ANEXOS A

ESPECIFICACIONES TÉCNICAS Y GUÍA PLC ALLEN BRADLEY COMPACT LOGIX 1769-L23E-QBFC1B
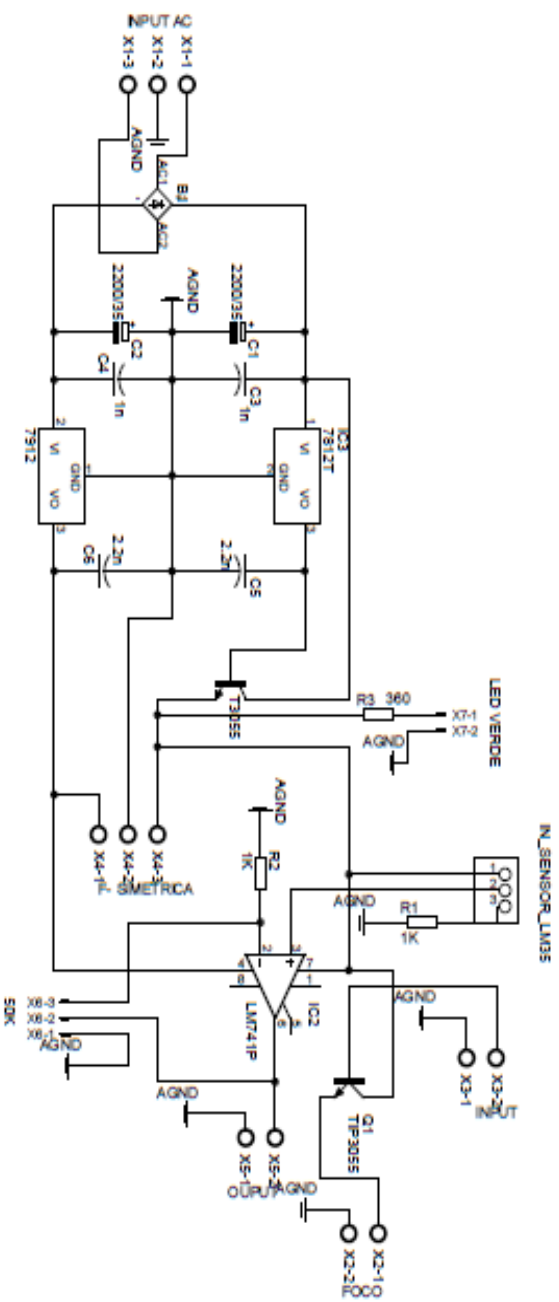
ANEXO B

ESPECIFICACIONES TÉCNICAS SENSOR DE TEMPERATURA LM35

ANEXO C

ESQUEMA ELECTRÓNICO DE MÓDULO DE TEMPERATURA USANDO SENSOR DE TEMPERATURA LM35

ACONDICIONAMIENTO DE SEÑAL DEL SENSOR LM35

Installation Instructions   **AB** *Allen-Bradley*

CompactLogix Packaged Controllers

Catalog Numbers 1769-L23E-QB1B, 1769-L23E-QBFC1B, 1769-L23-QBFC1B

Use this document as a guide to install the CompactLogix™ packaged controllers.

AB *Allen-Bradley* • *Rockwell Software*   **Rockwell Automation**

Important User Information

Solid-state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (Publication SGI-1.1 available from your local Rockwell Automation® sales office or online at http://www.rockwellautomation.com/literature/) describes some important differences between solid-state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid-state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Rockwell Automation, Inc. with respect to use of information, circuits, equipment, or software described in this manual.

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

⚠	**WARNING:** Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
⚠	**ATTENTION:** Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard and recognize the consequences.
⚡	**SHOCK HAZARD:** Labels may be on or inside the equipment, for example, drive or motor, to alert people that dangerous voltage may be present.
♨	**BURN HAZARD:** Labels may be on or inside the equipment, for example, drive or motor, to alert people that surfaces may reach dangerous temperatures.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

Environment and Enclosure

WARNING: This equipment is intended for use in a Pollution Degree 2 industrial environment, in overvoltage Category II applications (as defined in IEC publication 60664-1), at altitudes up to 2000 meters (6562 ft) without derating.

This equipment is considered Group 1, Class A industrial equipment according to IEC/CISPR Publication 11. Without appropriate precautions, there may be potential difficulties ensuring electromagnetic compatibility in other environments due to conducted as well as radiated disturbance.

This equipment is supplied as open-type equipment. It must be mounted within an enclosure that is suitably designed for those specific environmental conditions that will be present and appropriately designed to prevent personal injury resulting from accessibility to live parts. The enclosure must have suitable flame-retardant properties to prevent or minimize the spread of flame, complying with a flame spread rating of 5VA, V2, V1, V0 (or equivalent) if non-metallic. The interior of the enclosure must be accessible only by the use of a tool. Subsequent sections of this publication may contain additional information regarding specific enclosure type ratings that are required to comply with certain product safety certifications.
In addition to this publication, see the following:

- Industrial Automation Wiring and Grounding Guidelines, Allen-Bradley® publication 1770-4.1, for additional installation requirements
- NEMA Standards publication 250 and IEC publication 60529, as applicable, for explanations of the degrees of protection provided by different types of enclosure

Prevent Electrostatic Discharge

WARNING: This equipment is sensitive to electrostatic discharge, which can cause internal damage and affect normal operation. Follow these guidelines when you handle this equipment:

- Touch a grounded object to discharge potential static.
- Wear an approved grounding wrist-strap.
- Do not touch connectors or pins on component boards.
- Do not touch circuit components inside the equipment.
- Use a static-safe workstation, if available.
- Store the equipment in appropriate static-safe packaging when not in use.

North American Hazardous Location Approval

The following information applies when operating this equipment in hazardous locations.	Informations sur l'utilisation de cet équipement en environnements dangereux.
Products marked "CL I, DIV 2, GP A, B, C, D" are suitable for use in Class I Division 2 Groups A, B, C, D, Hazardous Locations and nonhazardous locations only. Each product is supplied with markings on the rating nameplate indicating the hazardous location temperature code. When combining products within a system, the most adverse temperature code (lowest "T" number) may be used to help determine the overall temperature code of the system. Combinations of equipment in your system are subject to investigation by the local Authority Having Jurisdiction at the time of installation.	Les produits marqués "CL I, DIV 2, GP A, B, C, D" ne conviennent qu'à une utilisation en environnements de Classe I Division 2 Groupes A, B, C, D dangereux et non dangereux. Chaque produit est livré avec des marquages sur sa plaque d'identification qui indiquent le code de température pour les environnements dangereux. Lorsque plusieurs produits sont combinés dans un système, le code de température le plus défavorable (code de température le plus faible) peut être utilisé pour déterminer le code de température global du système. Les combinaisons d'équipements dans le système sont sujettes à inspection par les autorités locales qualifiées au moment de l'installation.
WARNING: **Explosion Hazard -** • Do not disconnect equipment unless power has been removed or the area is known to be nonhazardous. • Do not disconnect connections to this equipment unless power has been removed or the area is known to be nonhazardous. Secure any external connections that mate to this equipment by using screws, sliding latches, threaded connectors, or other means provided with this product. • Substitution of components may impair suitability for Class I, Division 2. • If this product contains batteries, they must only be changed in an area known to be nonhazardous.	**AVERTISSEMENT:** **Risque d'Explosion –** • Couper le courant ou s'assurer que l'environnement est classé non dangereux avant de débrancher l'équipement. • Couper le courant ou s'assurer que l'environnement est classé non dangereux avant de débrancher les connecteurs. Fixer tous les connecteurs externes reliés à cet équipement à l'aide de vis, loquets coulissants, connecteurs filetés ou autres moyens fournis avec ce produit. • La substitution de composants peut rendre cet équipement inadapté à une utilisation en environnement de Classe I, Division 2. • S'assurer que l'environnement est classé non dangereux avant de changer les piles.

European Hazardous Location Approval

European Zone 2 Certification (The following applies when the product bears the Ex or EEx Marking.)

This equipment is intended for use in potentially explosive atmospheres as defined by European Union Directive 94/9/EC and has been found to comply with the Essential Health and Safety Requirements relating to the design and construction of Category 3 equipment intended for use in potentially explosive atmospheres, given in Annex II to this Directive.

Compliance with the Essential Health and Safety Requirements has been assured by compliance with EN 60079-15 and EN 60079-0.

WARNING:

- This equipment must be installed in an enclosure providing at least IP54 protection when applied in Zone 2 environments.

- This equipment shall be used within its specified ratings defined by Allen-Bradley.

