mV) for each of the lamp circuits. When the system detects a difference in voltage due to an open filament, the appropriate output driver is turned ON.

Sprague Electric Technical Paper TP 81-7 discusses the requirements of automotive lamp monitoring systems and presents a more detailed description of the operation of these differential sense amplifiers (page 10-56).

BASIC BRIDGE MONITORING SYSTEM



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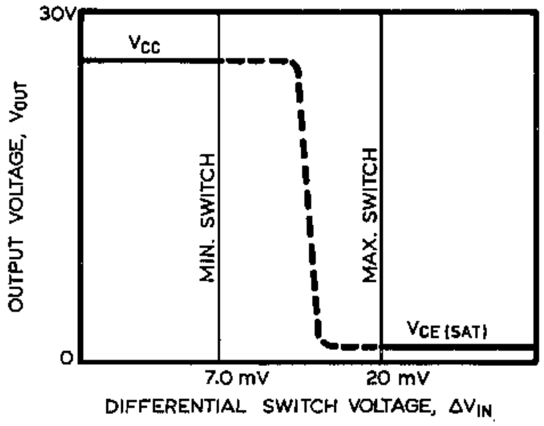
TYPICAL SWITCH CHARACTERISTICS



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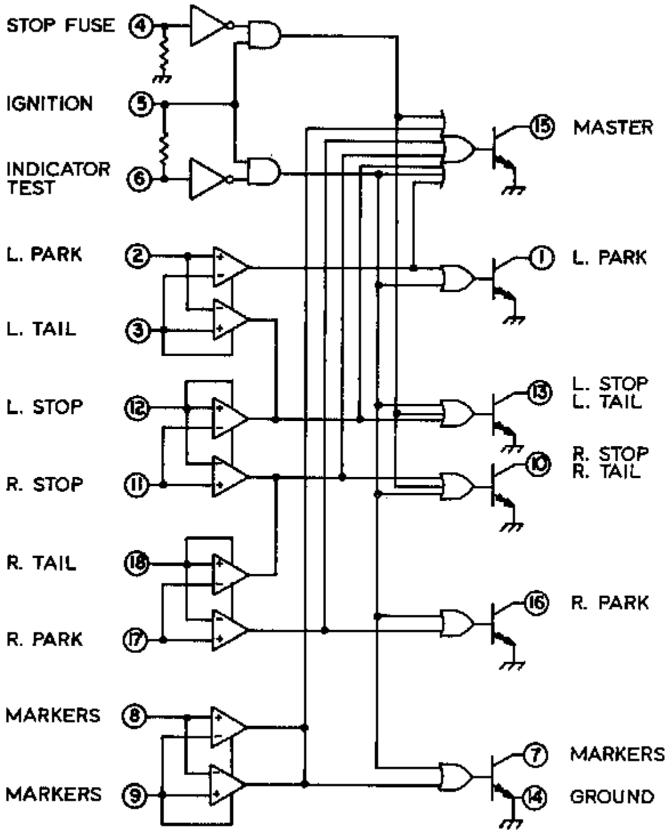
ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = V_{IN} = 10$ to 16 V (unless otherwise shown)

	Test Pins			Limits			
Characteristic	ULN-2435/45A	ULN-2455A	Test Conditions	Min.	Typ.	Max.	Units
Output Leakage Current	1, 7, 10, 13, 15, 16	1, 4, 8, 11	$V_{OUT} = 80$ V, $\Delta V_{IN} < 7$ mV	—	—	100	µA
Output Saturation Voltage	1, 7, 10, 13, 15, 16	1, 4, 8, 11	$I_{OUT} = 5$ mA, $\Delta V_{IN} > 20$ mV	—	0.8	1.0	V
			$I_{OUT} = 30$ mA, $\Delta V_{IN} > 20$ mV	—	1.4	2.0	V
Differential Switch Voltage	2-3, 8-9, 11-12, 17-18	2-3, 5-6, 9-10, 12-13	Absolute Value $V_{(2)} - V_{(3)}$	7.0	13	20	mV
Input Current	4	NA	$V_{IN} = V_{CC} = 16$ V	—	—	500	µA
	5	NA	$V_{IN} = V_{CC} = 16$ V	—	—	15	mA
	6	NA	$V_{IN} = 0$ V, $V_{CC} = 16$ V	—	—	−1.0	mA
	2, 8, 11, 17	2, 5, 9, 12	$\Delta V_{IN} = V_{(2)} - V_{(3)} = +30$ mV	150	300	800	µA
	3, 9, 12, 18	3, 6, 10,1 3	$\Delta V_{IN} = V_{(2)} - V_{(3)} = -30$ mV	0.5	1.7	3.5	mA

ULN-2435A
FUNCTIONAL BLOCK DIAGRAM



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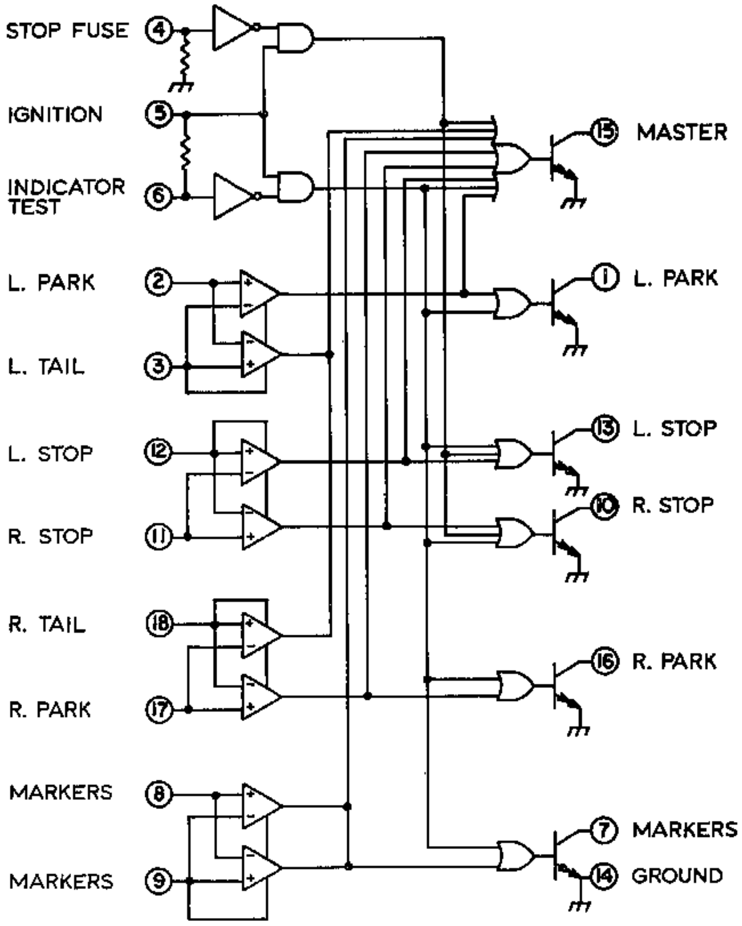
ULN-2435A and ULN-2445A TRUTH TABLES

								OUTPUT PINS											
	INPUT PINS							ULN-2435A						ULN-2445A					
CONDITIONS	2/3	8/9	11/12	17/18	6	4	5	1	7	10	13	15	16	1	7	10	13	15	16
Normal	=	=	=	=	0	H	X	H	H	H	H	H	H	H	H	H	H	H	H
L. Park Lamp Failure	>	=	=	=	0	H	X	L	H	H	H	L	H	L	H	H	H	L	H
L. Tail Lamp Failure	<	=	=	=	0	H	X	H	H	H	L	L	H	H	H	H	H	L	H
Marker Lamp Failure	=	>	=	=	0	H	X	H	L	H	H	L	H	H	L	H	H	L	H
Marker Lamp Failure	=	<	=	=	0	H	X	H	L	H	H	L	H	H	L	H	H	L	H
R. Stop Lamp Failure	=	=	>	=	0	H	X	H	H	L	H	L	H	H	H	L	H	L	H
L. Stop Lamp Failure	=	=	<	=	0	H	X	H	H	H	L	L	H	H	H	H	L	L	H
R. Park Lamp Failure	=	=	=	>	0	H	X	H	H	H	H	L	L	H	H	H	H	L	L
R. Tail Lamp Failure	=	=	=	<	0	H	X	H	H	L	H	L	H	H	H	H	H	L	H
Stop Lamp Fuse Failure	=	=	=	=	0	L	H	H	H	L	L	L	H	H	H	L	L	L	H
Indicator Lamp Test	X	X	X	X	L	X	H	L	L	L	L	L	L	L	L	L	L	L	L

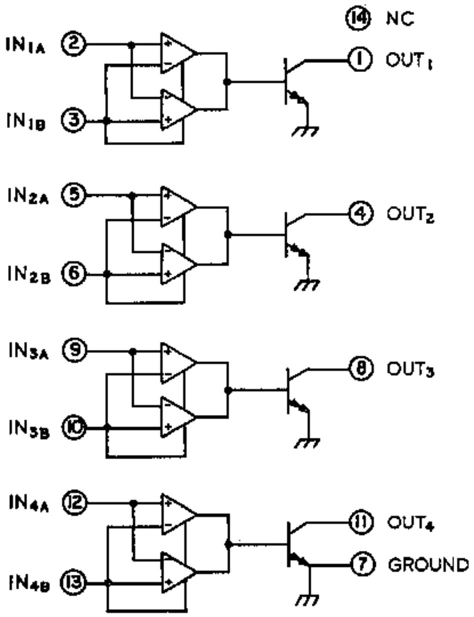
= — Less than 7 mV offset between a pair of input pins
> — Greater than +20 mV differential between a pair of input pins [$V_{(2)} - V_{(3)}$]
< — Greater than −20 mV differential between a pair of input pins [$V_{(2)} - V_{(3)}$]
H — V_{CC}
L — V_{SAT} (outputs) or GROUND (inputs)
0 — Open or V_{CC}
X — Irrelevant

