

# Vacuum Fluorescent Display Filament Driver

## General Description

The LM9022 is a bridged power amplifier capable of delivering typically 2W of continuous average power into a 10Ω filament load when powered by a 5V power supply.

To conserve power in portable applications, the LM9022's micropower shutdown mode ( $I_Q = 0.6\mu A$ , typ) is activated when  $V_{DD}$  is applied to the SHUTDOWN pin.

Additional LM9022 features include thermal shutdown protection, unity-gain stability, and external gain set.

## Key Specifications

- $I_{DD}$  during shutdown 0.6μA (typ)
- Thermal Shutdown Protection

## Features

- No transformers required
- SO or DIP packaging

## Applications

- VCR/DVD Displays
- RADIO/TUNER Displays

## Typical Application

$T_A = 25^\circ C$ ,  $V_{DD} = 5V$ , unless otherwise specified.

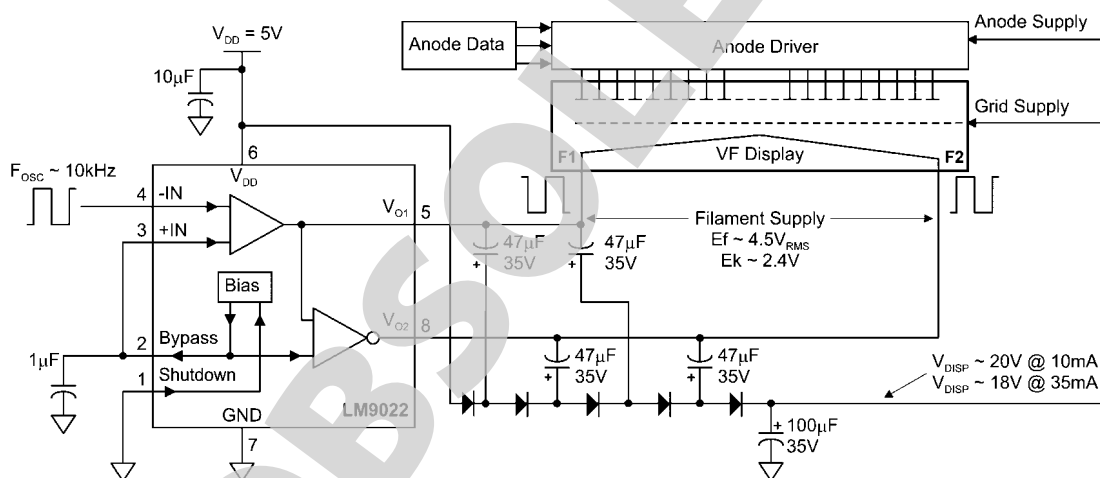
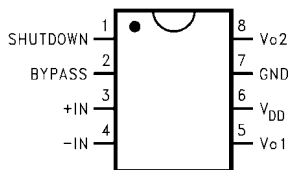


FIGURE 1. Typical Application Circuit

## Connection Diagram

### MSOP, Small Outline, and DIP Package



Top View

Order Number LM9022M or LM9022N  
See NS Package Number M08A or N08E

## Absolute Maximum Ratings (Note 1)

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

Supply Voltage	-0.3V to +6.0V
Supply Temperature	-65°C to +150°C
Input Voltage	-0.3V to $V_{DD} + 0.3V$
Power Dissipation (Note 3)	Internally Limited
ESD Susceptibility (Note 4)	5000V
ESD Susceptibility (Note 5)	250V
Junction Temperature	150°C
Soldering Information	
Small Outline Package	

Vapor Phase (60 sec.)	215°C
Infrared (15 sec.)	220°C
$\theta_{JC}$ (typ)—M08A	35°C/W
$\theta_{JA}$ (typ)—M08A	140°C/W
$\theta_{JC}$ (typ)—N08E	37°C/W
$\theta_{JA}$ (typ)—N08E	107°C/W

## Operating Ratings

Temperature Range	$T_{MIN} \leq T_A \leq T_{MAX}$	$-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$
Supply Voltage		$2.0V \leq V_{DD} \leq 5.5V$

## Electrical Characteristics (Note 1, Note 2)

The following specifications apply for  $V_{DD} = 5V$ ,  $V_{PIN3} = V_{PIN2}$ ,  $V_{SHUTDOWN} = 0V$ , and  $R_L = 10\Omega$  unless otherwise specified. Limits apply for  $T_A = 25^\circ\text{C}$ .