- Provisions shall be made to prevent the rated voltage from being exceeded by transient disturbances of more than 40% when applied in Zone 2 environments.

- Secure any external connections that mate to this equipment by using screws, sliding latches, threaded connectors, or other means provided with this product.

- Do not disconnect equipment unless power has been removed or the area is known to be nonhazardous.

ATTENTION: This equipment is not resistant to sunlight or other sources of UV radiation.

Verify Compatibility

IMPORTANT	The series B controllers are compatible only with the controller firmware and the RSLogix 5000 software versions as indicated in the table below.
	Attempting to use controllers with incompatible software and firmware revisions can result in the following:
	• An inability to connect to the series B controller in RSLogix 5000 software
	• Unsuccessful firmware upgrades in ControlFLASH™ or AutoFlash utilities

This table shows the compatible pairs of RSLogix 5000 software versions and controller firmware revisions.

Controller	RSLogix 5000 Software Version or Later	Controller Firmware Revision or Later
1769-L23E-QB1B, 1769-L23E-QBFC1B, 1769-L23-QBFC1B	16.00.00	16.023
	17.01.02	17.012
	19.01.00	19.015
	20.01.00	20.013

Before You Begin

This section contains information you should understand before installing the CompactLogix packaged controller.

Restrictions

The maximum amount of expansion modules that can be used with the packaged controllers is two. Within that limit, the number of expansion I/O modules that can be attached to the packaged controller depends on the bus current draw of the modules being attached.

Each packaged controller has a specified amount of available bus current as shown in this table.

Packaged Controller Bus Current and Expansion Module Limits

Cat. No.	Total Available 5V DC Bus Current
1769-L23E-QB1B	1 A (1000 mA)
1769-L23E-QBFC1B	450 mA
1769-L23-QBFC1B	800 mA

To determine the number of expansion I/O modules you can add, total the bus current draw (maximum) of your planned expansion I/O modules and the end cap. If your result is less than

the packaged controller's maximum available bus current, you are within the expansion I/O limit of your packaged controller.

Example of Expansion I/O Calculation

In this example, these expansion I/O modules and bus current draws are planned for use with the 1769-L23E-QBFC1B packaged controller.

Planned Expansion I/O Module	Bus Current Draw, max[1]
1769-OV16 Sink Output Module	200 mA
1769-IF4 Analog Input Module	105 mA
1769-ECR End Cap	5 mA
Total Bus Current Draw	**310 mA**

(1)   The maximum bus current draw specification for each Compact I/O™ module is available in the Compact I/O Selection Guide, publication 1769-SG002. This publication also provides further explanation of and a table for the calculation of Compact I/O power supply requirements.

The total bus current draw of the Compact I/O modules (310 mA) is less than the total available bus current of the packaged controller (450 mA). These planned expansion I/O modules are within the limits of the 1769-L23E-QBFC1B packaged controller.

Parts (included with the controller)

These components are included with your CompactLogix packaged controller.

Cat. No.	Part
1747-KY	Key
1769-BA	Battery
1769-ECR	End cap

Parts (optional, not included with the controller)

In addition to the parts included with the packaged controller, you may choose to use these components specific to your application.

If using	Then use this component
RS-232 port to connect to the packaged controller.	1756-CP3 or 1747-CP3 serial cable.
EtherNet/IP port to connect to the packaged controller.	Standard Ethernet cable with an RJ45 connector, or, for industrial grade requirements, 1585J Ethernet connectivity media.
Panel mount method to install the packaged controller.	4…8 M4 or #8 panhead screws (depending on the number of expansion modules used).

Replacement Parts

These CompactLogix packaged controller replacement parts are available for order.

Catalog No.	Description	Compatible Packaged Controllers
1769-BA	CompactLogix controller battery	1769-L23E-QB1B, 1769-L23E-QBFC1B, and 1769-L23-QBFC1B
1769-ECR	Compact right end cap	1769-L23E-QB1B, 1769-L23E-QBFC1B, and 1769-L23-QBFC1B
1769-RDQB	CompactLogix packaged controller door	1769-L23E-QB1B
1769-RDQBFC	CompactLogix packaged controller door	1769-L23E-QBFC1B and 1769-L23-QBFC1B

Required Tools

The only tool required for the installation of the CompactLogix packaged controller is a medium-sized Phillips-head screwdriver.

Installation Checklist

This table lists tasks that must be completed to fully install and begin using your packaged controller.

✔	Installation Tasks
	Install the Battery
	Connect Expansion Modules (optional)
	Panel Mount the System or DIN-rail Mount the System
	Grounding Considerations
	Wiring Power to the System
	Wire the I/O Removable Terminal Blocks
	Connect Using the RS-232 Connection
	Connect Using the Ethernet Connection
	Download and Install EDS Files
	Download Packaged Controller Firmware
	Use the AutoFlash Feature of RSLogix 5000 Software to Load Firmware or Use the ControlFLASH Utility to Load Firmware

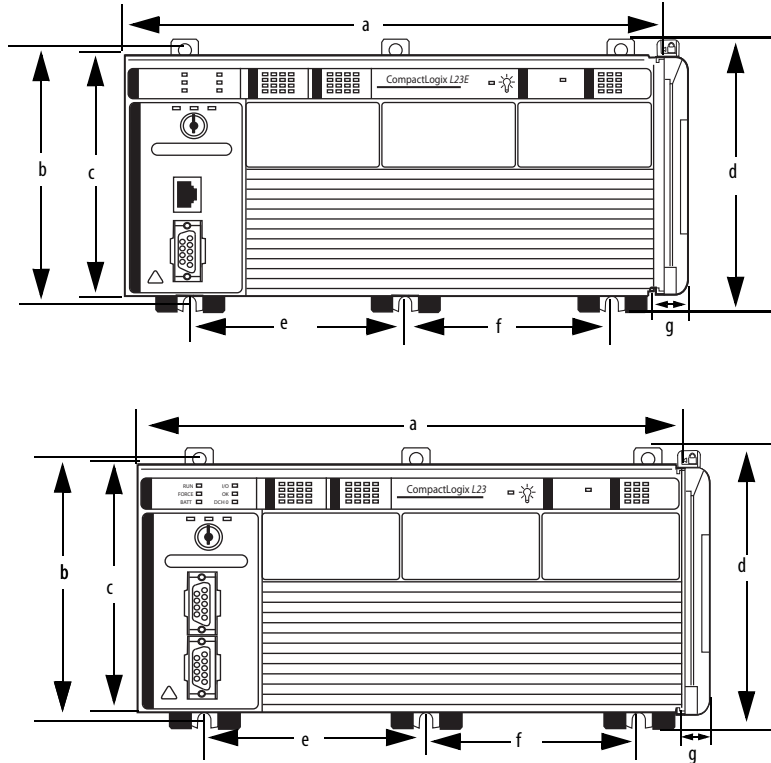# Packaged Controller Dimensions

1769-L23E-QB1B Packaged Controller

The 1769-L23E-QB1B controller has these approximate dimensions.
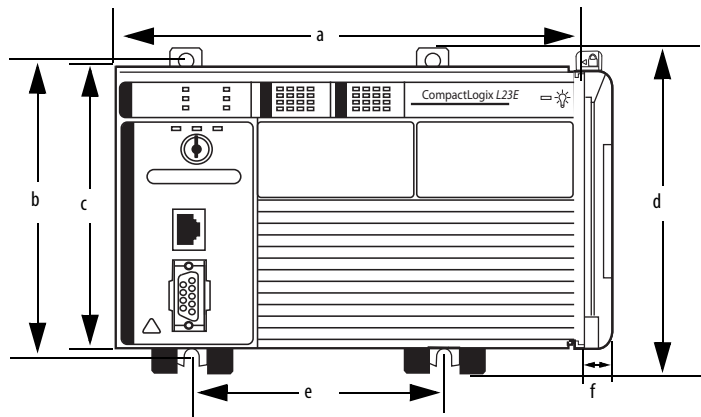
Measurement	Dimension, approximate
a	185.2 mm (7.29 in.)
b	123.86 mm (4.88 in.)
c	118 mm (4.65 in.)
d	132 mm (5.20 in.)
e	132.9 mm (5.23 in.)
f	18 mm (0.71 in.)

1769-L23E-QBFC1B and 1769-L23-QBFC1B Packaged Controllers

The 1769-L23E-QBFC1B and 1769-L23-QBFC1B packaged controllers have these approximate dimensions.


Measurement[1]	Dimension, approximate
a	249.25 mm (9.81 in.)
b	123.86 mm (4.88 in.)
c	118 mm (4.65 in.)
d	132 mm (5.20 in.)
e	98.475 mm (3.88 in.)
f	98.475 mm (3.88 in.)
g	18 mm (0.71 in.)