ULN-2445A FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-12,032A

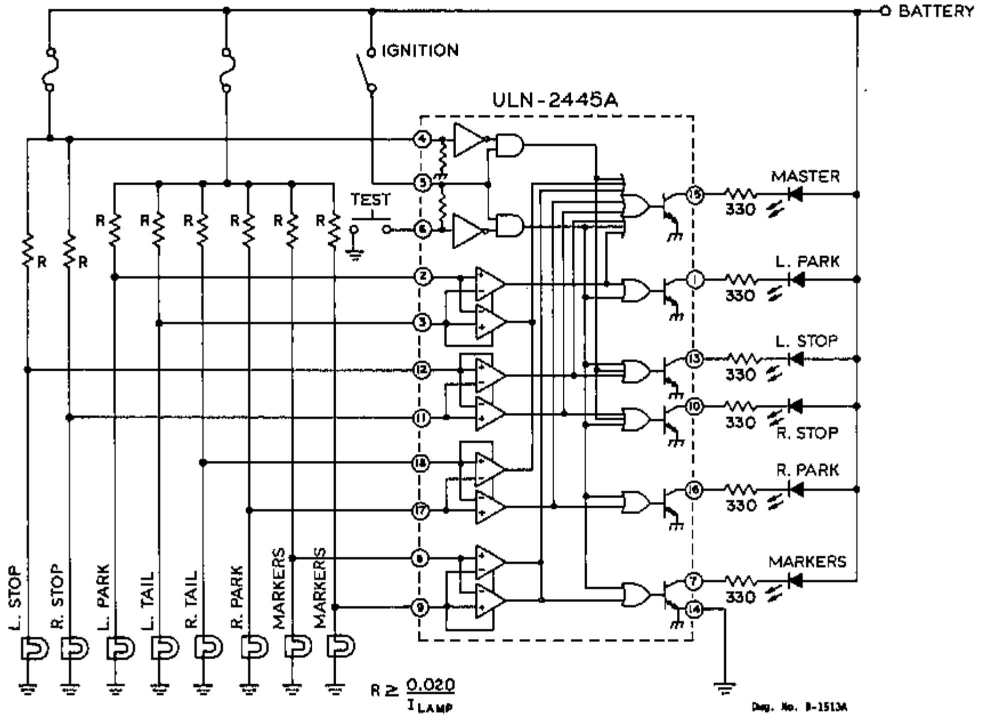
ULN-2455A FUNCTIONAL BLOCK DIAGRAM



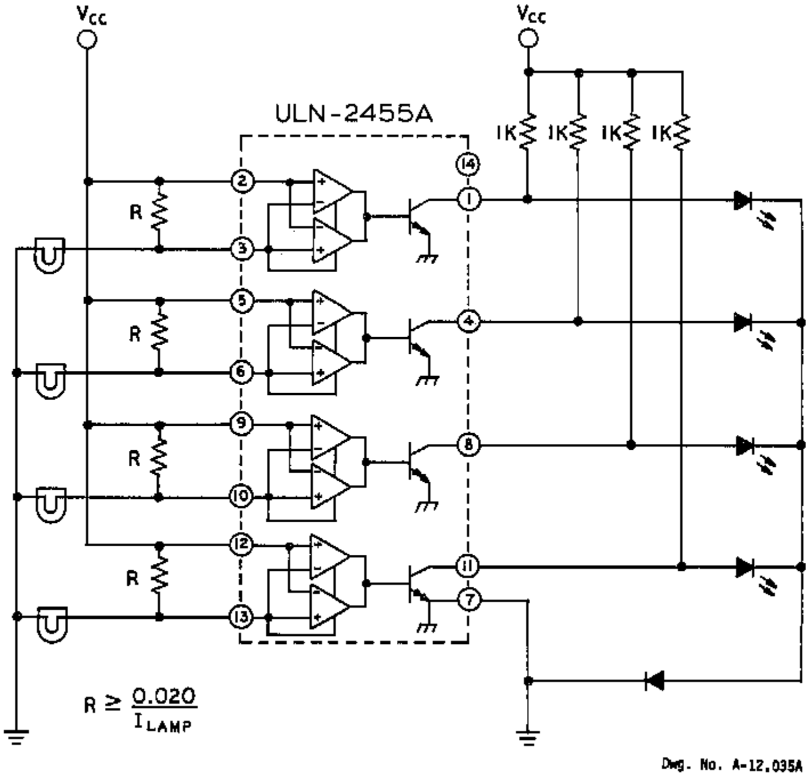
Dwg. No. A-12,033A

TYPICAL APPLICATIONS

AUTOMOTIVE LAMP MONITOR

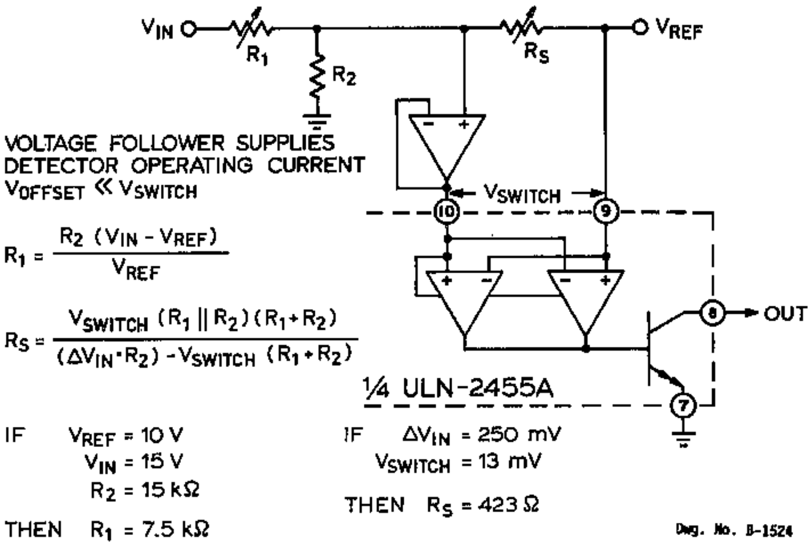


QUAD LAMP MONITOR



TYPICAL APPLICATIONS (Continued)

POWER SUPPLY SUPERVISORY CIRCUIT



VOLTAGE FOLLOWER SUPPLIES DETECTOR OPERATING CURRENT $V_{OFFSET} \ll V_{SWITCH}$

$$R_1 = \frac{R_2\ (V_{IN} - V_{REF})}{V_{REF}}$$

$$R_S = \frac{V_{SWITCH}\ (R_1 \parallel R_2)(R_1 + R_2)}{(\Delta V_{IN} \cdot R_2) - V_{SWITCH}\ (R_1 + R_2)}$$

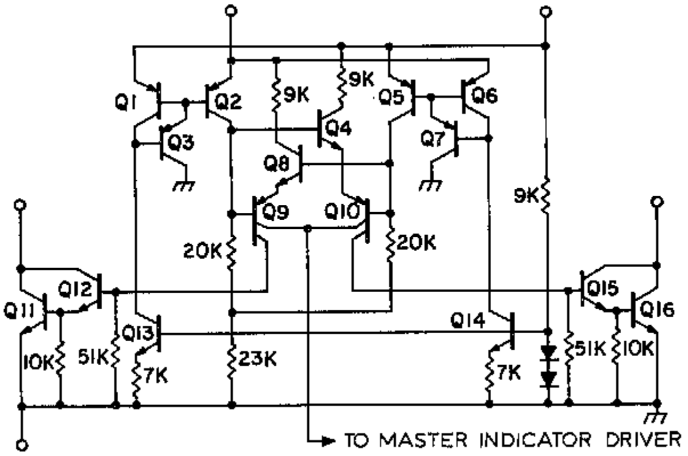
IF $V_{REF} = 10$ V
$V_{IN} = 15$ V
$R_2 = 15$ kΩ
THEN $R_1 = 7.5$ kΩ

IF $\Delta V_{IN} = 250$ mV
$V_{SWITCH} = 13$ mV
THEN $R_S = 423$ Ω

Dwg. No. B-1524

SIMPLIFIED SCHEMATIC

(One of 4 differential sense amplifiers)



Dwg. No. A-12,036

ULN-2457A AND ULN-2457L QUAD LAMP MONITORS FOR 24 V SYSTEMS

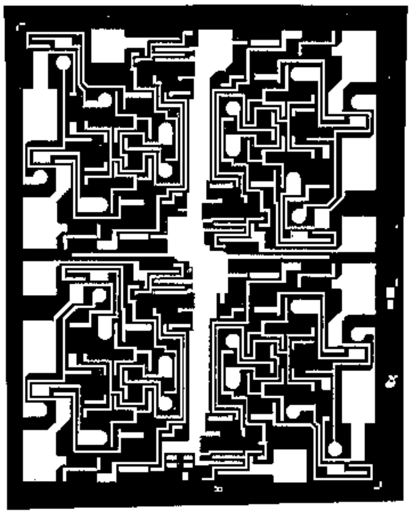
FEATURES

- 18 to 32 V Operation
- No Standby Power
- Integral to Wiring Assembly
- Fair-Safe
- Reverse-Voltage Protected
- Internal Transient Protection

CAPABLE of monitoring lamps in truck or bus, railroad, marine, and other applications using 24 V power systems, the ULN-2457A and ULN-2457L lamp monitors provide LED outputs (to 35 mA) to indicate the circuit in which a lamp failure has occurred. Differential amplifiers sense the voltage drops in the wiring assemblies (approximately 20 mV) for similar lamps. When the monitor detects a difference in voltage due to an open filament or lamp socket, the appropriate output driver is turned ON. Both devices are general-purpose quad comparators that can also be used to monitor multiple low-voltage power supplies and, with appropriate sensors, industrial processes.

The installation and operation of these quad lamp monitors has negligible effect on normal lamp operation. Comparators sense the normal voltage drop in the lamp wiring for each of the monitored lamp circuits. Little additional wiring is necessary for installation because the system can be completely integral to the wiring assembly. No standby power is required. The operating voltage is obtained from the sense leads; the system is energized only when the lamps are turned ON.

These integrated circuits were designed to withstand the severe environment of heavy-duty automotive applications. Lateral PNP transistors and thin-film resistors provide high-frequency noise immunity, transient-voltage protection, and reverse voltage protection. Internal regulators and temperature compensation are included in the circuit design. A failure within the device will not affect lamp operation. For low-voltage applications (10 to 16 V) the pin-compatible ULN-2455A is suggested.

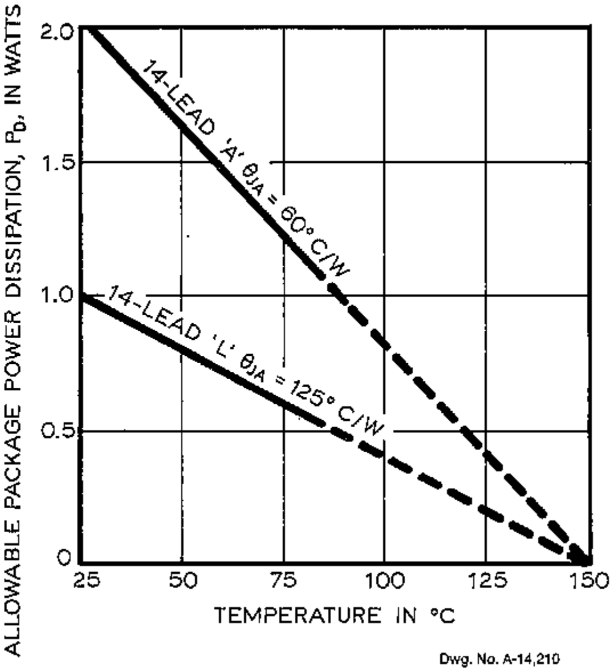


The ULN-2457A is supplied in a standard 14-pin dual in-line plastic package. The ULN-2457L is supplied in a surface-mount 14-lead SOIC plastic package. Both devices are rated for operation over the temperature range of −40°C to +85°C.

ABSOLUTE MAXIMUM RATINGS
at +25°C Free-Air Temperature

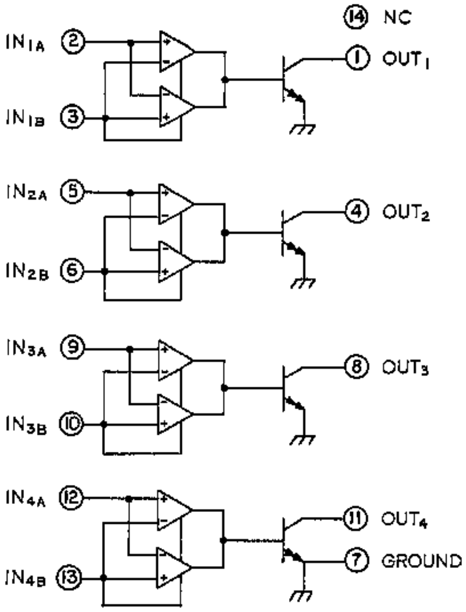
Supply Voltage, V_{CC}	34 V
Peak Supply Voltage, V_{CC} (0.1 s)	80 V
Peak Reverse Voltage, V_R	30 V
Output Current, I_{OUT}	35 mA
Package Power Dissipation, P_D	See Graph
Operating Temperature Range, T_A	−40°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

ALLOWABLE PACKAGE POWER DISSIPATION AS A FUNCTION OF TEMPERATURE



Dwg. No. A-14,210

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. A-12,033A

ELECTRICAL CHARACTERISTICS at $T_A = +25°C$, $V_{CC} = V_{IN} = 18$ to 32 V (unless otherwise shown)

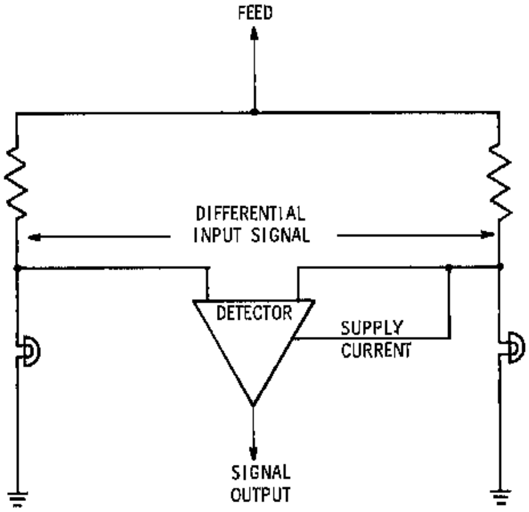
Characteristic	Test Pins	Test Conditions	Limits			
			Min.	Typ.	Max.	Units
Output Leakage Current	1, 4, 8, 11	$V_{OUT} = 80$ V, $\Delta V_{IN} < 7$ mV	—	—	100	µA
Output Saturation Voltage	1, 4, 8, 11	$I_{OUT} = 5$ mA, $\Delta V_{IN} > 20$ mV	—	0.8	1.0	V
		$I_{OUT} = 30$ mA, $\Delta V_{IN} > 20$ mV	—	1.4	2.0	V
Differential Switch Voltage	2-3, 5-6, 9-10, 12-13	Absolute Value $V_{(2)} - V_{(3)}$	7.0	13	20	mV
Input Current	2, 5, 9, 12	$\Delta V_{IN} = V_{(2)} - V_{(3)} = +30$ mV	150	300	800	µA
	3, 6, 10, 13	$\Delta V_{IN} = V_{(2)} - V_{(3)} = -30$ mV	0.5	1.7	3.5	mA

PRINCIPLE OF OPERATION

Operation of these lamp monitors is similar to that of a simple bridge circuit in which the top two legs of the bridge are formed by the wiring assembly resistance or discrete low-value resistors. The bottom legs of the bridge are the monitored lamps. Four differential amplifier circuits sense the voltage drops in the wiring assemblies (approximately 20 mV) for each of the lamp circuits. When the system detects a difference in voltage due to an open filament, the appropriate output driver is turned ON.

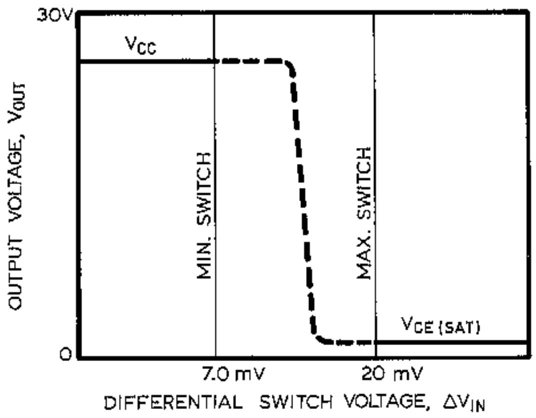
Sprague Technical Paper TP 81-7 discusses the requirements of automotive lamp monitoring systems and presents a more detailed description of the operation of these differential sense amplifiers.