Symbol	Parameter	Conditions	LM9022			Units
			Min (Note 7)	Typical (Note 6)	Max (Note 7)	
$I_{DD}$	Quiescent Power Supply Current	$V_{IN} = 0V$ , $I_o = 0A$ , $V_{SHUTDOWN} = 0V$		6.5	10.0	mA
	Power Supply Current during shutdown	$V_{SHUTDOWN} = V_{DD}$ (Note 8)		0.6	2	$\mu\text{A}$
$V_{BP}$	Bypass Pin Voltage	$V_{IN} = 0V$	2.4	2.5	2.6	V
$V_{OUT}$	Output Voltage Across $R_L$	$R_L = 10\Omega$	3.6	4.3		V
		$R_L = 20\Omega$	4.2	4.6		V

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

**Note 2:** All voltages are measured with respect to the ground pin, unless otherwise specified.

**Note 3:** The maximum power dissipation must be derated at elevated temperatures and is dictated by  $T_{JMAX}$ ,  $\theta_{JA}$ , and the ambient temperature  $T_A$ . The maximum allowable power dissipation is  $P_{DMAX} = (T_{JMAX} - T_A) / \theta_{JA}$  or the number given in Absolute Maximum Ratings, whichever is lower. For the LM9022,  $T_{JMAX} = 150^\circ\text{C}$ . For the  $\theta_{JA}$ 's for different packages, please see the Application Information section or the Absolute Maximum Ratings section.

**Note 4:** Human body model, 100pF discharged through a 1.5k $\Omega$  resistor.

**Note 5:** Machine Model, 220pF–240pF discharged through all pins.

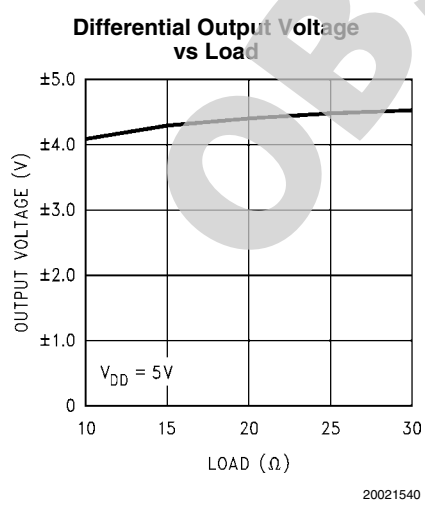
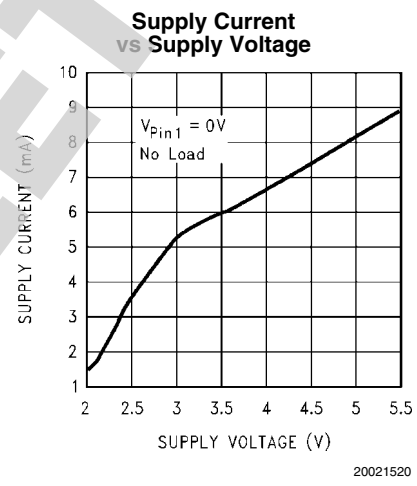
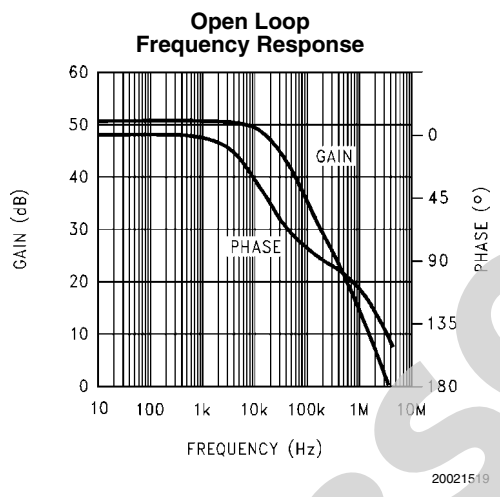
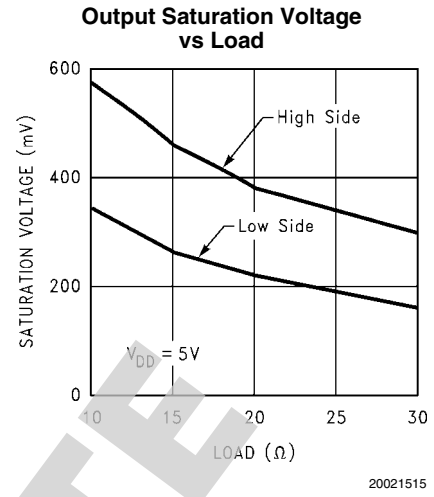
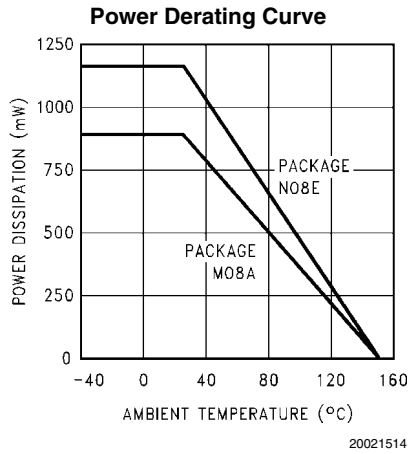
**Note 6:** Typicals are specified at 25°C and represent the parametric norm.