(1) Applies to both the 1769-L23E-QBFC1B and 1769-L23-QBFC1B packaged controllers.

Minimum Spacing Requirements

When using any of the CompactLogix packaged controllers, maintain spacing from enclosure walls, wireways, and adjacent equipment. Allow 50 mm (1.97 in.) of space on all sides, as shown. This provides ventilation and electrical isolation.
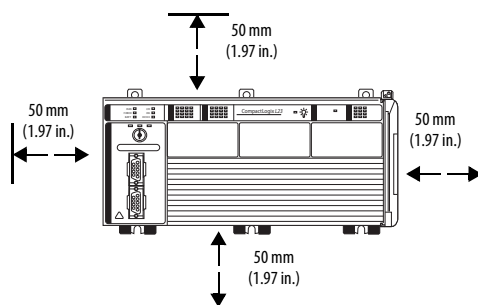
Install the Battery

Complete these steps to install the battery on your packaged controller.

> ⚠ **WARNING:** When you connect or disconnect the battery an electrical arc can occur. This could cause an explosion in hazardous location installations. Be sure that the area is nonhazardous before proceeding.
>
> For Safety information on the handling of lithium batteries, including handling and disposal of leaking batteries, see Guidelines for Handling Lithium Batteries, publication AG 5-4.

1. Open the battery door on the left side of the packaged controller.
2. Carefully attach the battery connector to the port located inside the packaged controller.
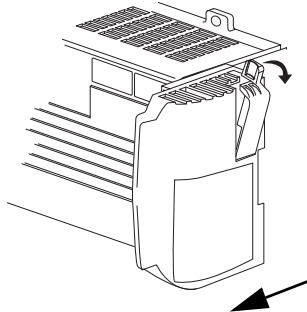3. Insert the battery, wires down, in the slot on the battery door.

4. Close the battery door.
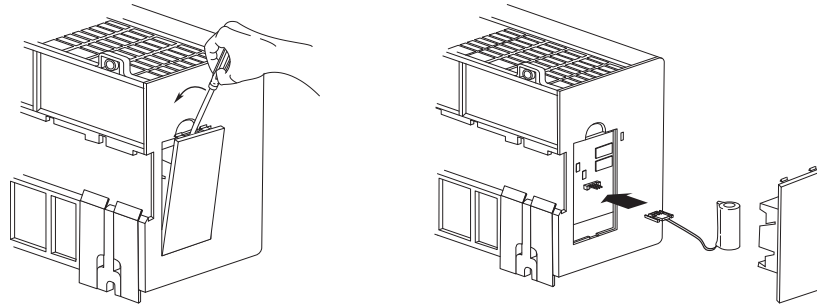
## Connect Expansion Modules (optional)

If using expansion modules with your packaged controller, complete these steps to attach the modules.

1. Remove the end cap by unlocking it and sliding it forward.

2. Align the tongue-and-groove slots of the expansion module with those on the right end of the packaged controller.

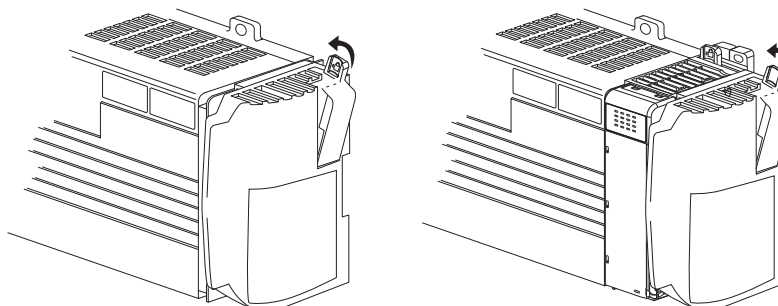3. Slide the module onto the packaged controller.

4. Close the locking tab on the top of the module.
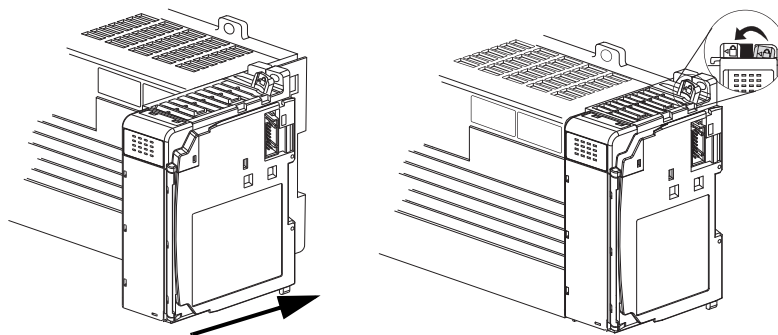
5. If using another expansion module, complete steps 2...4 for the second module.

6. Align the tongue-and-groove slots of the end cap with those on the right of the packaged controller or expansion module.
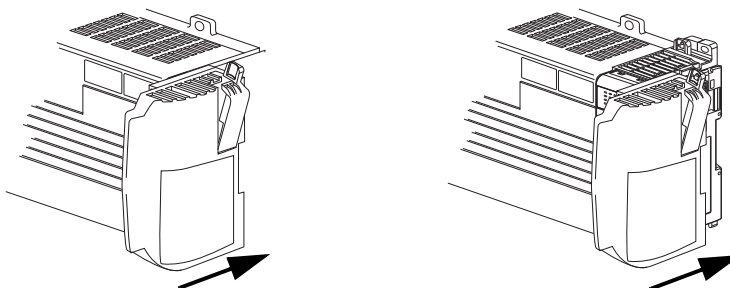
7. Close the locking tab located on the top of the end cap.

Panel Mount the System

To mount your system to a panel, complete these steps.

1. Using the assembled system as a template, carefully mark the center of all mounting holes on the panel.

2. Remove the system and drill and tap the mounting holes for the recommended M4 or #8 screws.

3. Place the grounding panel (if used) and CompactLogix system on the panel to check for proper hole alignment.

4. Insert the recommended screws into the mounting tabs on the packaged controller and expansion modules (if used) and tighten.
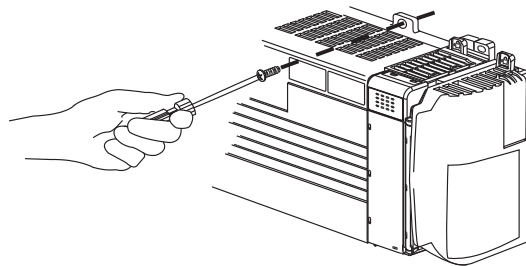
DIN-rail Mount the System

To mount your system on a DIN rail, complete these steps.

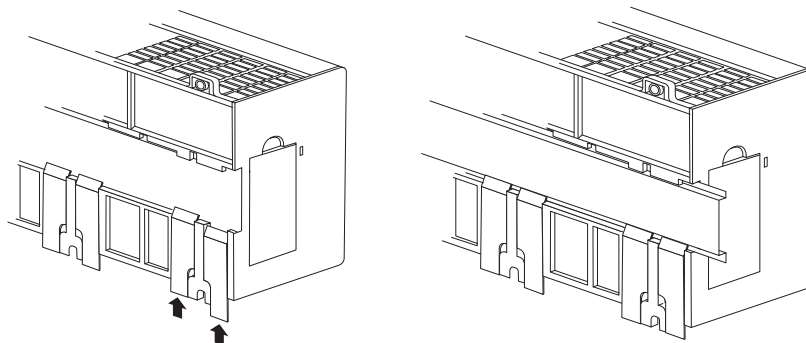The packaged controller can be mounted on these DIN rails:

- EN 50 022 - 35 x 7.5 mm (1.38 x 0.30 in.)

- EN 50 022 - 35 x 15 mm (1.38 x 0.59 in.)

> **ATTENTION:** When this product is grounded through the DIN rail to chassis ground, use zinc-plated yellow-chromate steel DIN rail to assure proper grounding. The use of other DIN rail materials (for example, aluminum or plastic) that can corrode, oxidize, or are poor conductors, can result in improper or intermittent grounding. Secure DIN rail to mounting surface approximately every 200 mm (7.8 in.) and use end-anchors appropriately.

1. Before mounting the packaged controller on a DIN rail, close the DIN-rail latches.
2. Press the DIN-rail mounting area of the packaged controller against the DIN rail.

   The latches momentarily open and lock into place on the DIN rail.

3. Press the DIN rail mounting area of the packaged controller against the DIN rail.

   The latches momentarily open and lock into place on the DIN rail.

Grounding Considerations

This product is intended to be mounted to a well-grounded mounting surface such as a metal panel. Additional grounding connections from the packaged controller's mounting tabs or DIN rail (if used) are not required unless the mounting surface cannot be grounded.