BASIC BRIDGE MONITORING SYSTEM



Dwg. No. A-11,473A

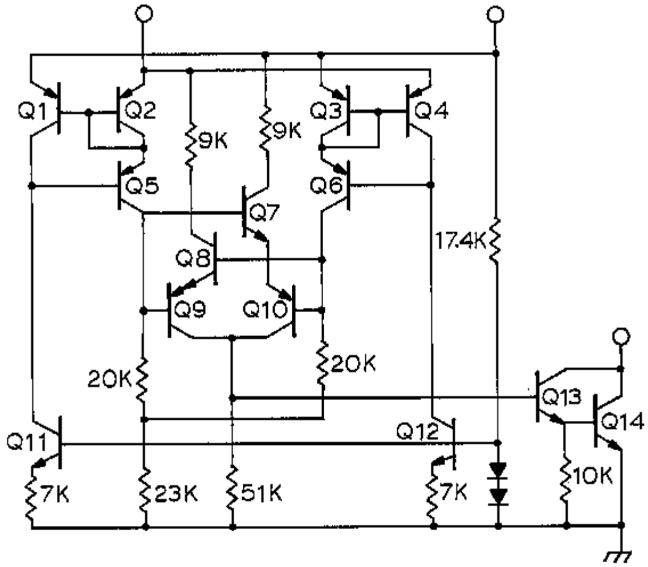
TYPICAL SWITCH CHARACTERISTICS



Dwg. No. A-12,187

SIMPLIFIED SCHEMATIC

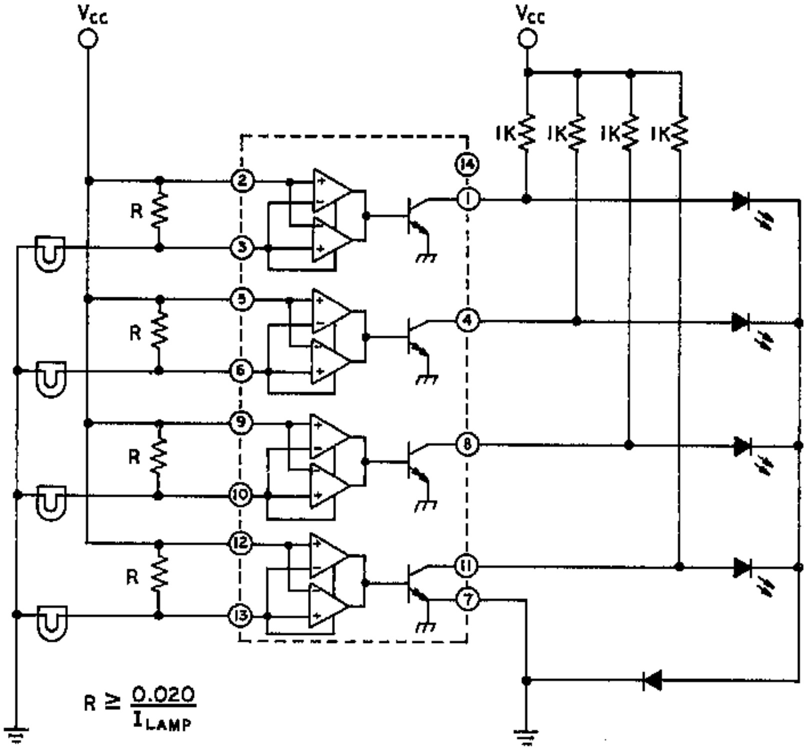
(One of 4 differential sense amplifiers)



Dwg. No. A-14,212

TYPICAL APPLICATIONS

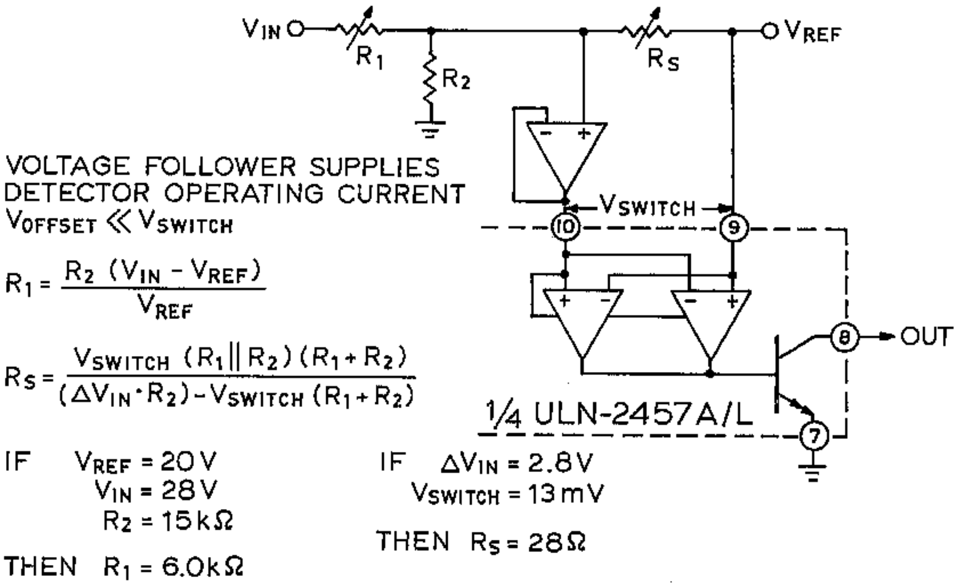
QUAD LAMP MONITOR



$R \geq \frac{0.020}{I_{LAMP}}$

Dwg. No. A-14,209

POWER SUPPLY SUPERVISORY CIRCUIT



VOLTAGE FOLLOWER SUPPLIES
DETECTOR OPERATING CURRENT
$V_{OFFSET} \ll V_{SWITCH}$

$$R_1 = \frac{R_2\,(V_{IN} - V_{REF})}{V_{REF}}$$

$$R_S = \frac{V_{SWITCH}\,(R_1 \| R_2)(R_1 + R_2)}{(\Delta V_{IN} \cdot R_2) - V_{SWITCH}\,(R_1 + R_2)}$$

IF $V_{REF} = 20\,V$
$V_{IN} = 28\,V$
$R_2 = 15\,k\Omega$
THEN $R_1 = 6.0\,k\Omega$

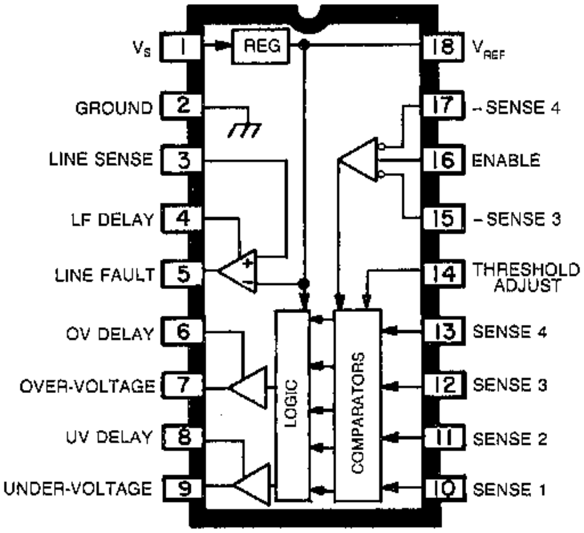
IF $\Delta V_{IN} = 2.8\,V$
$V_{SWITCH} = 13\,mV$
THEN $R_S = 28\Omega$

Dwg. No. A-14,211

ULN-8130A
PRECISION SUPERVISORY SYSTEMS MONITOR
Quad Voltage and Line Monitor

FEATURES

- 10 V to 35 V Operation
- Low Standby Current
- Reference Trimmed to 1%
- Monitors 4 Separate DC Levels
- Separate Under-Voltage Comparators
- Fixed Under-Voltage Threshold
- Line Sense Input
- Pull-Up Clamped Outputs
- Programmable Output Delays
- V_S Under-Voltage Lockout



Dwg. No. A-13,221

Capable of monitoring four dc power lines, the ULN-8130A is a power fault monitor for both under-voltage and over-voltage conditions. Two of the four inputs are designed to monitor positive voltages while the other two inputs can be used to monitor two positive or two negative voltages. An additional comparator is used to monitor the primary power line and will provide early warning of line voltage drop-out.

An under-voltage lockout, monitoring the ULN-8130A internal supply, prevents false outputs from occurring during low supply-voltage operation. The logic outputs can be used to operate LEDs or other low-voltage indicators.

The circuit configuration of the ULN-8130A allows easy programming of over-voltage thresholds which are referenced to a 1% trimmed 2.5 V bandgap reference. The UV FAULT (pin 9) is initiated by one or more of the four sense inputs falling below the UV trip point (the internal reference voltage). The OV FAULT (pin 7) is activated by one or more of the sense inputs rising above the externally set (pin 14) OV trip point. The LINE OK output (pin 5) will remain high as long as the LINE SENSE input (pin 3) is above the internal reference voltage. The LINE SENSE will accept a positive dc voltage proportional to either the high-voltage master bus or the ac line.

Output delays can be introduced by adding capacitors from the appropriate DELAY pins to ground. The LINE FAULT DELAY capacitor value should be large enough to prevent false shutdowns due to short line transients.

The ULN-8130A is supplied in an 18-pin dual in-line plastic package with a copper lead frame that gives it enhanced power dissipation ratings. It is rated for continuous operation over the temperature range of 0°C to +70°C.

ABSOLUTE MAXIMUM RATINGS at $T_A = +25°C$

Supply Voltage, V_{CC}	35 V
Power Dissipation, P_D	2.3 W*
Operating Temperature, T_A	0°C to +70°C
Storage Temperature, T_S	−65°C to +150°C
Junction Temperature, T_J	+150°C

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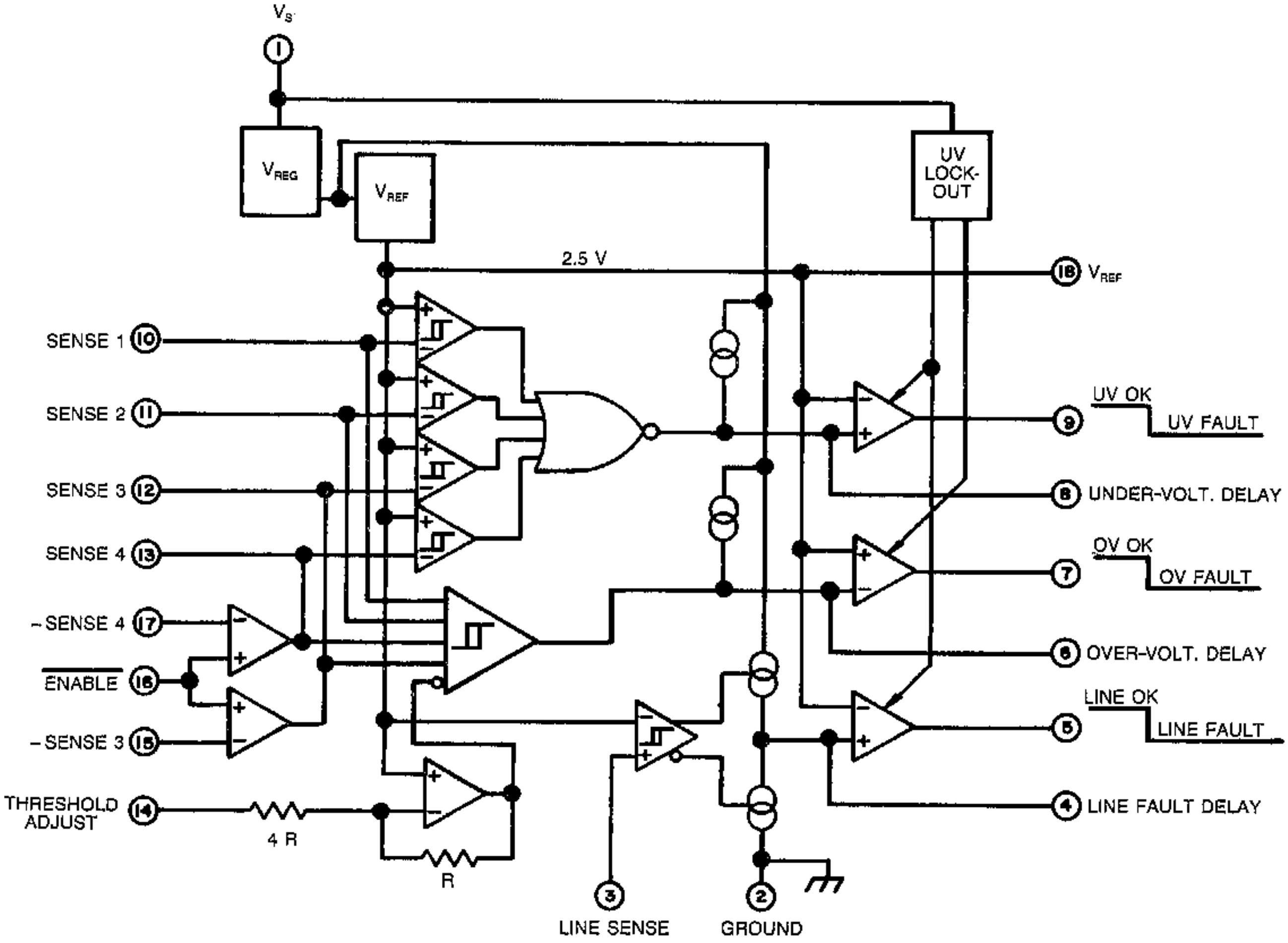
*Derate at the rate of 18.2 mW/°C above $T_A = 25°C$