**Note 7:** Limits are guaranteed to National's AOQL (Average Outgoing Quality Level) by design, test, or statistical analysis.

**Note 8:** Both outputs are high impedance when in shutdown mode.

# Typical Performance Characteristics

$T_A = 25^\circ\text{C}$ ,  $V_{DD} = 5\text{V}$ , unless otherwise specified.



## Application Information

### LM9022 FUNCTIONALITY

Typically a VFD filament requires a low voltage AC power source in order to create a constant brightness across its length. Such a power source is not readily available in a most systems. Existing implementations show different circuits for supplying an AC power for a VFD filament but they require an AC power input, or do not have a standby control, or generate high EMI. The LM9022 can solve all these problems in one compact circuit.

A DC power supply is employed to power two power operational amplifiers: POA1 and POA2. The first power operational amplifier (POA1) can utilize an external feedback circuit that will cause it self-oscillate. In a second version, POA1 is driven from an external signal source. The shape of the output wave delivered by POA1 can be square, sinusoidal, triangular, trapezoidal, clipped sinusoidal or any other shape, depending on the feedback circuit or the signal source used. The output of this POA1 is connected externally to one end of the VFD filament, and internally to the input of a second power operational amplifier: POA2. POA2 is internally configured as an inverting unity gain circuit. The output of the POA2 is connected to the second end of the VFD filament. This provides a differential and symmetrical AC signal to the fila

An external standby control signal applied to the Shutdown pin can be used to turn of both power operational amplifiers.

### BRIDGE CONFIGURATION EXPLANATION

As shown in *Figure 1*, the LM9022 has two operational amplifiers internally. *Figure 1* shows that the output of amplifier one serves as the input to amplifier two, which results in both amplifiers producing signals identical in magnitude, but 180° out of phase.

By driving the load differentially through outputs Vo1 and Vo2, an amplifier configuration commonly referred to as "bridged mode" is established. Bridged mode operation is different from the classical single-ended amplifier configuration where one side of its load is connected to ground.

A bridge amplifier design has a few distinct advantages over the single-ended configuration, as it provides differential drive to the load, thus doubling output swing for a specified supply voltage. Four times the output power is possible as compared to a single-ended amplifier under the same conditions.