Refer to the Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1, for additional information.

Wiring Power to the System

Use this diagram as a reference when wiring the required 24V DC power to your system.

⚠	**WARNING:** • Do not connect directly to line voltage. Line voltage must be supplied by a suitable, approved isolating transformer or power supply having short-circuit capacity not exceeding 100VA maximum or equivalent. • Explosion hazard, do not remove or replace fuses on the packaged controller unless power has been disconnected or the area is known to be free of lb. concentrations of flammable gases or vapors. For more information about replacing the fuse, see the Fuse Replacement Procedure in the Compact Expansion Power Supplies Installation Instructions, publication 1769-IN028.

> **IMPORTANT**   To comply with the CE Low Voltage Directive (LVD), this equipment and all connected I/O must be powered from a source compliant with one of the following:
>
> - safety extra low voltage (SELV)
> - protected extra low voltage (PELV)

⊗	No Connection
⊗	No Connection
⊗	+24 V DC
⊗	DC Neutral
⊗	System Power Ground
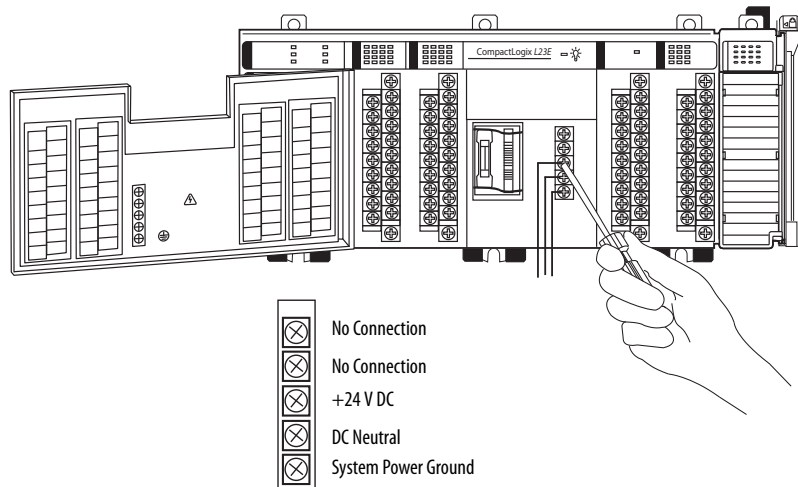
Power Wire Size and Terminal Screw Torque

Wire Type		Wire Size	Terminal Screw Torque
Solid or stranded	Cu: 75 °C (167 °F)	0.25... 2.5 mm^2 (22...14 AWG)	1.27 Nm (11.24 lb•in)

Wire the I/O Removable Terminal Blocks

| ⚠	**WARNING:** ● When you connect or disconnect the Removable Terminal Block (RTB) with field side power applied, an electrical arc can occur. This could cause an explosion in hazardous location installations. ● If you connect or disconnect wiring while the field-side power is on, an electrical arc can occur. This could cause an explosion in hazardous location installations. Be sure that power is removed or the area is nonhazardous before proceeding.

⚠	**ATTENTION:** ● Mis-wiring the removable terminal blocks to an AC power source causes damage to the packaged controller. ● Be careful when stripping wires. Wire fragments that fall into an removable terminal block could cause damage at power up. Once wiring is complete, ensure the removable terminal blocks are free of all metal fragments. ● When wiring I/O removable terminal blocks, tighten terminal screws with care. Excessive tightening can strip a screw.

To begin wiring your embedded I/O removable terminal blocks, loosen the screws at the top and bottom of the removable terminal block and remove the removable terminal block from the packaged controller.
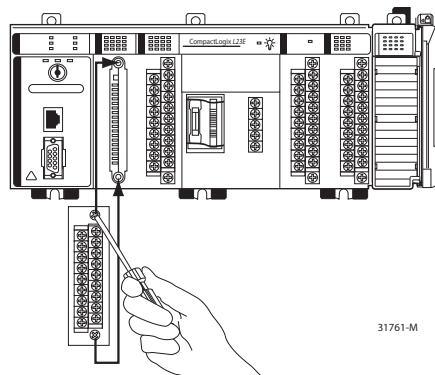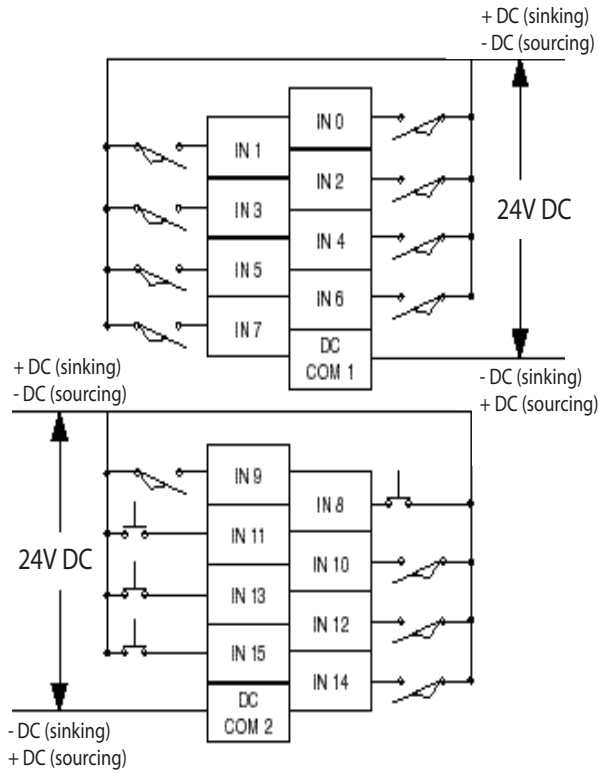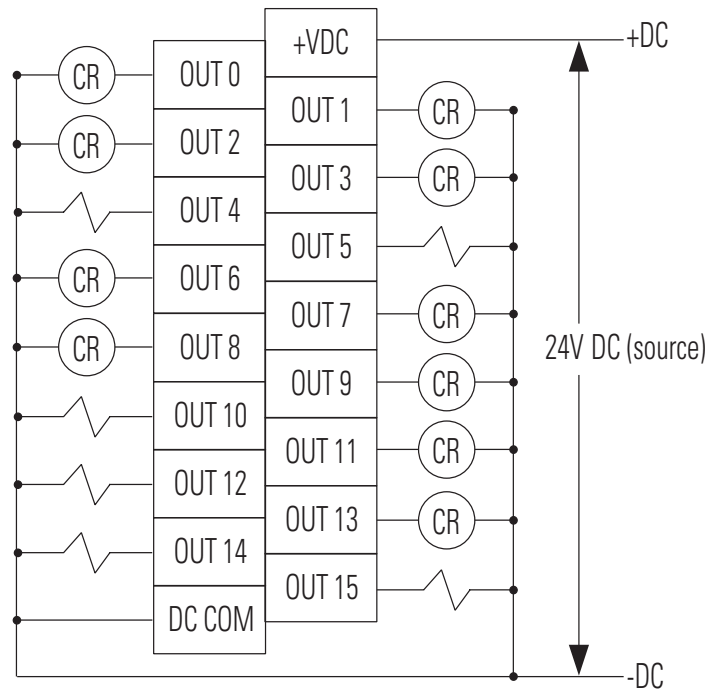

31761-M

I/O Removable Terminal Block Wire Size and Screw Torques

Wire Type		Wire Size	Terminal Screw Torque	Retaining Screw Torque
Solid or stranded	Cu: 75 °C (167 °F)	0.5… 0.8 mm^2 (20…18 AWG)	0.68 Nm (6 lb•in)	0.46 Nm (4.1 lb•in)

DC Inputs Wiring Diagram[(1)]

(1)   **Sinking/Sourcing Inputs** - Sourcing/sinking describes the current flow between the I/O and the field device. Sourcing I/O circuits supply (source) current to sinking field devices. Sinking I/O circuits are driven by a current sourcing field device. Field devices connected to the negative side (DC Common) of the field power supply are sinking field devices. Field devices connected to the positive side (+V) of the field supply are sourcing field devices. *Europe:* DC sinking input and sourcing output circuits are the commonly used options.