FUNCTIONAL BLOCK DIAGRAM



DWG A-13,002

ELECTRICAL CHARACTERISTICS at $T_A = +25°C, V_S = 15\ V$

			Limits		
Characteristic	Test Pin	Test Conditions	Min.	Max.	Units
Functional V_S Range	1		10	35	V
Quiescent Current	1	$V_S = 35\ V, V_{16} = V_{18}$, No Fault	—	15	mA

REFERENCE VOLTAGE SECTION

Characteristic	Test Pin	Test Conditions	Min.	Max.	Units
Reference Voltage	18	No Load, $T_A = +25°C$	2.47	2.53	V
		No Load, Change Over Temp.	—	25	mV
Load Regulation	18	$I_{REF} = 0$ to 10 mA	—	20	mV
Line Regulation	18	$V_S = 10$ to 35 V	—	10	mV
Ripple Rejection	18	f = 120 Hz	60	—	dB
Short-Circuit Current Protection	18		—	40	mA

COMPARATOR SECTION

Characteristic	Test Pin	Test Conditions	Min.	Max.	Units
Under-Voltage Trip Points	10-13*	$T_A = +25°C$	2.47	2.53	V
		Over Temperature	2.46	2.54	V
Under-Voltage Trip Hysteresis	10-13*	Over Temperature	10	25	mV
Over-Voltage Trip Points	10-13*	$V_{14} = 0$	3.08	3.17	V
Over-Voltage Trip Hysteresis	14	$V_{14} = 0$ to 2.5 V, Over Temp.	10	25	mV
Line Monitor Trip Threshold	3		2.40	2.54	V
Under-Voltage Lockout Enable	1	V_S Decreasing	8.5	—	V
Under-Voltage Lockout Disable	1	V_S Increasing	—	10.5	V
Input Bias Current	3, 10, 11	$V_{IN} = 2.0\ V$	—	−6.0	μA
		$V_{IN} = 3.0\ V$	—	6.0	μA
	14	$V_{IN} = 0$	—	−50	μA
	15, 17	$V_{IN} = -2.0\ V, V_{16} = 0\ V$	—	−2.0	μA

OUTPUT DRIVERS

Characteristic	Test Pin	Test Conditions	Min.	Max.	Units
Output Saturation Voltage	5, 9	$I_{SINK} = 5.0\ mA$	—	0.5	V
	7	$I_{SINK} = 10\ mA$	—	0.5	V
	5, 7, 9	$I_{SOURCE} = 500\ \mu A$	4.0	5.25	V
Output Leakage Current	5, 7, 9	$V_{OUT} = 35\ V$	—	50	μA
Line Fault Delay Current Source	4	$V_4 = 2.0\ V$	160	350	μA
Line Fault Delay Current Sink	4	$V_4 = 2.0\ V$	3.2	7.0	mA
Over-Voltage Delay Current Source	6	$V_6 = 2.0\ V$	160	300	μA
Under-Voltage Delay Current Source	8	$V_8 = 2.0\ V$	35	75	μA

*All inputs connected to 2.75 V except input being tested.

APPLICATIONS

The basic voltage monitors are based on a 2.5 V precision bandgap reference. External resistive dividers are used to present a nominal 2.5 V level to each under-voltage comparator at the minimum allowable under-voltage condition. The over-voltage reference is set up by another resistive divider at pin 14 determined by the tightest over-voltage tolerance requirement.

BASIC FORMULAS:

(1) An under-voltage fault is detected, (pin 9 goes low), when the positive input voltage being monitored is less than:

$$V_{MON(LO)} = 2.5\ (R_1 + R_2)/R_2$$

(2) The internal over-voltage threshold is defined as:

$$V_{OVT} = 2.5\left[1 + \frac{R_A}{4(R_A + R_B)}\right]$$

where R_A // R_B << 100 kΩ.

(3) An over-voltage fault is detected when the positive input voltage being monitored exceeds:

$$V_{MON(HI)} = V_{OVT}\ (R_1 + R_2)/R_2$$

(4) Individual over-voltage thresholds can be increased by the addition of R_X with

$$R_X = R_1\left[\frac{V_{OVT} - 2.5}{V_{MON(HI)} - V_{OVT}\left(\frac{R_1 + R_2}{R_2}\right)}\right]$$

(5) To monitor negative supplies at SENSE 3 and SENSE 4, pin 16 is connected to ground. In this condition, an under-voltage fault indication will occur when either negative supply being monitored falls below:

$$V_{MON(LO)} = 2.5\ R_3/R_4$$

Note that for monitor purposes, under-voltage means the negative supply is actually going net positive, or toward ground.

(6) For negative supplies, an over-voltage fault indication will occur when:

$$V_{MON(HI)} = V_{OVT}\ R_3/R_4$$

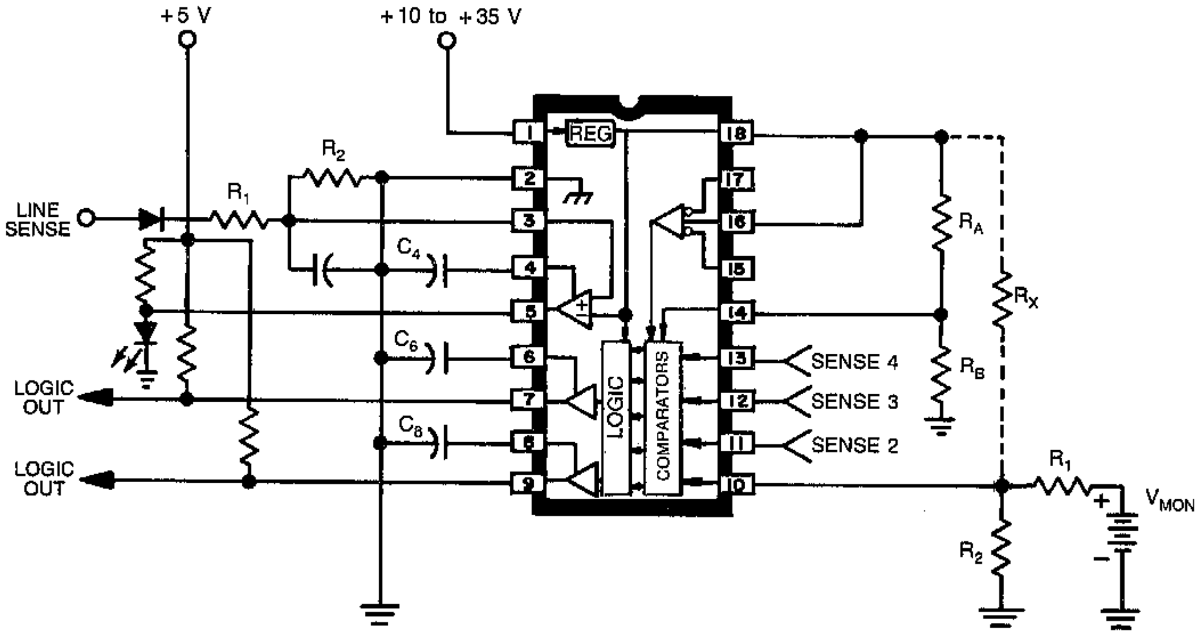
(7) Fault delay capacitor values are determined by:

$$C_4 \text{ or } C_6 = \frac{200 \times 10^{-6} \times t}{2.5}$$

$$C_9 = \frac{55 \times 10^{-6} \times t}{2.5}$$

where t is the output delay in seconds.

LINE SENSE AND POSITIVE SUPPLY MONITORING
(SENSE 1, 2, 3, and 4)



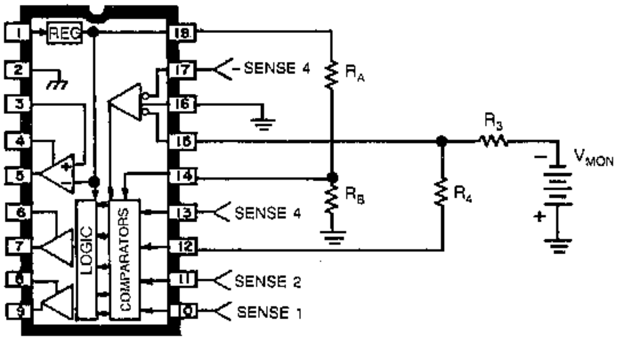
Dwg. No. A-13,222

UNUSED INPUTS

Unused positive sense channel inputs (pins 3, 10-13) must not be left unconnected. Neither can they be tied high (over-voltage fault indication), tied low (under-voltage fault indication), or tied to the internal reference (susceptible to noise and voltage offsets). Unused sense channel inputs should be connected to any operating sense channel input. For example, if channels 1, 2, and 4 are being used, the unused channel 3 sense input (pin 12) should be connected to the sense 2 or sense 4 input.

Unused negative sense channel inputs (pins 15 and 17) can be left open-circuited *provided* the associated enable input (pin 16) is tied high and the associated positive sense channel inputs (pins 12 and 13) are utilized to monitor positive supplies or are connected as described above.

NEGATIVE SENSE MONITORING
SENSE 3 and 4 Only



Dwg. No. A-13,223

DESIGN EXAMPLE

As an example, consider the following set of monitoring conditions:

V_1 = +5 V+10%, –5%
V_2 = +12 V ±10%
V_3 = +15 V ±5%
V_4 = +24 V ±10%

The required input dividers are calculated per (1) to yield the resistor divider ratios, R_2 (R_1 + R_2), of: 0.5263, 0.2315, 0.1754 (Note 1), and 0.1157 respectively. The over-voltage threshold, V_{OVT}, would be dictated by the tightest tolerance supply which gives the lowest V_{OVT} from (3). Therefore, $V_{MON(HI)}$ = 15 x 1.05 = 15.75 volts and V_{OVT} = 15.75 x 0.1754 = 2.763 volts[1]. This is the voltage appearing at the SENSE terminal and is equal to the over-voltage threshold to be set via the resistor ratio at pin 14. From (2), $R_A/(R_A + R_B)$ is calculated to be 0.4096. It is good practice to keep the equivalent external impedances as low as possible, in order to minimize bias current and offset errors. For the purpose of this example, all resistor dividers will be taken to have an equivalent impedance of 1000 ohms. This being the case, the final values are: R_A = 1.7 kΩ and R_B = 2.44 kΩ.

In order to provide accurate over-voltage sensing for the V_1, V_2, and V_4 supplies, resistors are connected from the respective input sense nodes and returned to the 2.5 V reference. Calculation is made by first picking values for the input dividers and then calculating the required value of R_X from (4). Again, assuming 1 kΩ equivalent divider impedances and making the calculations, a summary of results is given below.

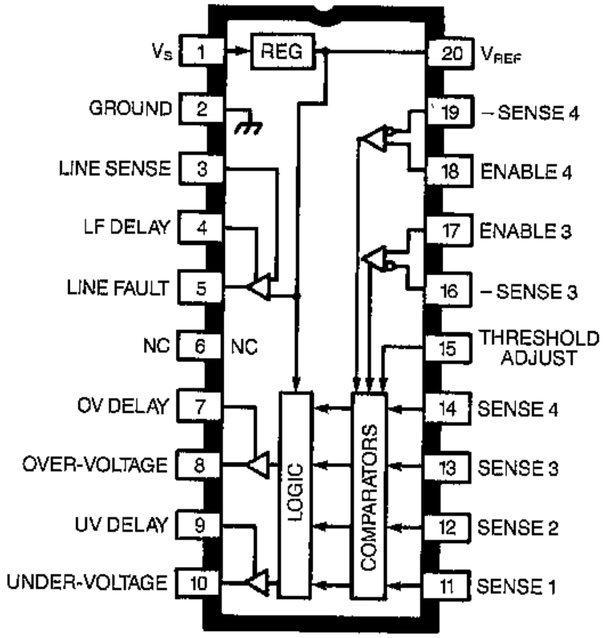
MONITORED SUPPLY	$V_{MON(HI)}$	$V_{MON(LO)}$	R_1	R_2	R_X
+5 V (+10%, –5%)	5.5 V	4.75 V	1.90 kΩ	2.11 kΩ	2.0 kΩ
+12 V (±10%)	13.2 V	10.8 V	4.32 kΩ	1.30 kΩ	900 Ω
+15 V (±5%)	15.75 V	14.25 V	5.70 kΩ	1.21 kΩ	∞
+24 V (±10%)	26.4 V	21.6 V	8.64 kΩ	1.13 kΩ	900 Ω

1. Note that the number 0.1754 is rounded off. Due to required accuracies in the external dividers, round off numbers only after final resistor values are calculated. For the same reason, use stable high-accuracy metal film resistors. Many applications may benefit from combining the ULN-8130A and functionally trimmed Sprague resistor-capacitor networks.