### POWER DISSIPATION

For the SO package,  $\theta_{JA} = 140^{\circ}\text{C/W}$ , for the DIP package,  $\theta_{JA} = 107^{\circ}\text{C/W}$ , and for the MSOP package,  $\theta_{JA} = 210^{\circ}\text{C/W}$  assuming free air operation. The  $\theta_{JA}$  can be decreased by using some form of heat sinking. The resultant  $\theta_{JA}$  will be the

summation of the  $\theta_{JC}$ ,  $\theta_{CS}$ , and  $\theta_{SA}$ .  $\theta_{JC}$  is the junction to case of the package,  $\theta_{CS}$  is the case to heat sink thermal resistance and  $\theta_{SA}$  is the heat sink to ambient thermal resistance. By adding additional copper area around the LM9022, the  $\theta_{JA}$  can be reduced from its free air value for the SO package. Depending on the ambient temperature,  $T_A$ , and the  $\theta_{JA}$ , Equation 2 can be used to find the maximum internal power dissipation supported by the IC packaging. If the result of Equation 1 is greater than that of Equation 2, then either the supply voltage must be decreased, the load impedance increased, the  $\theta_{JA}$  decreased, or the ambient temperature reduced. For the typical application of a 5V power supply, with an  $10\Omega$  load, and no additional heatsinking, the maximum ambient temperature possible without violating the maximum junction temperature is approximately  $61^{\circ}\text{C}$  provided that device operation is around the maximum power dissipation point and assuming surface mount packaging.

### POWER SUPPLY PIN

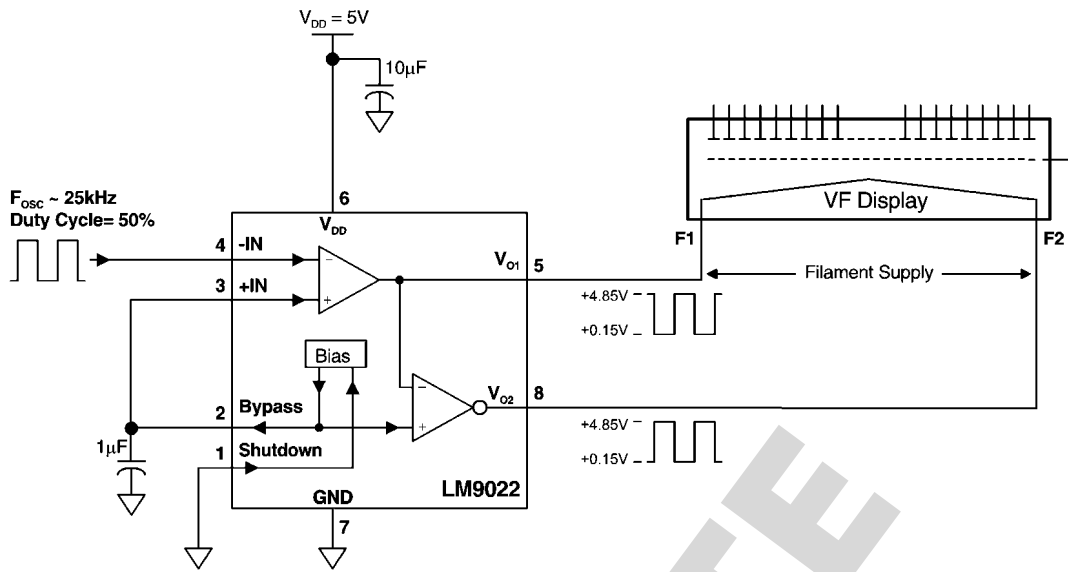
As with any power device, proper supply bypassing is critical for low noise performance. Typical applications will require both a 22 $\mu\text{F}$  electrolytic and a 0.1 $\mu\text{F}$  ceramic capacitor to bypass the supply pin to ground. These capacitors should be as close to the LM9022 as is physically possible, and are in addition to any capacitors that may be needed for regulator stability.

### BYPASS PIN

The internal bias circuit (Fig 1) generates an internal reference voltage that is typically equal to one half of  $V_{DD}$ . This voltage is available at the bypass pin and is applied directly to the non-inverting input of the inverting driver. Typical applications will require a bypass capacitor in the range of 0.1 $\mu\text{F}$  to 1 $\mu\text{F}$  to bypass the supply pin to ground. This capacitor should be as close to the LM9022 as is physically possible.