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DC Outputs Wiring Diagram[(1)(2)]
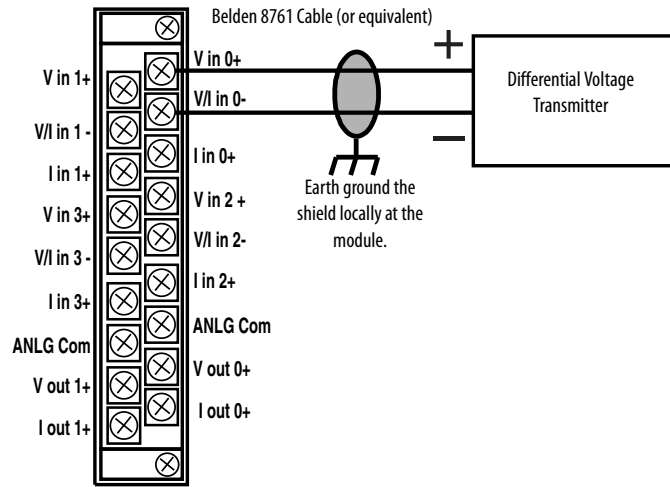
Analog I/O Wiring Diagrams

⚠️ **ATTENTION:** Analog outputs may fluctuate for less than a second when power is applied or removed. This characteristic is common to most analog outputs. While the majority of loads will not recognize the short signal, take preventive measures to ensure that connected equipment is not affected.

IMPORTANT In environments where high-frequency noise may be present, it may be necessary to directly ground cable shields to earth at the removable terminal block end and via a 0.1µF capacitor at the sensor end.
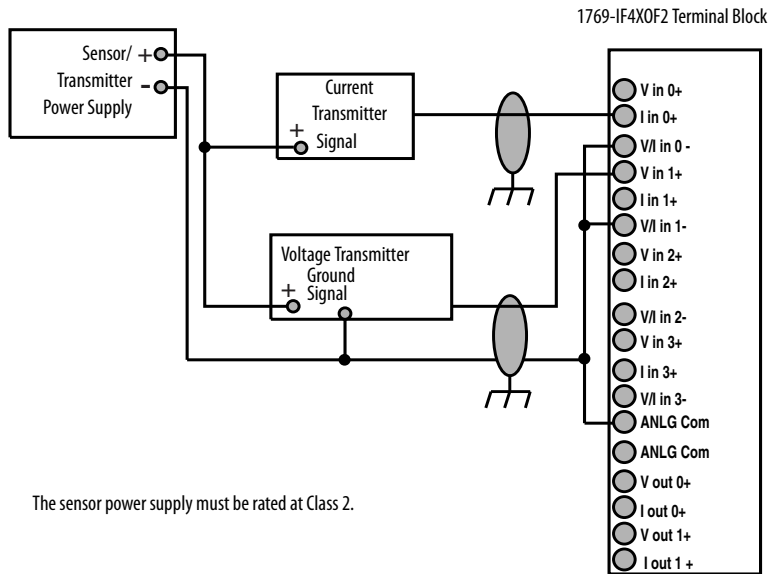
- All analog I/O commons (ANLG COM) are connected in the analog I/O card of the packaged controller. The analog common (ANLG COM) is not connected to earth ground inside the packaged controller.

- Analog I/O channels are not isolated from each other.

- Use Belden 8761 (or equivalent) shielded wire.

- Under normal conditions, the drain wire and shield junction must be connected to earth ground via a panel or DIN rail mounting screw at the analog I/O removable terminal block end. Keep the shield connection to ground as short as possible.

- To ensure optimum accuracy, limit overall cable impedance by keeping your cable as short as possible. Plan to place the packaged controller as close to your sensors or actuators as your application permits.[1]

- If multiple power supplies are used with analog inputs:

- the power supply commons must be connected.

- do not exceed the specified isolation voltage.

- The embedded analog I/O does not provide loop power for analog inputs. Use a power supply that matches the input transmitter specifications.

- Differential analog inputs are more immune to noise than single-ended analog inputs.

- Voltage outputs (Vout 0+ and Vout 1+) of the analog I/O are referenced to ANLG COM. Load resistance for a voltage output channel must be equal to or greater than 1 KΩ.

- Current outputs (Iout 0+ and Iout 1+) of the analog I/O source current that returns to ANLG COM. Load resistance for a current output channel must remain between 0...300 Ω.

- Voltages on Vin+, V/Iin-, and Iin+ of the analog I/O must be within 0 to +10V DC of analog common.

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(1) Cable length over 50 m (164.04 ft) may impact accuracy. For details, refer to the Compact Combination Analog I/O Module, publication 1769-UM008.

Differential Input Wiring Diagram

Belden 8761 Cable (or equivalent)

V in 1+
V/I in 1 -
I in 1+
V in 3+
V/I in 3 -
I in 3+
ANLG Com
V out 1+
I out 1+

V in 0+
V/I in 0-
I in 0+
V in 2 +
V/I in 2-
I in 2+
ANLG Com
V out 0+
I out 0+

Earth ground the shield locally at the module.

Differential Voltage Transmitter

Single-ended Sensor/Transmitter Types Wiring Diagram

1769-IF4XOF2 Terminal Block

Sensor/ Transmitter Power Supply

Current Transmitter Signal

Voltage Transmitter Ground Signal

V in 0+
I in 0+
V/I in 0 -
V in 1+
I in 1+
V/I in 1-
V in 2+
I in 2+
V/I in 2-
V in 3+
I in 3+
V/I in 3-
ANLG Com
ANLG Com
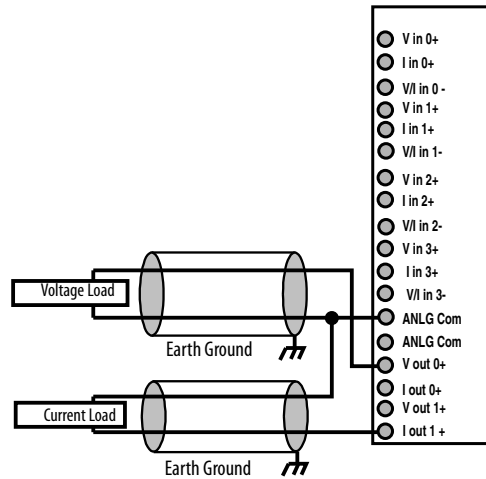V out 0+
I out 0+
V out 1+
I out 1 +

The sensor power supply must be rated at Class 2.

Mixed-input Transmitter Wiring Diagram
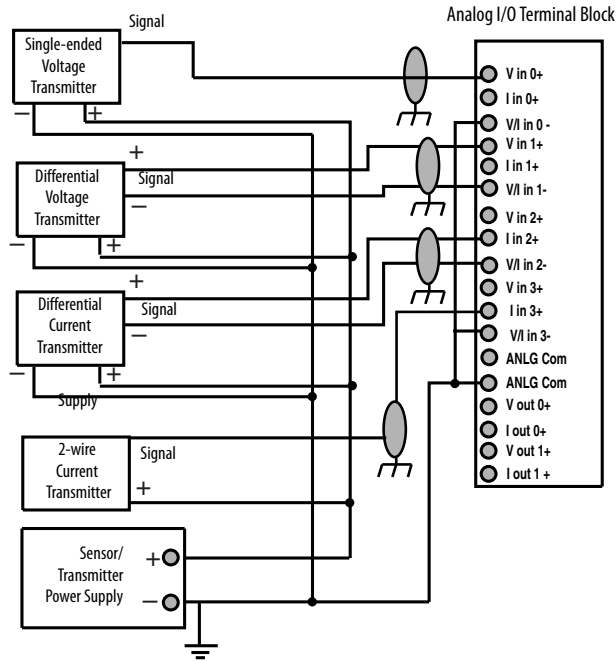
The sensor power supply must be rated at Class 2.

Analog Outputs Wiring Diagram

High-speed Counter Wiring Diagrams

> ⚠️ **ATTENTION:** Disconnect power before wiring the HSC removable terminal block. This includes sensor and packaged controller power.

- Input and output channels are isolated from the packaged controller. Input channels are isolated from one another; output channels are not.

- Shielded cable is required for high-speed input signals A, B, and Z. Use individually shielded, twisted-pair cable (or the type recommended by the encoder manufacturer) for lengths up to 300 m (1000 ft).

- Route field wiring away from any other wiring and as far as possible from sources of electrical noise, such as motors, transformers, contactors, and AC devices.

- Routing field wiring in a grounded conduit can reduce electrical noise.

- If field wiring must cross AC or power cables, ensure that they cross at right angles.

- Make sure the system is properly grounded using these guidelines:

  - This product is intended to be mounted to a well-grounded mounting surface such as a metal panel. Additional grounding connections from the packaged controller's mounting tabs or DIN rail (if used) are only required when the mounting surface is non-conductive and cannot be grounded.

  - Keep the shield connection to ground as short as possible.

  - Ground the shield drain wire only at the HSC input end, except where high-frequency noise is present.