ULN-8131A
PRECISION SUPERVISORY SYSTEMS MONITOR
Quad Voltage and Line Monitor

FEATURES

- Reference Trimmed to 1%
- Monitors Four DC Supplies
- 10 to 35 Volts Operation
- Low Standby Current
- Separate Under-Voltage Comparators
- Fixed Under-Voltage Threshold
- Programmable Over-Voltage Threshold
- Line Sense Input
- Full-Up Clamped Outputs
- Programmable Output Delays
- V_S Under-Voltage Lockout



Dwg. No. W-185

Capable of monitoring four dc power lines, the ULN-8131A is a power-fault monitor for both under-voltage and over-voltage conditions. Two of the four inputs are designed to monitor positive voltages, while the other two inputs can be used to monitor positive or negative voltages. Typical examples might be a +5 V logic supply, +15 V and −15 V analog supplies, and a positive peripheral power load supply. The primary power line is monitored by an additional comparator and will provide early warning of line voltage drop-out.

During low-supply voltage operations, an under-voltage lockout which monitors the ULN-8131A internal supply, prevents false outputs from occurring. The logic outputs can be used to operate LEDs or other low-voltage indicators.

The circuit configuration of the ULN-8131A allows easy programming of over-voltage thresholds which are referenced to a 1% trimmed 2.5 V bandgap reference. The UV FAULT (pin 10) is initiated by one or more of the four sense inputs falling below the UV trip point (the internal reference voltage). The OV FAULT (pin 8) is activated by one or more of the sense inputs rising above the externally set (pin 15) OV trip point. The LINE OK output (pin 5) will remain high as long as the LINE SENSE input (pin 3) is above the internal reference voltage. The LINE SENSE will accept a positive dc voltage proportional to either the high-voltage master bus or the ac line.

Output delays can be introduced by adding capacitors from the appropriate DELAY pins to ground. The LINE FAULT DELAY capacitor value should be large enough to prevent false shutdowns due to short line transients.

The ULN-8131A is supplied in a 20-pin dual in-line plastic package with a copper lead frame that gives it enhanced power dissipation ratings. The similar ULN-8130A is intended for monitoring four positive supplies, or two positive and two negative supplies. It is supplied in an 18-pin DIP.

ABSOLUTE MAXIMUM RATINGS
at $T_A = +25°C$

Supply Voltage, V_{CC}	35 V
Power Dissipation, P_D	2.3 W*
Operating Temperature, T_A	0°C to +70°C
Storage Temperature, T_S	−65°C to +150°C
Junction Temperature, T_J	+150°C

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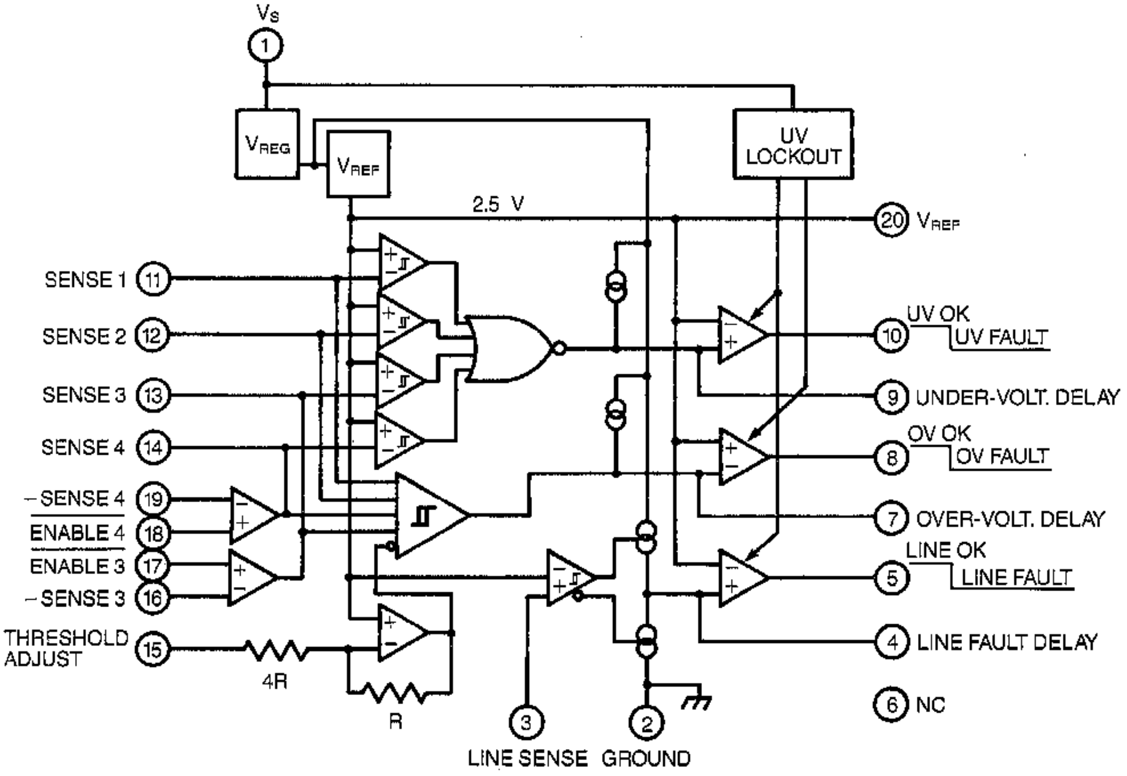
*Derate at the rate of 18.2 mW/°C above $T_A = 25°C$

FUNCTIONAL BLOCK DIAGRAM



Dwg. No. W-186

ELECTRICAL CHARACTERISTICS at $T_A = +25°C, V_S = 15\,V$

Characteristic	Test Pin	Test Conditions	Limits Min.	Limits Max.	Units
Functional V_S Range	1		10	35	V
Quiescent Current	1	$V_S = 35V, V_{17} = V_{18} = V_{20}$ No Fault	—	15	mA

REFERENCE VOLTAGE SECTION

Characteristic	Test Pin	Test Conditions	Limits Min.	Limits Max.	Units
Reference Voltage	20	No Load, $T_A = +25°C$	2.47	2.53	V
		No Load, Change Over Temp.	—	25	mV
Load Regulation	20	$I_{REF} = 0$ to 10mA	—	20	mV
Line Regulation	20	$V_S = 10$ to 35V	—	10	mV
Ripple Rejection	20	f = 120Hz	60	—	dB
Short-Circuit Current Protection	20		—	40	mA

COMPARATOR SECTION

Characteristic	Test Pin	Test Conditions	Limits Min.	Limits Max.	Units
Under-Voltage Trip Points	11-14*	$T_A = +25°C$	2.47	2.53	V
		Over Temperature	2.46	2.54	V
Under-Voltage Trip Hysteresis	11-14*	Over Temperature	10	25	mV
Over-Voltage Trip Points	11-14*	$V_{15} = 0$	3.08	3.17	V
Over-Voltage Trip Hysteresis	15	$V_{15} = 0$ to 2.5V, Over Temp.	10	25	mV
Line Monitor Trip Threshold	3		2.40	2.54	V
Under-Voltage Lockout Enable	1	V_S Decreasing	8.5	—	V
Under-Voltage Lockout Disable	1	V_S Increasing	—	10.5	V
Input Bias Current	3, 11, 12	$V_{IN} = 2.0V$	—	−6.0	μA
		$V_{IN} = 3.0V$	—	6.0	μA
	15	$V_{IN} = 0$	—	−50	μA
	16, 19	$V_{IN} = -2.0V, V_{17} = V_{18} = 0V$	—	−2.0	μA

OUTPUT DRIVERS

Characteristic	Test Pin	Test Conditions	Limits Min.	Limits Max.	Units
Output Saturation Voltage	5, 10	$I_{SINK} = 5.0mA$	—	0.5	V
	8	$I_{SINK} = 10mA$	—	0.5	V
	5, 8, 10	$I_{SOURCE} = 500\mu A$	4.0	5.25	V
Output Leakage Current	5, 8, 10	$V_{OUT} = 35V$	—	50	μA
Line Fault Delay Current Source	4	$V_4 = 2.0V$	160	350	μA
Line Fault Delay Current Sink	4	$V_4 = 2.0V$	3.2	7.0	mA
Over-Voltage Delay Current Source	7	$V_7 = 2.0V$	160	300	μA
Under-Voltage Delay Current Source	9	$V_9 = 2.0V$	35	75	μA

**All inputs connected to 2.75 V except input being tested.*

APPLICATIONS

The basic voltage monitors are based on a 2.5 V precision bandgap reference. External resistive dividers are used to present a nominal 2.5 V level to each under-voltage comparator at the minimum allowable under-voltage condition. The over-voltage reference is set up by another resistive divider at pin 15 determined by the tightest over-voltage tolerance requirement.

BASIC FORMULAS:

(1) An under-voltage fault is detected, (pin 10 goes low), when the positive input voltage being monitored is less than:

$$V_{MON(LO)} = 2.5\,(R_1 + R_2)/R_2$$

(2) The internal over-voltage threshold is defined as:

$$V_{OVT} = 2.5 \left[1 + \frac{R_A}{4(R_A + R_B)} \right]$$

where $R_A \,//\, R_B << 100\ k\Omega$.

(3) An over-voltage fault is detected when the positive input voltage being monitored exceeds:

$$V_{MON(HI)} = V_{OVT}\,(R_1 + R_2)/R_2$$

(4) Individual over-voltage thresholds can be increased by the addition of R_X with

$$R_X = R_1 \left[\frac{V_{OVT} - 2.5}{V_{MON(HI)} - V_{OVT}\left(\frac{R_1 + R_2}{R_2}\right)} \right]$$

(5) To monitor negative supplies at SENSE 3 or SENSE 4, pin 17 or 18, respectively, is connected to ground. In this condition, an under-voltage fault indication will occur when the negative supply being monitored falls below:

$$V_{MON(LO)} = 2.5\,R_3/R_4$$

Note that for monitor purposes, under-voltage means the negative supply is actually going net positive, or toward ground.

(6) For negative supplies, an over-voltage fault indication will occur when:

$$V_{MON(HI)} = V_{OVT}\,R_3/R_4$$

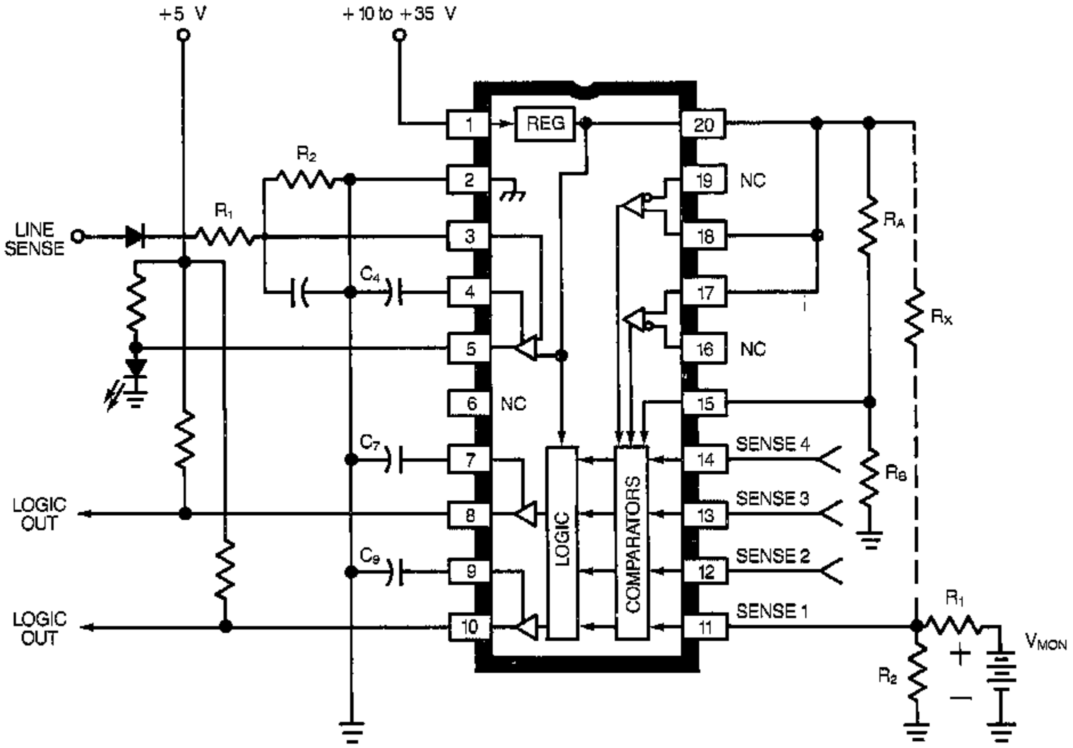
(7) Fault delay capacitor values are determined by:

$$C_4 \text{ or } C_7 = \frac{200 \times 10^{-6} \times t}{2.5}$$

$$C_9 = \frac{55 \times 10^{-6} \times t}{2.5}$$

where t is the output delay in seconds.