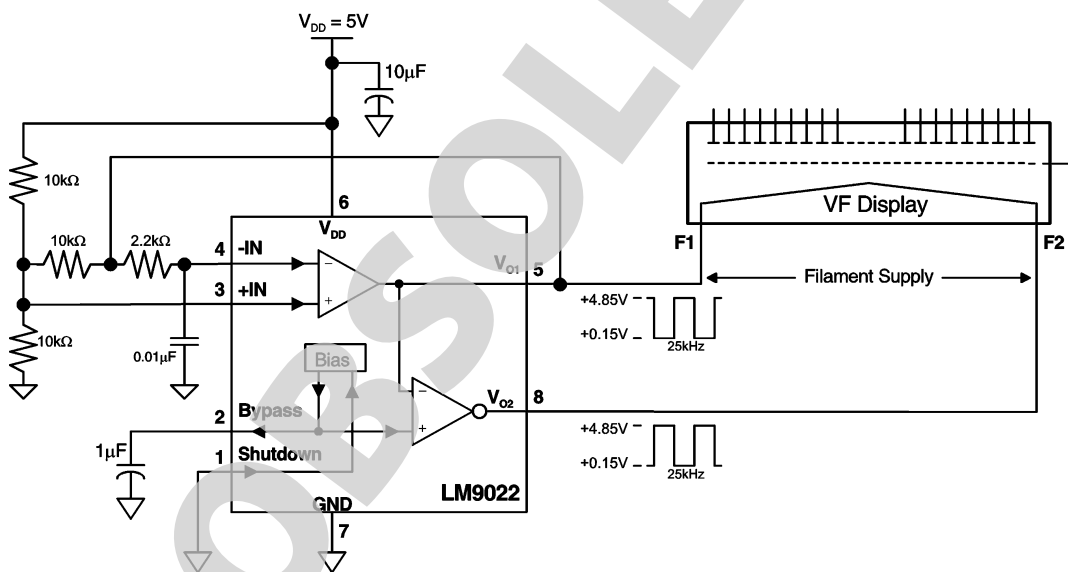
### SHUTDOWN FUNCTION

In order to reduce power consumption while not in use, the LM9022 contains a shutdown pin to externally turn off the amplifier's bias circuitry. This shutdown feature turns the amplifier off when a logic high is placed on the shutdown pin. The trigger point between a logic low and logic high level is typically half- supply. It is best to switch between ground and supply to provide maximum device performance. By switching the shutdown pin to  $V_{DD}$ , the LM9022 supply current draw will be minimized in idle mode. While the device will be disabled with shutdown pin voltages less than  $V_{DD}$ , the idle current may be greater than the typical value of 0.6 $\mu\text{A}$ . In either case, the shutdown pin should be tied to a definite voltage to avoid unwanted state changes.



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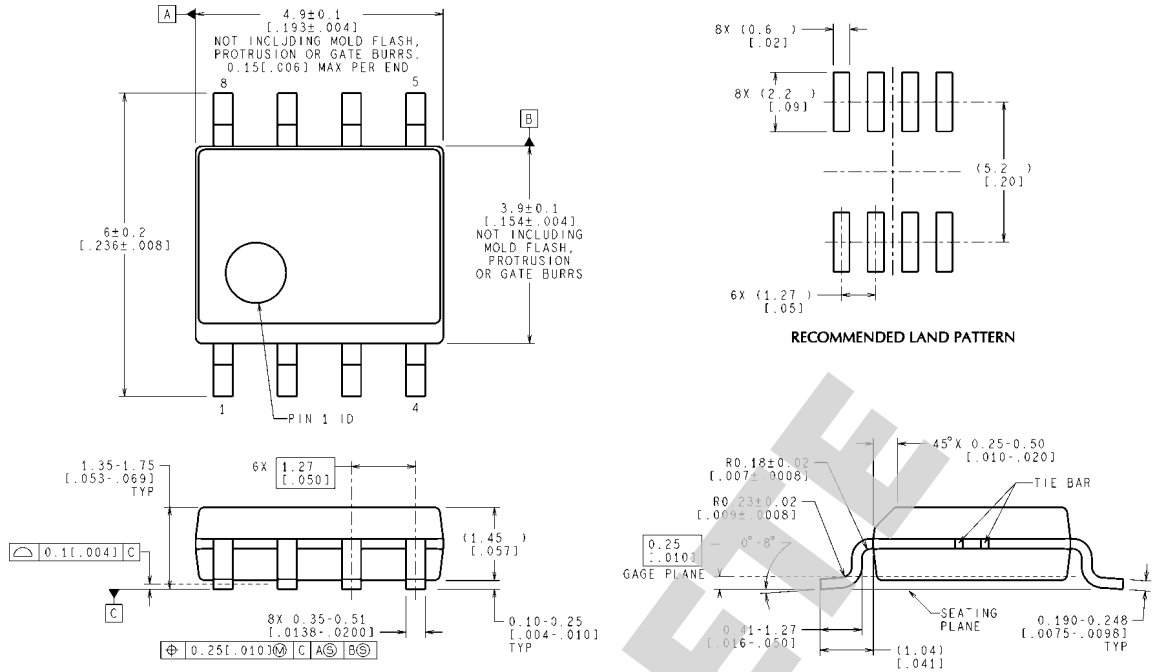
FIGURE 2. Filament Supply using External Oscillator