> **IMPORTANT**   **ATTENTION:** In environments where high-frequency noise may be present, it may be necessary to directly ground cable shields to earth at the removable terminal block end and via a 0.1μF capacitor at the sensor end.
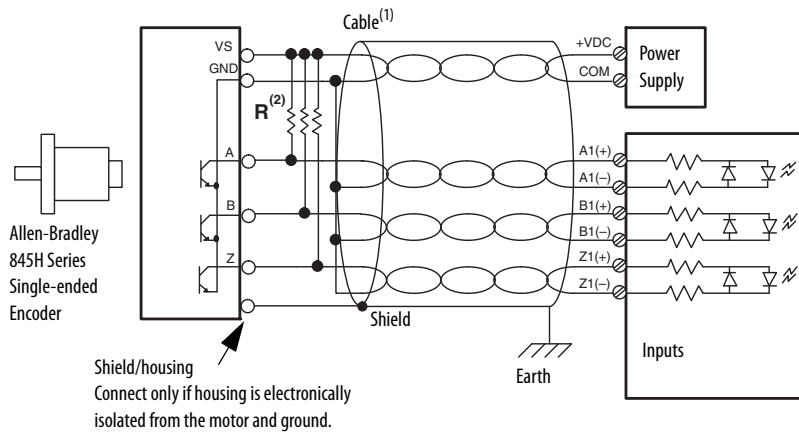
- To establish optimum accuracy, limit overall cable impedance by keeping cable as short as possible. Locate the packaged controller as close to input devices as your application permits.

HSC Differential Encoder Wiring
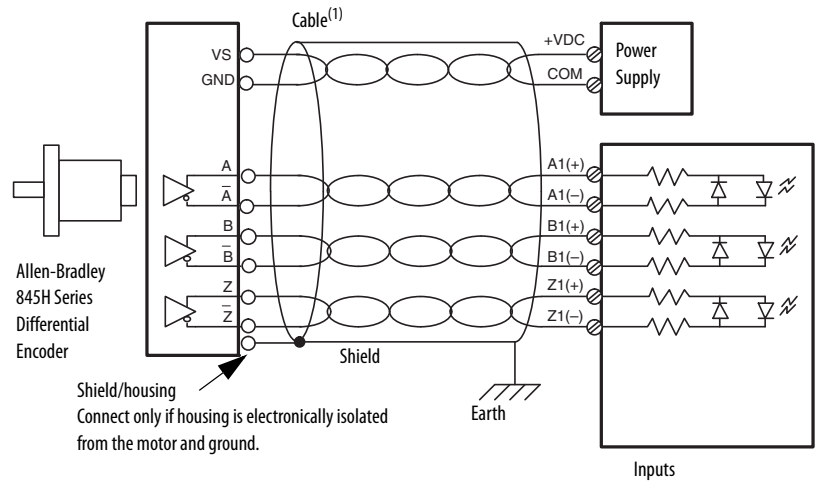
(1) Refer to your encoder manual for proper cable type. The type of cable used should be twisted pair, individually shielded cable with a maximum length of 300 m (1000 ft.).

HSC Single-ended Encoder Wiring Diagram

Shield/housing
Connect only if housing is electronically
isolated from the motor and ground.

(1) Refer to your encoder manual for proper cable type. The type of cable used should be twisted-pair, individually shielded cable with a maximum length of 300 m (1000 ft.).

(2) External resistors are required if they are not internal to the encoder. The pull-up resistor (R) value depends on the power supply value. The table below shows the maximum resistor values for typical supply voltages. To calculate the maximum resistor value, use this formula:
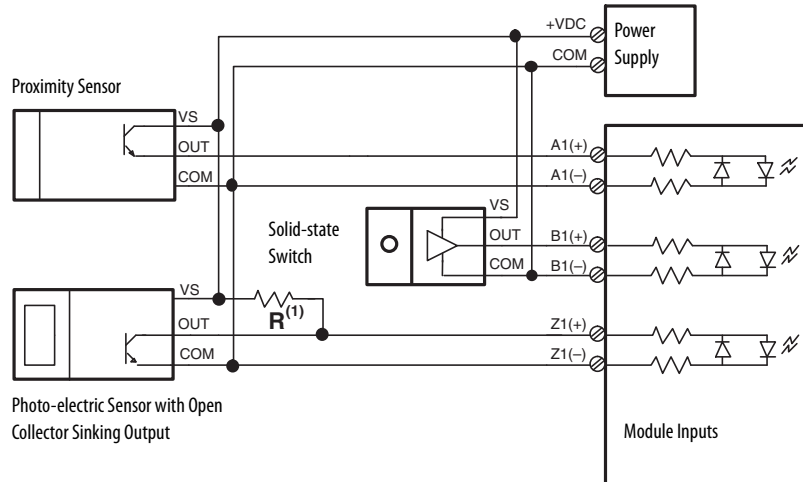
$$R = \frac{(VDC - Vmin)}{Imin}$$

Where:
R = maximum pull-up resistor value
VDC = power supply voltage
Vmin = 2.6V DC
Imin = 6.8 mA

Power Supply Voltage (V DC)	Maximum Pull-up Resistor Value (R)[1]
5V DC	352 Ω
12V DC	1382 Ω
24V DC	3147 Ω

(1) Resistance values may change, depending upon your application.

The minimum resistor (R) value depends on the current sinking capability of the encoder. Refer to your encoder's documentation for more information.

HSC Discrete Device Wiring

(1) External resistors are required if they are not internal to the sensor. The pull-up resistor (R) value depends on the power supply value. The table below shows the maximum resistor values for typical supply voltages. To calculate the maximum resistor value, the following formula:

$$R= \frac{(VDC - Vmin)}{Imin}$$

Where:
R = maximum pull-up resistor value
VDC = power supply voltage
Vmin = 2.6V DC
Imin = 6.8 mA

Power Supply Voltage (VDC)	Maximum Pull-up Resistor Value (R)[1]
5V DC	352 Ω
12V DC	1382 Ω
24V DC	3147 Ω

(1) Resistance values may change, depending upon your application.

The minimum resistor (R) value depends on the current sinking capability of the sensor. Refer to your sensor's documentation for more information.

HSC Output Wiring[(1) (2)]

> ⚠️ **ATTENTION:** Mis-wiring the embedded HSC to an AC power source or applying reverse polarity causes damage to the embedded HSC.

---
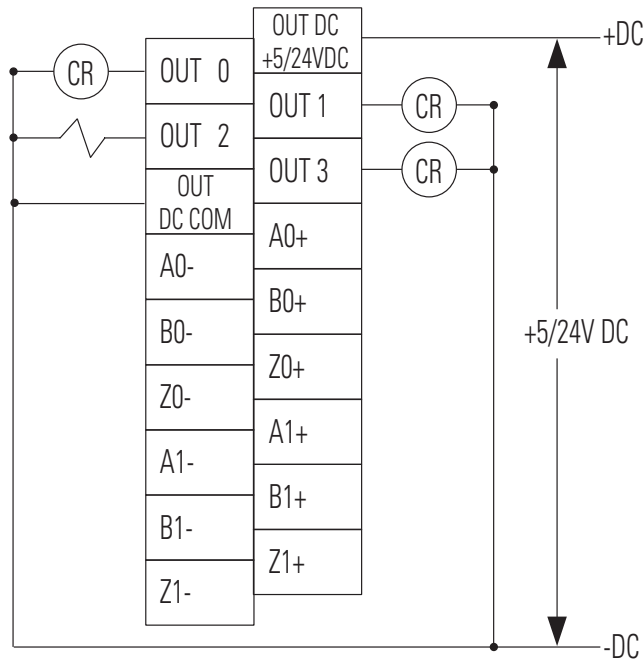
(1)   Recommended Surge Suppression - The embedded HSC has built-in suppression which is sufficient for most applications, however, for high-noise applications, use a 1N4004 diode reverse-wired across the load for transistor outputs switching 24V DC inductive loads. For additional details, refer to Industrial Automation Wiring and Grounding Guidelines, Allen-Bradley publication 1770-4.1.

(2)   Sourcing Output - Source describes the current flow between the I/O and the field device. Sourcing output circuits supply (source) current to sinking field devices. Field devices connected to the negative side (DC Common) of the field power supply are sinking field devices. Field devices connected to the positive side (+V) of the field supply are sourcing field devices. *Europe:* DC sinking input and sourcing output circuits are the commonly used options.

Connect Using the RS-232 Connection

1769-L23E-QB1B, 1769-L23-QBFC1B, and 1769-L23E-QBFC1B Controllers

> ⚠️ **WARNING:** If you connect or disconnect the serial cable with power applied to this module or the serial device on the other end of the cable, an electrical arc can occur. This could cause an explosion in hazardous location installations.
>
> Be sure that power is removed or the area is nonhazardous before proceeding.

To connect to your controller using the RS-232 (serial) connection, simply connect the 9-pin female end of the serial cable to the serial port of the controller.