LINE SENSE AND POSITIVE SUPPLY MONITORING
(SENSE 1, 2, 3, and 4)



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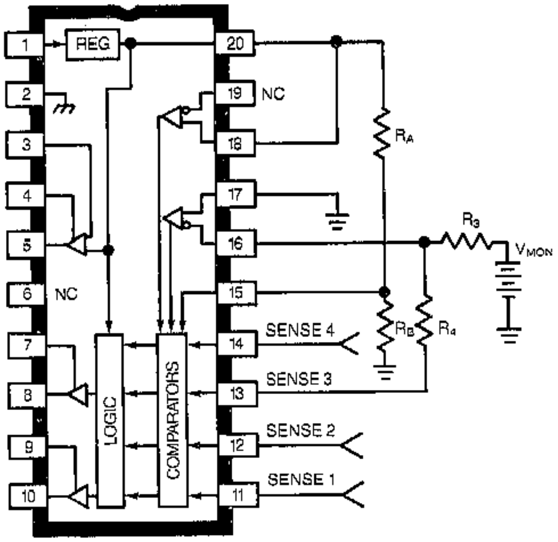
UNUSED INPUTS

Unused positive sense channel inputs (pins 3, 11-14) must not be left unconnected. They cannot be tied high (over-voltage fault indication), tied low (under-voltage fault indication), or tied to the internal reference (susceptible to noise and voltage offsets). Unused sense channel inputs should be connected to any operating sense channel input. For example, if channels 1, 2, and 4 are being used, the unused channel 3 sense input (pin 13) should be connected to the SENSE 2 or SENSE 4 input.

Unused negative sense channel inputs (pins 16 and 19) can be left open-circuited *provided* the associated ENABLE inputs (pins 17 and 18) are tied high and the associated positive sense channel inputs (pins 13 and 14) are utilized to monitor positive supplies or are connected as described above.

NEGATIVE SENSE MONITORING

SENSE 3 and 4 Only



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DESIGN EXAMPLE

As an example, consider the following set of monitoring conditions:

$V_1 = +5\,V\ (+10\%, -5\%)$
$V_2 = +12\,V\ (\pm 10\%)$
$V_3 = +15\,V\ (\pm 5\%)$
$V_4 = +24\,V\ (\pm 10\%)$

The required input dividers are calculated per (1) to yield the resistor divider ratios, $R_2 (R_1 + R_2)$, of: 0.5263, 0.2315, 0.1754 (Note 1), and 0.1157 respectively. The over-voltage threshold, V_{OVT}, would be dictated by the tightest tolerance supply which gives the lowest V_{OVT} from (3). Therefore, $V_{MON(HI)} = 15 \times 1.05 = 15.75\,V$ and $V_{OVT} = 15.75 \times 0.1754 = 2.763\,V$[1]. This is the voltage appearing at the SENSE terminal and is equal to the over-voltage threshold to be set via the resistor ratio at pin 15. From (2), $R_A/(R_A + R_B)$ is calculated to be 0.4096. It is good practice to keep the equivalent external impedances as low as possible, in order to minimize bias current and offset errors. For the purpose of this example, all resistor dividers will be taken to have an equivalent impedance of 1000 ohms. This being the case, the final values are: $R_A = 1.7\,k\Omega$ and $R_B = 2.44\,k\Omega$.

In order to provide accurate over-voltage sensing for the V_1, V_2, and V_4 supplies, resistors are connected from the respective input sense nodes and returned to the 2.5 V reference. Calculation is made by first picking values for the input dividers and then calculating the required value of R_X from (4). Again, assuming 1 kΩ equivalent divider impedances and making the calculations, a summary of results is given below.

MONITORED SUPPLY	$V_{MON(HI)}$	$V_{MON(LO)}$	R_1	R_2	R_X
+5V (+10%, −5%)	5.5V	4.75V	1.90kΩ	2.11kΩ	2.0kΩ
+12V (±10%)	13.2V	10.8V	4.32kΩ	1.30kΩ	900Ω
+15V (±5%)	15.75V	14.25V	5.70kΩ	1.21kΩ	∞
+24V (±10%)	26.4V	21.6V	8.64kΩ	1.13kΩ	900Ω

---

1. Note that the number 0.1754 is rounded off. Due to required accuracies in the external dividers, round off numbers only after final resistor values are calculated. For the same reason, use stable high-accuracy metal film resistors. Many applications may benefit from combining the ULN-8131A and functionally trimmed Sprague resistor-capacitor networks.

ULN-8163A AND ULN-8163R SWITCHED-MODE POWER SUPPLY CONTROL CIRCUITS

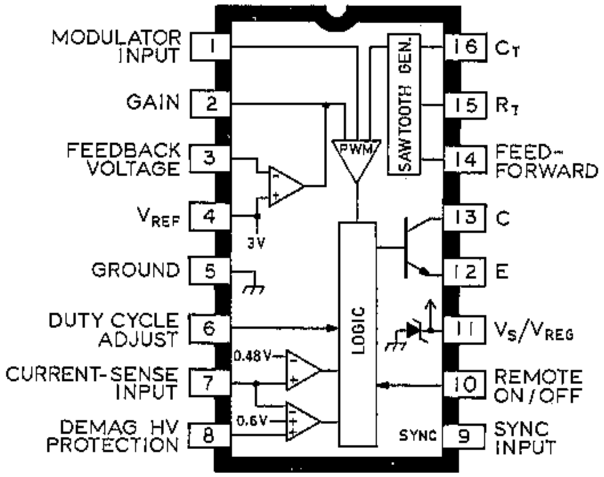
FEATURES

- Supply Range of 4.5 V to 14 V; Internal Shunt Regulator for Higher-Voltage Source Operation
- Low Standby Current
- 300 kHz Sawtooth Generator
- Improved Feed-forward Control (4:1 Range)
- Precision Current-Limit Threshold
- Precision (1%) Bandgap Voltage Reference
- Improved Stability Over Temperature
- Direct Pulse-Width Modulator Access
- External TTL-Compatible Synchronization
- Precision Over-Voltage Threshold
- TTL-Compatible Shutdown

The ULN-8163A and ULN-8163R are switched-mode power supply control circuits featuring low-voltage operation, precision reference, and protective features. Both have a temperature-compensated bandgap reference, an internal error amplifier, wide-range feedforward capability, a high-frequency 300 kHz sawtooth waveform generator, a pulse-width modulator, a variety of protection circuitry, and a 200 mA output driver.

Low-voltage operation and low quiescent current drain make them suitable for automotive and other general SMPS applications such as dc-to-dc converters operating directly from 5 V or 12 V supplies and off-line primary-side control.

The ULN-8163A is supplied in a 16-pin dual in-line package with a copper lead frame for enhanced power dissipation ratings for operation over a temperature range of −20°C to +85°C. The ULN-8163R is furnished in a 16-pin hermetically sealed glass/ceramic package which will withstand severe environmental contamination.



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ABSOLUTE MAXIMUM RATINGS at $T_A = +25°C$

Supply Voltage, V_S	(See Note)
Supply Current, I_{REG}	30 mA
Output Current, I_C (peak)	200 mA
(continuous)	100 mA
Reference Output Current, I_{REF}	10 mA
Logic Input Voltage, V_9, V_{10}	8.0 V
Package Power Dissipation, P_D	
(ULN-8163A)	2.1 W*
(ULN-8163R)	1.7 W*
Operating Temperature Range, T_A	−20°C to +85°C
Storage Temperature Range, T_S	−65°C to +150°C

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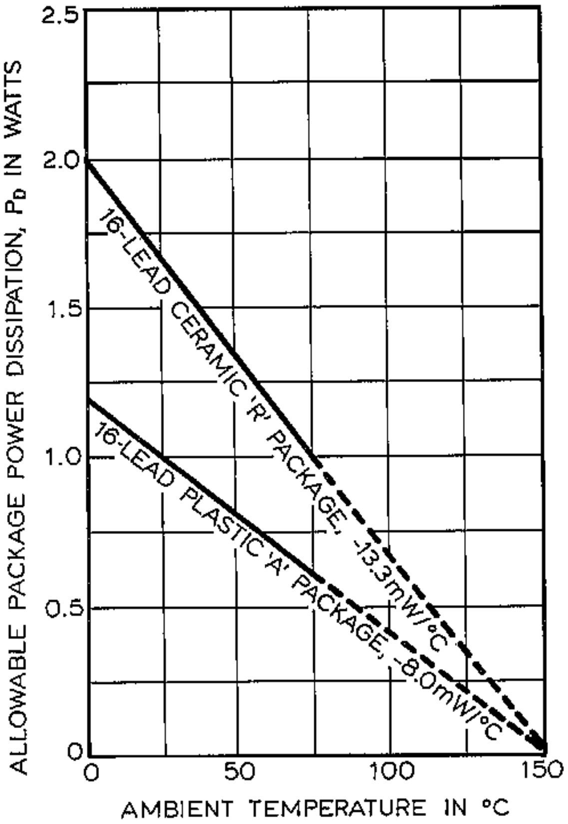
*Derate linearity to 0 W at $T_A = +150°C$

NOTE: Maximum allowable supply voltage is dependent on value of external current limiting resistor: 14 V at 0 Ω.

ALLOWABLE AVERAGE PACKAGE POWER DISSIPATION AS A FUNCTION OF TEMPERATURE



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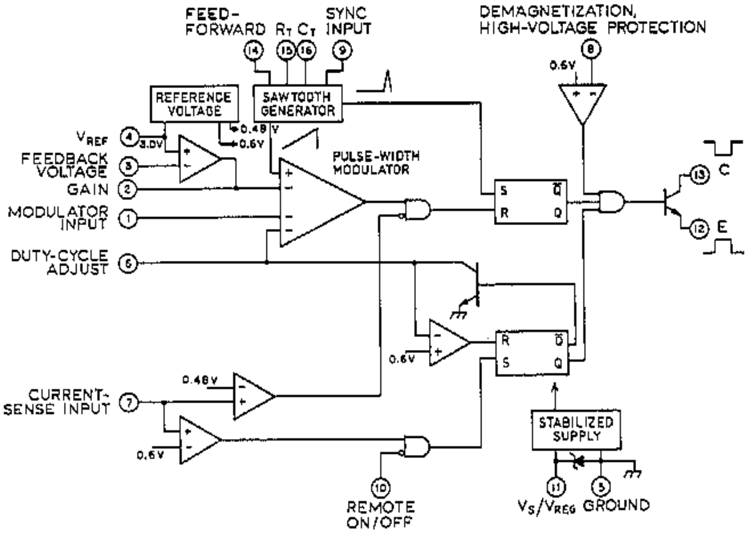
FUNCTIONAL BLOCK DIAGRAM



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ELECTRICAL CHARACTERISTICS at T_A = 25°C, V_S = 12 V, f_o = 40 kHz (unless otherwise specified).

Characteristic	Test Pin	Test Conditions	Limits Min.	Limits Typ.	Limits Max.	Units
Supply Clamp Voltage	11	I_S = 10 mA	14	—	18	V
	11	I_S = 30 mA	15	—	19	V
Supply Current	11	$V_{12} = V_{13} = 0$	2.0	5.5	7.0	mA
REFERENCE SECTION						
Internal Reference, V_{REF}	4	T_A = +25°C	2.97	3.00	3.03	V
	4	Over Operating Temp. Range†	2.94	—	3.06	V
Temperature Coefficient of V_{REF}	4		—	±100	—	ppm/°C
Line Regulation	4	6 V < V_S < 12 V	—	1.0	3.0	mV/V
Load Regulation	4	0 < I_{REF} < 5 mA	—	3.0	10	mV

Note: Negative current is defined as coming out of (sourcing) the specified device pin.
†These parameters, although guaranteed over the operating temperature range, are tested at T_A = +25°C only.
*These parameters are tested to a lot sample plan only.
°Any output other than zero is not allowed.

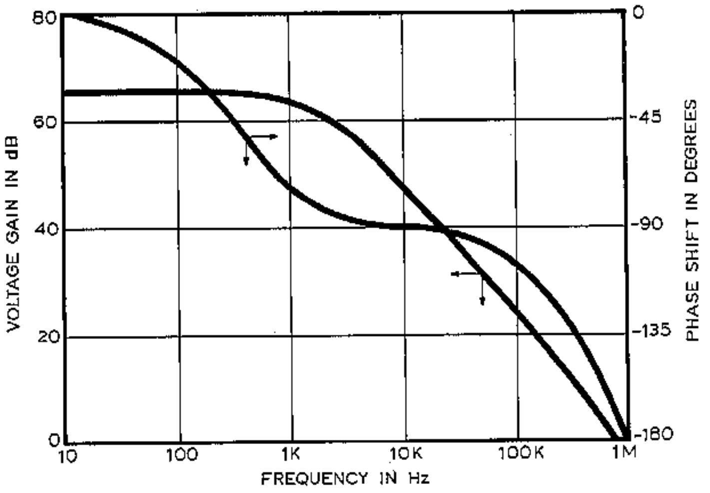
ELECTRICAL CHARACTERISTICS at $T_A = 25°C$, $V_S = 12$ V, $f_o = 40$ kHz (unless otherwise specified).