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FIGURE 3. Filament Supply using Self Oscillation

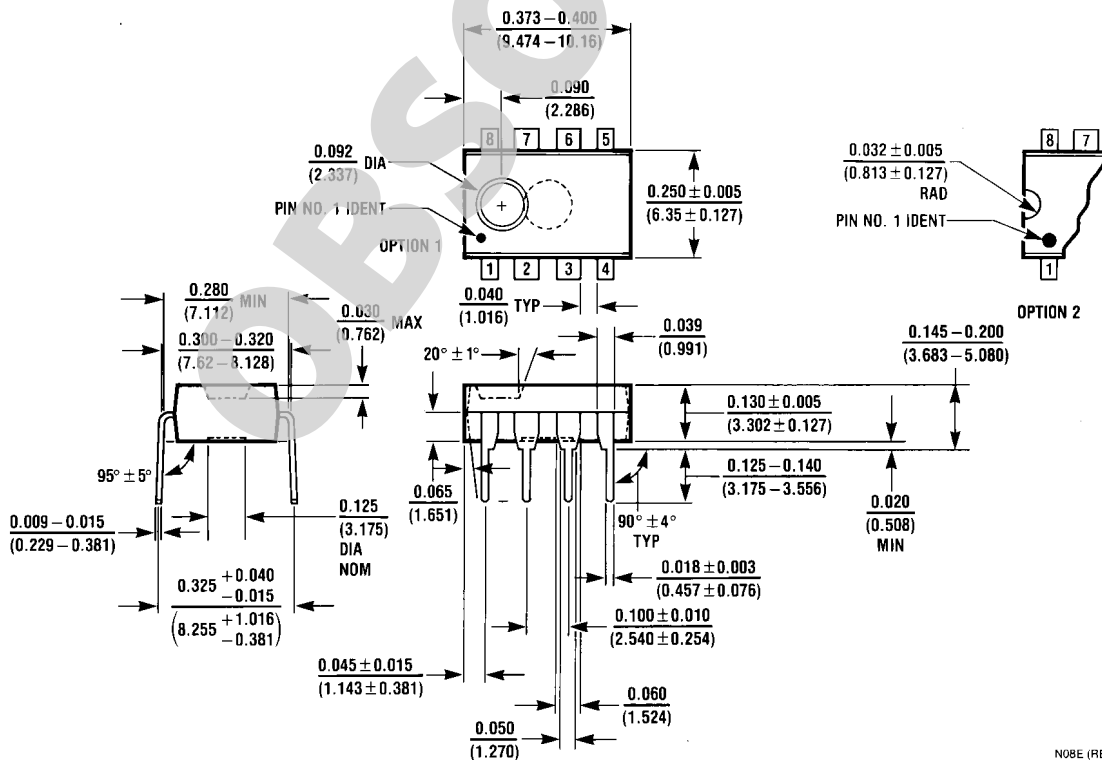
**Physical Dimensions** inches (millimeters) unless otherwise noted



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M08A (Rev M)

Order Number **LM9022M**  
NS Package Number **M08A**



Order Number **LM9022N**  
NS Package Number **N08E**

N08E (REV F)

## Notes

LM9022

**OBSOLETE**

## Notes

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