Connect Using the Ethernet Connection

1769-L23E-QB1B and 1769-L23E-QBFC1B Controllers

Complete these steps to connect to the controller using the Ethernet connection.

> ⚠️ **WARNING:** If you connect or disconnect the Ethernet cable with power applied to this module or any device on the network, an electrical arc can occur. This could cause an explosion in hazardous location installations.
>
> Be sure that power is removed or the area is nonhazardous before proceeding.

> ⚠️ **ATTENTION:** Do not plug a DH-485 network cable or a NAP port cable into the Ethernet port. Undesirable behavior and/or damage to the port may result.

1. Insert the RJ45 connector of the Ethernet cable into the Ethernet port located on the front of the controller.
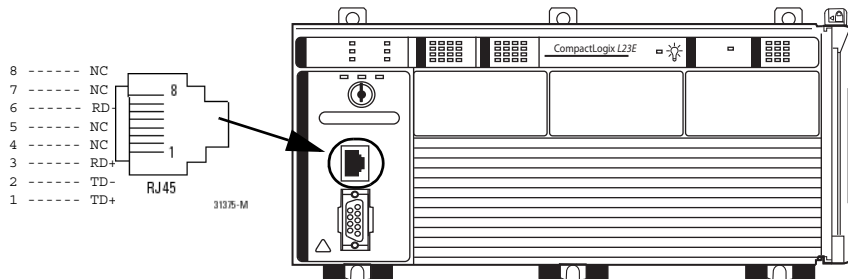
2. Use the BOOTP utility or RSLogix 5000 software to assign an IP address to the controller.

   The controller ships with BOOTP functionality enabled. This means that no extra steps must be taken to make the controller work with a BOOTP utility.

For more information about setting the controller's IP address (a network parameter), see the EtherNet/IP Modules in Logix5000™ Control Systems User Manual, publication [ENET-UM001](#).

Download and Install EDS Files

If you have RSLinx® software, version 2.52 or later, the most current EDS files were installed with the software.

If you are using an earlier version of RSLinx software, you need to download and install EDS files specific to each component of the packaged controller. This includes firmware and icons specific to the packaged controller, its Ethernet interface, virtual backplane, virtual adapter, and embedded I/O.

EDS files are available on the RSLogix 5000 software, version 17 CD, at http://support.rockwellautomation.com, and at http://www.ab.com/networks/eds.

Download Packaged Controller Firmware

Packaged controller firmware is available on the RSLogix 5000 software CD or you can download it from http://www.rockwellautomation.com/support.

Use the AutoFlash Feature of RSLogix 5000 Software to Load Firmware

RSLogix 5000 Software lets you update your packaged controller firmware without having to open the ControlFLASH utility. You can load firmware via an Ethernet (preferred) or serial connection.

| IMPORTANT	When upgrading your packaged controller firmware, it is extremely important to allow the upgrade to complete without interruption.
	If you interrupt the firmware upgrade either in the software or by disturbing the physical media, you may render the packaged controller inoperable.
	For more information about upgrading your CompactLogix packaged controller firmware, see information posted at http://www.rockwellautomation.com/knowledgebase/.

1. Make sure the appropriate network connection is made and your network driver is configured in RSLinx software.

2. Use RSLogix 5000 programming software to create a packaged controller project.

3. Click RSWho to specify the controller path.

4. Select your packaged controller and click Download.
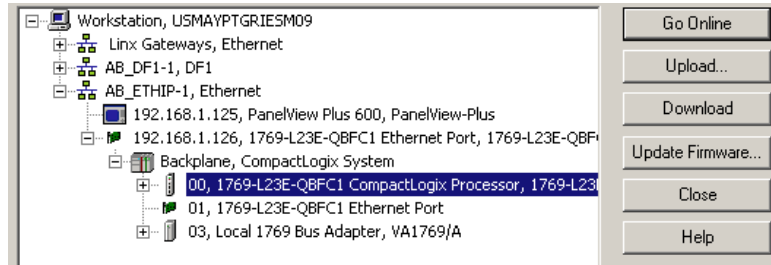
You may also choose to click Update Firmware to complete this process. If you do so, skip to step 8.

A dialog box displays indicating that the project revision and controller firmware revision are different.
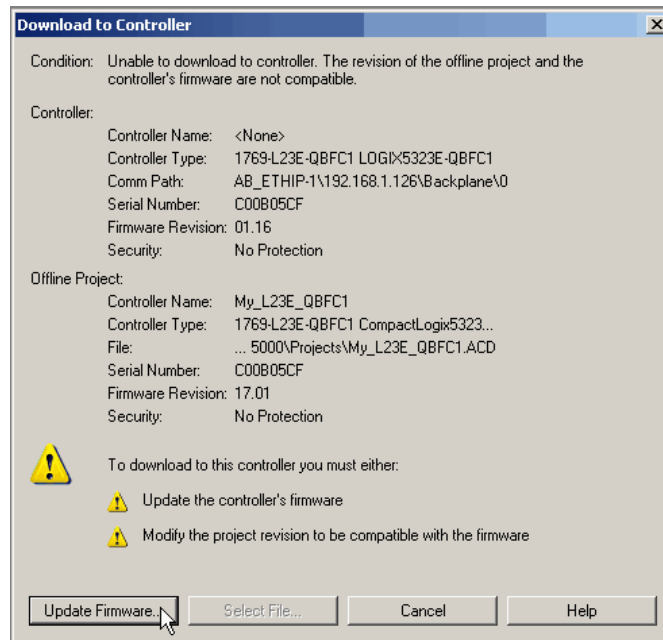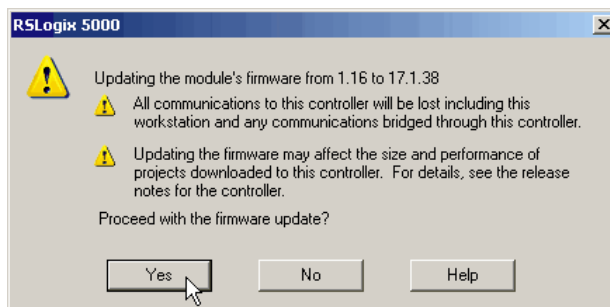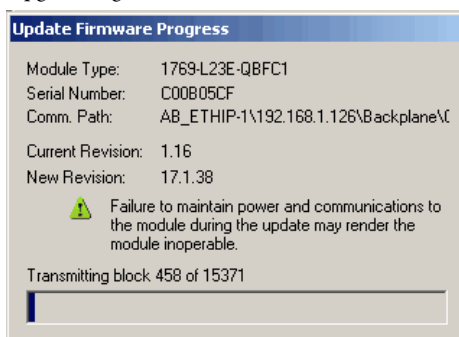

5. Click Update Firmware.

6. Use the checkbox and pull-down to select your controller and firmware revision.

	Module Name	Parent Name : Module Address	Module Type	Firmware Revision	
				In Module	Update To
☑	My_L23E_QBFC1	Local:0	1769-L23E-QBFC1 CompactLogi...	1.16	17.1.38 ▾ Browse...

7. Click Update.

8. Click Yes.
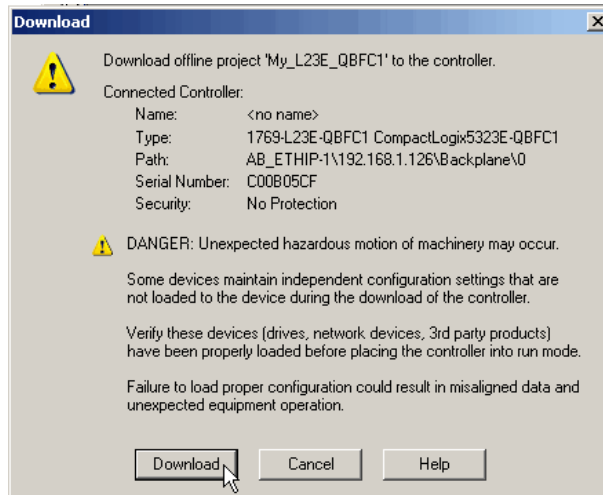

The firmware upgrade begins.

IMPORTANT	**Do not interrupt the firmware upgrade once it has begun.**
	Interrupting the firmware upgrade may result in an inoperable packaged controller.

During the firmware upgrade you see the status change as shown below.

Update Firmware Progress

Module Type:	1769-L23E-QBFC1
Serial Number:	C00B05CF
Comm. Path:	AB_ETHIP-1\192.168.1.126\Backplane\(
Current Revision:	1.16
New Revision:	17.1.38

⚠️ Failure to maintain power and communications to the module during the update may render the module inoperable.