Characteristic	Test Pin	Test Conditions	Limits Min.	Typ.	Max.	Units
OSCILLATOR SECTION						
Min. Oscillator Frequency*	15, 16	$R_T = 5$ MΩ, $C_T = 15000$ pF	—	—	50	Hz
Max. Oscillator Frequency	15, 16	$R_T = 2.3$ kΩ, $C_T = 500$ pF	200	300	—	kHz
Initial Oscillator Accuracy	15, 16	$R_T = 5$ kΩ	—	±2.0	—	%
Voltage Stability	15, 16	$5 V < V_S < 12 V$	—	0.2	0.5	kHz/V
Temperature Stability			—	30	100	ppm/°C
MODULATOR/COMPARATOR SECTION						
Modulator Input Current	1	$V_1 = 1.0$ V	—	−1.0	−3.0	μA
Maximum Duty Cycle	12	$V_6 < 3.0$ V	95	—	99	%
Minimum Duty Cycle•	12	$V_6 > 0.9$ V	—	—	0	%
Duty Cycle Accuracy	12	$V_6 = 2.0$ V	44	47	50	%
Propagation Delay	6-12		—	200	—	ns
Input Current, Duty Cycle Control	6		—	−1.0	−3.0	μA
PROTECTIVE FUNCTIONS						
Under-Voltage Lockout	11-12		3.80	4.0	4.25	V
Start Threshold	11-12		4.25	4.5	4.75	V
Over-Voltage Threshold	8-12		570	600	630	mV
Over-Voltage Delay	8-12		—	200	500	ns
Over-Voltage Input Current	8		—	2.0	5.0	μA
EXTERNAL SYNCHRONIZATION						
Sync Input OFF Voltage	9		0	—	0.8	V
Sync Input ON Voltage	9		2.0	—	—	V
Sync Input Current	9	$V_9 = 0$ V, $T_A = +25°C$	—	−85	−125	μA
	9	$V_9 = 0$ V, Over Operating Temp. Range†	—	—	−125	μA
REMOTE						
Remote OFF Voltage	10		0	—	0.8	V
Remote ON Voltage	10		2.0	—	—	V
Remote Input Current	10	$T_A = +25°C$	—	−85	−125	μA
	10	Over Operating Temp. Range†	—	—	−125	μA
CURRENT LIMITING						
Input Current	7	$V_7 < 450$ mV	—	−5.0	−20	μA
Inhibit Delay*	7	One Pulse, 20% Overdrive at $I_C = 40$ mA	—	400	600	ns
Trip Levels	7	Shutdown/Slow Start	570	600	630	mV
	7	Current Limit	455	480	505	mV
Shutdown/Current Limit Ratio	—		1.15	1.25	1.40	—
ERROR AMPLIFIER						
Error-Amplifier Gain	3-2	Open Loop	60	66	—	dB
Error-Amplifier Feedback Resistance	2		10	—	—	kΩ
Small-Signal Bandwidth	3-2		700	—	—	kHz
Input Offset Voltage	3		−10	—	10	mV
Input Current	3		—	0.1	1.0	μA
Power Supply Rejection			60	70	—	dB
OUTPUT STAGE						
Output-Saturation Voltage	13	$V_{CE(SAT)}$ at $I_C = 10$ mA, $V_E = 0$	—	—	750	mV
		$V_{CE(SAT)}$ at $I_C = 100$ mA, $V_E = 0$	—	—	1.0	V
Output Voltage	12		—	—	30	V
Output Source Compliance	11	$5 V < V_S < 14 V$	$V_S - 3$	—	—	V

Note: Negative current is defined as coming out of (sourcing) the specified device pin.
†These parameters, although guaranteed over the operating temperature range, are tested at $T_A = +25°C$ only.
*These parameters are tested to a lot sample plan only.
•Any output other than zero is not allowed.

TYPICAL CHARACTERISTICS

ERROR AMPLIFIER VOLTAGE GAIN AND PHASE SHIFT AS FUNCTIONS OF FREQUENCY



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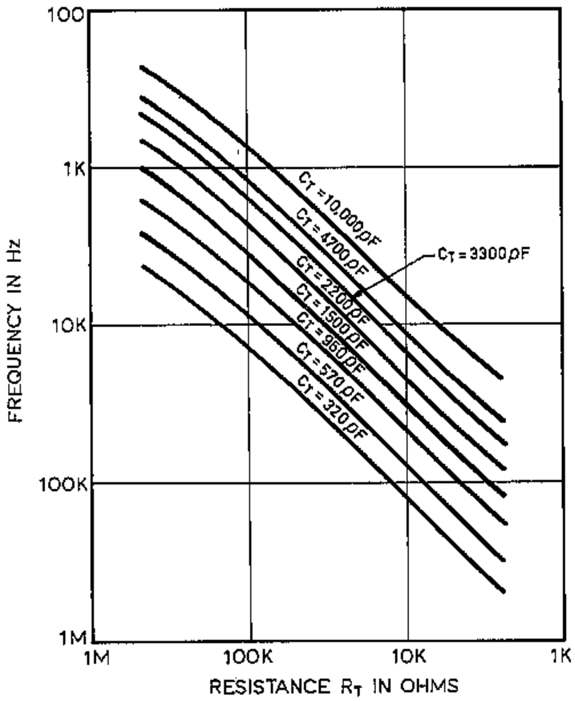
FREQUENCY AS A FUNCTION OF R_T



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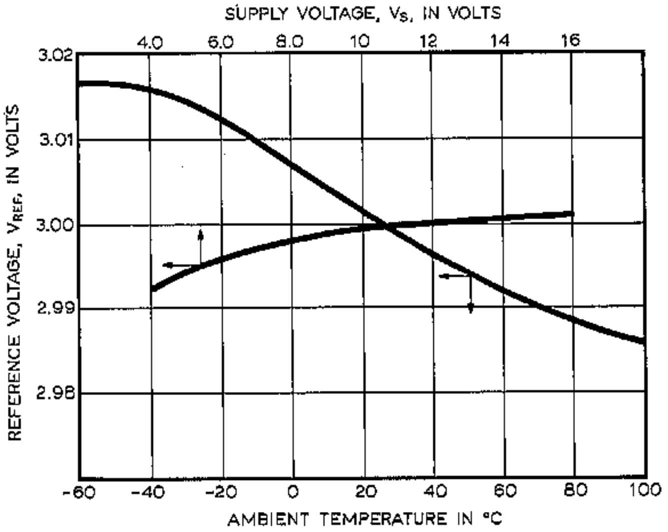
REFERENCE VOLTAGE AS A FUNCTION OF SUPPLY VOLTAGE AND TEMPERATURE



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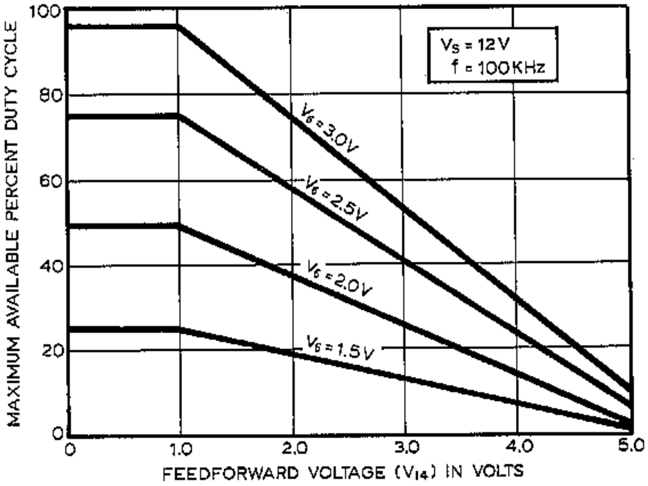
MAXIMUM DUTY CYCLE AS A FUNCTION OF FEED FORWARD VOLTAGE



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TYPICAL APPLICATION

The boost converter shown in Figure 1 is an example of a step-up type dc-to-dc converter that might be used in an automotive application. The ULN-8163A is used due to its wide supply operating range, over-voltage protection, and current-limiting circuits. The application shown will produce an output of 30 V from an input source which varies from 8 V to 24 V (typical of automotive requirements). By changing the feedback, the output switch, and the storage inductor, a wide range of output voltages and power levels can be produced.

The IC supply requirements allow powering the controller through a 470 Ω current-limiting resistor. A 0.1 μF capacitor provides adequate supply bypassing. Over the normal operating range of 8 V to 16 V, the ULN-8163A is voltage driven. The low quiescent current of the circuit, coupled with the low dc current required to drive the power FET switch, results in an IR drop of typically 2 V in the supply resistor, which means that the circuit will remain active at input supply levels as low as 6.5 V. The output regulation may be compromised at these low voltages, depending on the load requirements. At supply voltages above approximately 16 V, the controller will operate in the current-driven mode. The usual maximum supply voltage of 18 V results in a power dissipation requirement of only 10 mW in the supply resistor. With a 24 V supply, the supply resistor dissipation rises to 136 mW, worst case, suggesting the 250 mW resistor. The internal Zenor diode, plus external RC network, provides the additional benefit of excellent protection against over-voltage transients.

The output voltage is set by the feedback resistor divider R_1, R_2. Error amplifier compensation is provided by the RC network connected between pins 2 and 3.

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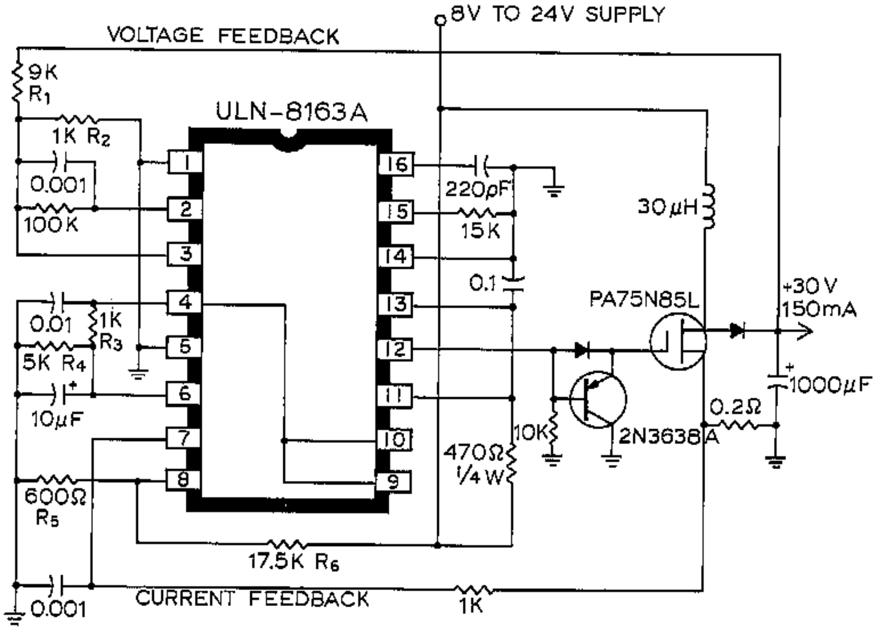

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FIGURE 1
BOOST CONVERTER

The supply operates at a frequency of 100 kHz, set by the timing components at pins 15 and 16. The maximum available duty cycle is set up by the resistor ratio R_3:R_4. The setting is determined by the output voltage and required minimum supply input and in this application is set at 75 percent by a 5:1 resistor divider producing 2.5 V at pin 6.

The over-voltage function provides protection to the power switch during over-voltage transients. This is accomplished by setting the R_5, R_6 divider so that, at some supply voltage, a pin 8 voltage of 600 mV disables the circuit. In this example, the over-voltage trip threshold is at a supply voltage of 18 V. Adjustment of the divider ratio allows the threshold to be adjusted as required.

The output switch is a G.I. PA75N85L n-channel power FET. Alternatively, an IR520 or MTP10N10 can be substituted. The power FET switch results in very low current drive requirements, which significantly eases the supply requirements on the control circuitry. The gate turn-ON is done directly by the sourcing output of the ULN-8163A through the diode. The 2N3638A PNP provides a very simple, low-cost, and effective means of providing rapid (<50 ns) turn-OFF. The value of the storage inductor is determined by the output power requirement and frequency of operation.

For increased output current requirements, a Darlington bipolar power switch can be implemented by using the output drive circuit of Figure 2. In this case, the output collector requires a separate supply return from pin 13 to the input supply.

Additionally, the output connection for a voltage buck converter is shown in Figure 3. With the same 8 V to 24 V supply, the buck converter can be used to provide a high-efficiency 2.5 V to 5 V supply. Considerable literature exists that analyzes both the buck and boost converters.

**FIGURE 2
HIGH-CURRENT
BOOST CONVERTER**

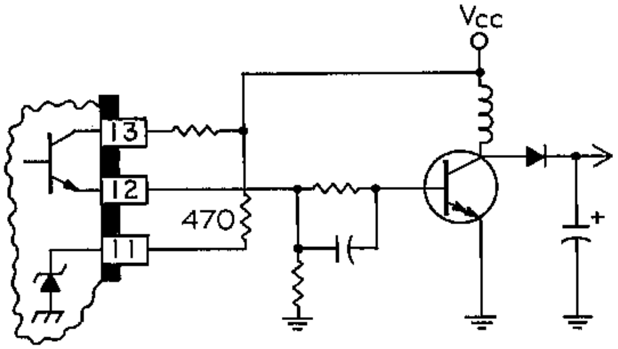

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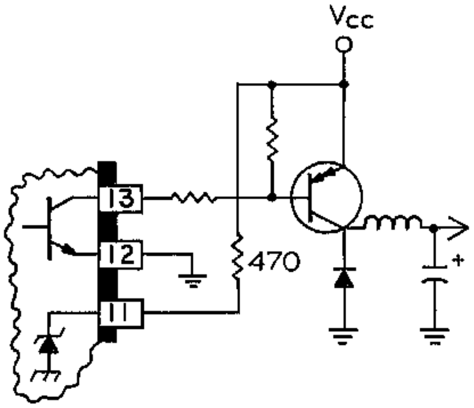
**FIGURE 3
BUCK CONVERTER**



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AN ELECTRONIC LAMP MONITOR

REQUIREMENTS

There are several requirements for a lamp monitoring system. The system should be able to monitor all types of exterior lamps on the automobile; the number of lamps must not be critical to the design. The system must be easy to assemble; it should be simple in design so that it can be repaired in the field with minimal training of personnel; it must be reliable and must be able to withstand the electrical and environmental conditions to which the vehicle is subjected. There should be minimal change from one car line to another, and from one model year to another. Most importantly, the unit cost should be reasonable.

LAMP MONITORING METHODS

Several methods of detecting lamp failure have been examined by the automotive industry. In one, reed relays mounted close to the wiring harness are closed by the electromagnetic force produced by the lamp current. If a lamp fails, the relay opens, resulting in an indication on the dashboard. The system has inherent problems, including a lack of uniformity of the relays, tight tolerances on the proximity of the relays to the wiring assemblies, and the effects of vibration in the automobile.

Another method of monitoring lamps involves the use of phototransistors (Figure 1). These light-sensitive solid-state devices detect the presence of light at each monitored lamp. The signals from each lamp are brought to a common switch, which controls the operation of an indicator on the dash. This monitoring system is unattractive to the user because of cost, difficulty in placement of the sensing devices, inability to detect a single failure in a dual filament lamp, and the need for calibration of devices for various types of lamps.

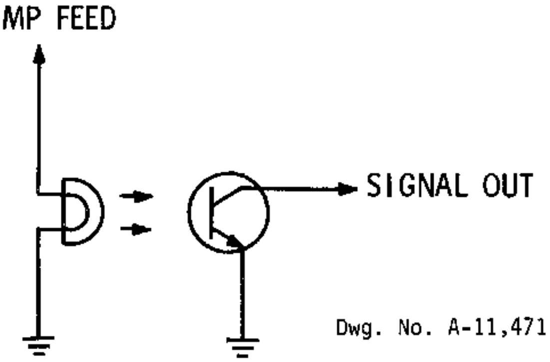


Figure 1
PHOTOTRANSISTOR SYSTEM

One of the more frequently used systems employs fiber optics (Figure 2). The fiber-optic system uses a plastic or glass fiber that transmits light and gives a positive-function indication for each of the lamps monitored. However, this system is used only in applications requiring the monitoring of a small number of lamps, since the cost of materials and of routing fiber optics is prohibitively expensive.

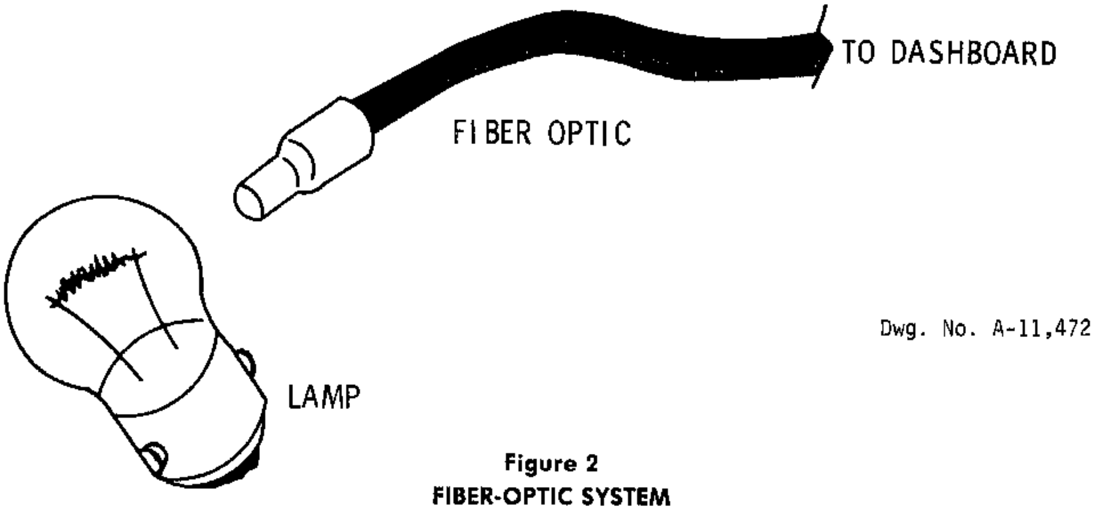


Figure 2
FIBER-OPTIC SYSTEM

SOLUTION

The Sprague Type ULN-2435A electronic lamp monitor overcomes technical problems discussed above while taking advantage of the low cost of integrated circuits. This integrated circuit monitors all types of exterior lamps and provides five outputs capable of driving light-emitting diodes that indicate the location of automotive lamp failure.

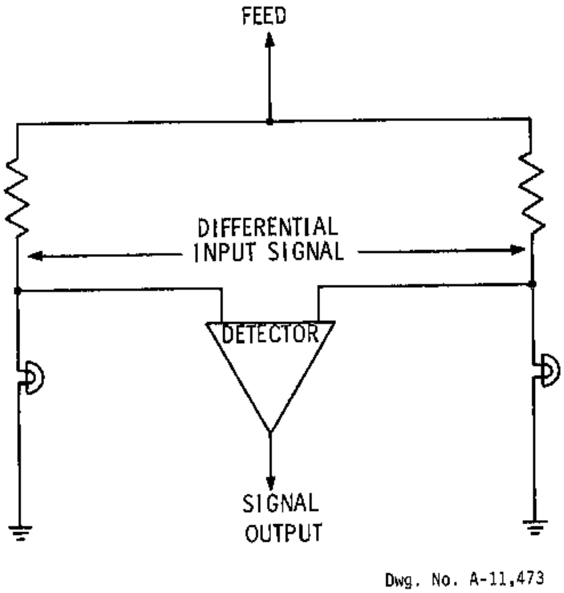


Figure 3
BRIDGE MONITORING SYSTEM

The principle of operation is that of a simple bridge circuit (Figure 3) in which the top two legs of the bridge are the wiring-assembly resistance or discrete resistors. The bottom legs of the bridge circuit are the monitored lamps. Four differential amplifiers sense the voltage drops in the wiring assemblies (approximately 20 mV) for each of the various lamp circuits. When the system detects a difference in voltage due to an open filament, the appropriate output driver is turned ON.

A sixth output driver gives an indication if any of the monitored lamps fail. This output can be used to drive an audible signaling device or a centrally-located warning lamp.

CIRCUIT DESCRIPTION

A simplified detector is shown in Figure 4. Q1 and Q2 form a differential amplifier. The amplified differential signal is applied at Point A-B to threshold detectors Q3 and Q4, which drive the LED driver transistors. D1 and D2 perform the dual function of level-shifting the input signal and establishing required bias currents for Q1 and Q2. Since the supply current is derived from the lamp lines, standby current is reduced to zero when the lamps are turned off.

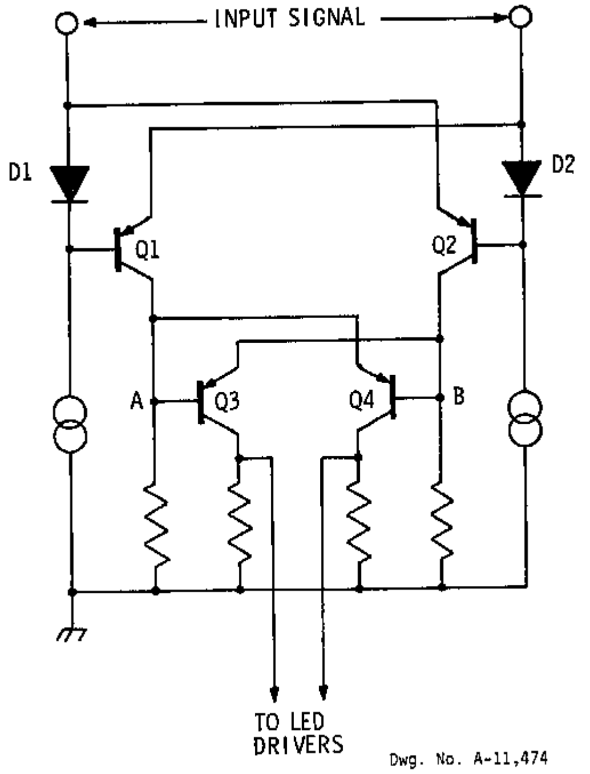


Figure 4
SIMPLIFIED DETECTOR

The use of PNPs in the detectors reduces the system's susceptibility to high-frequency noise. Figure 5 shows a comparison of frequency response for a monolithic NPN transistor and a monolithic PNP transistor.

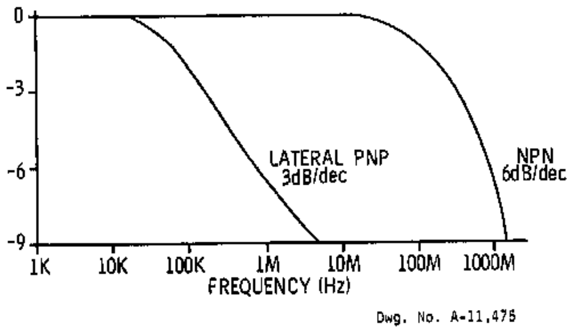


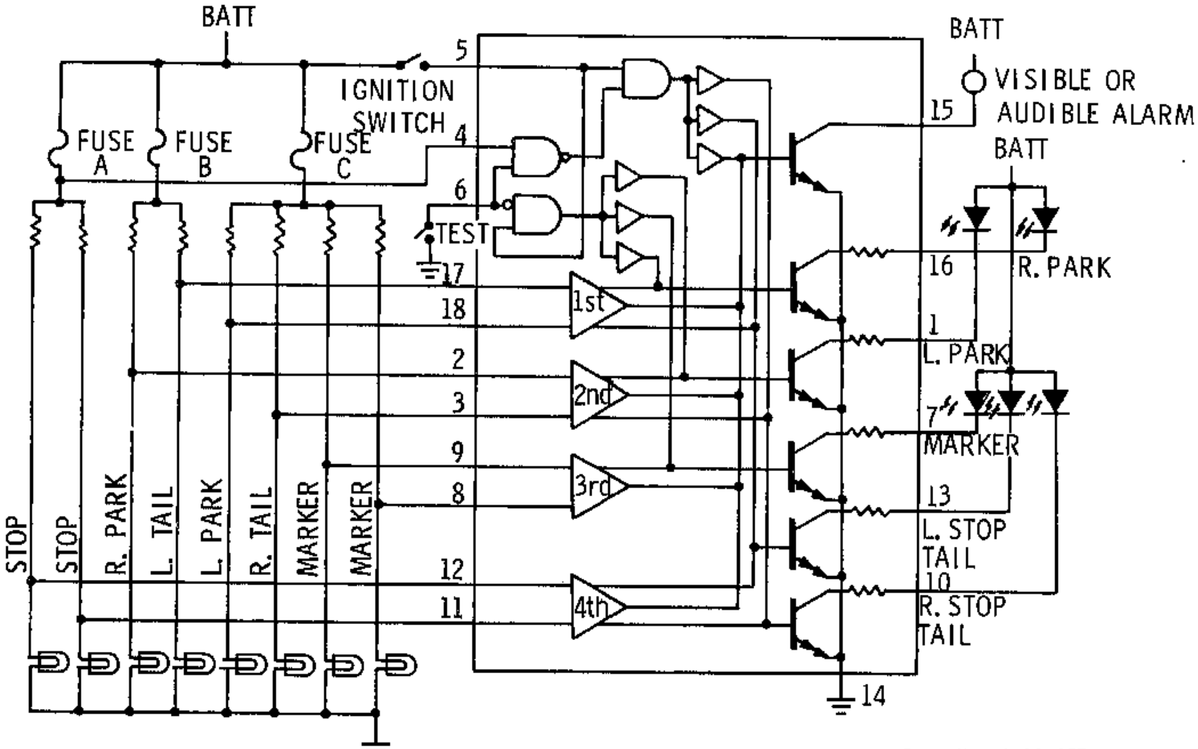
Figure 5
FREQUENCY RESPONSE

A block diagram of a typical application of Type ULN-2435A is depicted in Figure 6. In this application, eight lamps and three fuses are monitored. The stop-lamp fuse (A) is monitored by the circuitry at Pin 4. If the fuse blows, the LEDs connected to pins 10 and 13 turn ON. By using separate fuses for the park lamps and tail/marker-lamp circuits, detectors 1 and 2 can double as fuse monitors. If, for example, fuse B blows, detectors 1 and 2 turn on the LEDs connected to pins 1 and 16. An additional input, pin 6, is used to test the LEDs and the master indicator during cranking.

The simplistic design of this system enables easy installation in an automobile. No external components are required, other than the LED indicators and the voltage-dropping resistors, to complete the system. The integrated circuit may be mounted on a printed wiring board. Depending on lamp current, the copper runs of a printed wiring board might be used as the top legs of the bridge circuit. A failure within the integrated circuit will not affect lamp operation or other automotive functions.

TRANSIENT PROTECTION

In laying out the integrated circuit, careful consideration was given to providing on-chip voltage-transient protection. The LED driver transistors, for example, were designed to withstand an 80-volt load-dump transient. The detector inputs are also designed to withstand 80 volts. In addition, the inputs to the detectors are essentially grounded through the low-resistance lamps being monitored, which further protects the integrated circuit from transients. Reverse-battery protection is included on the chip. In the event of a battery reversal, the PNPs provide inherent protection, while the dielectrically-isolated resistors provide additional safeguards.



Dwg. No. A-11,477

Figure 6

TYPICAL APPLICATION