Status Change ⟶ Polling for power-up... Time left until abort: 300 seconds.
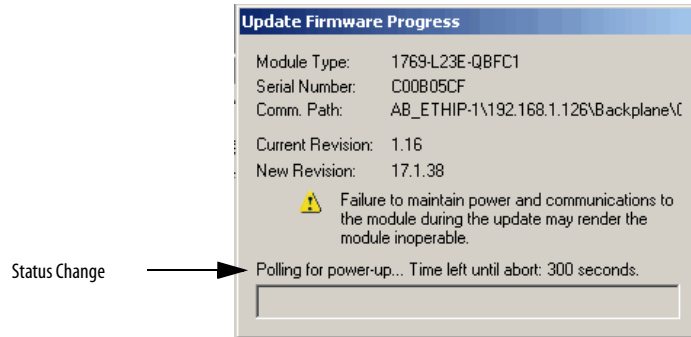
Continue to allow the firmware upgrade to complete without interruption.

When the firmware upgrade is complete, the Download dialog box displays and you may continue by downloading your project to the packaged controller.

Download ✕

⚠️ Download offline project 'My_L23E_QBFC1' to the controller.

Connected Controller:

Name:	<no name>
Type:	1769-L23E-QBFC1 CompactLogix5323E-QBFC1
Path:	AB_ETHIP-1\192.168.1.126\Backplane\0
Serial Number:	C00B05CF
Security:	No Protection

⚠️ DANGER: Unexpected hazardous motion of machinery may occur.

Some devices maintain independent configuration settings that are not loaded to the device during the download of the controller.

Verify these devices (drives, network devices, 3rd party products) have been properly loaded before placing the controller into run mode.

Failure to load proper configuration could result in misaligned data and unexpected equipment operation.

[Download]   [Cancel]   [Help]

Use the ControlFLASH Utility to Load Firmware

You can use the ControlFLASH utility to load firmware via an Ethernet (preferred) or serial connection.

| **IMPORTANT**	When upgrading your packaged controller firmware, it is extremely important to allow the upgrade to complete without interruption.
	If you interrupt the upgrade either in ControlFLASH software or by disturbing the physical media, you may render the packaged controller inoperable.
	For more information about upgrading your CompactLogix packaged controller firmware, see information posted at http://www.rockwellautomation.com/knowledgebase/.

1. Make sure the appropriate network connection is made and your network driver is configured in RSLinx software.

2. Start the ControlFLASH utility.

3. When the Welcome dialog box appears, click Next.

4. Choose the catalog number of the packaged controller and click Next.

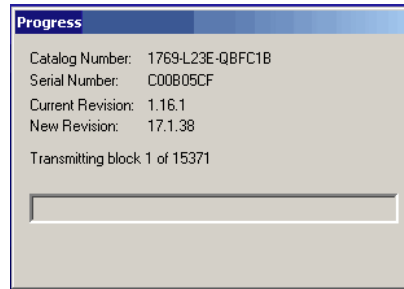5. Expand the network until you see your packaged controller and select it.
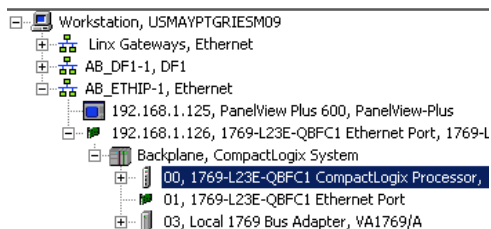
6. Click OK.

7. Choose the revision level to which you want to update the packaged controller and click Next.
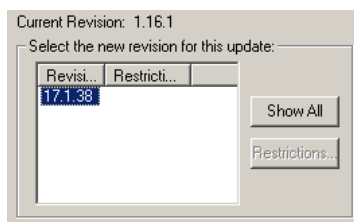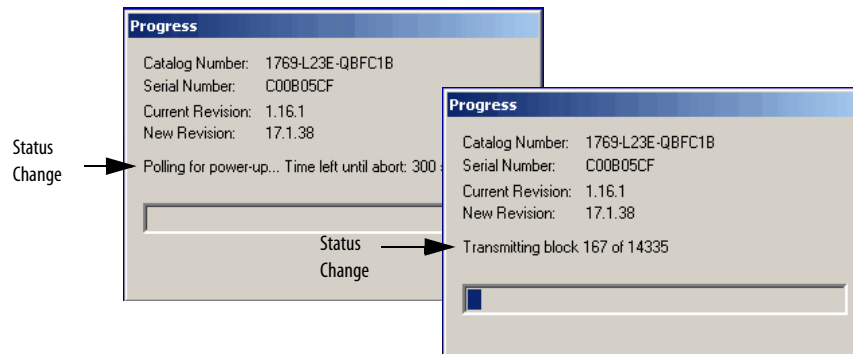
8. Click Finish and then click Yes.
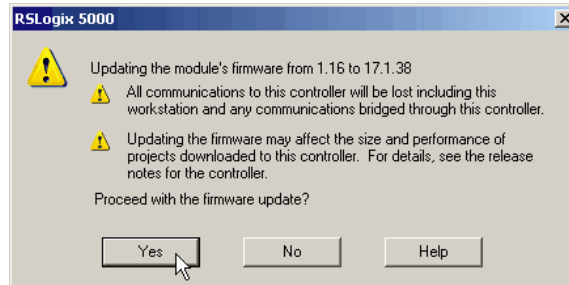

The firmware upgrade begins.

IMPORTANT	**Do not interrupt the firmware upgrade once it has begun.**
	Interrupting the firmware upgrade may result in an inoperable packaged controller.

During the firmware upgrade you see the status change as shown below.

Continue to allow the firmware upgrade to complete without interruption.

The Upgrade Status dialog box indicates that the firmware upgrade has been successfully completed.
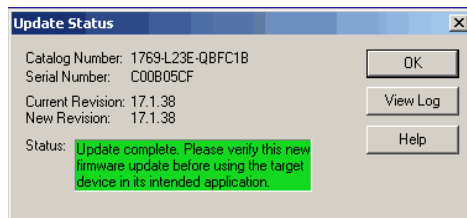
9. Click OK.

10. To close the ControlFLASH utility, click Cancel and then click Yes.

Select the Packaged Controller's Operating Mode

Use the keyswitch on the front panel of the packaged controller to select the packaged controller's operating mode.

| Use this operating mode	To achieve these tasks
RUN	• Upload projects. • Run the program and enable outputs. When the keyswitch is in the RUN position, you cannot change the operating mode by using the Controller Status menu in RSLogix 5000 software.
PROG	• Disable outputs. • Upload/download projects. • Create, modify, and delete tasks, programs, or routines. • Stop the execution (scanning) of tasks. That is, the packaged controller does not execute (or scan) tasks while the keyswitch is in the Prog position. When the keyswitch is in the PROG position, you cannot change the operating mode by using the Controller Status menu in RSLogix 5000 software.
REM	• Upload/download projects. • Switch between Remote Program, Remote Test, and Remote Run modes by using the Controller Status menu in RSLogix 5000 programming software. These Remote modes are can be selected using the Controller Status menu: **Remote Run** - In this mode, the controller executes (scans) tasks, enables outputs, and enables online edits. **Remote Program** - In this mode, the controller: disables outputs, allows program and task edits while online, downloads projects, and inhibits execution (scanning) of tasks. **Remote Test** - In this mode, the controller executes tasks with outputs disabled and enables online editing.

Power Supply Status Indicator

The green power supply status indicator is located next to the lightbulb symbol and indicates these power states:

- ON = +5 and +24V DC current available from power supply

- Off = No input power, power-fail enabled, or overvoltage exceeded/protection enabled

Controller Status Indicators

The six status indicators are located at the top left corner of the CompactLogix packaged controller. Use this table as a reference when interpreting all six of the packaged controller status indicators.

```
        RUN ☐        I/O ☐
      FORCE ☐         OK ☐
       BATT ☐      DCH 0 ☐
```
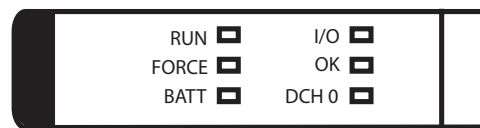
> **TIP** When power is first applied to the controller, the OK, NS, MS, and LNK status indicators display a complex sequence of varying red and green states. This sequence indicates the power-up self test and takes approximately 1…2 minutes for the packaged controller to complete.

Controller Status Indicators

Indicator	Status	Description
RUN	Off	The packaged controller is in Program or Test mode.
	Steady green	The packaged controller is in Run mode.
FORCE	Off	Either one of the following is true: • No tags contain I/O force values. • I/O forces are inactive (disabled).
	Steady amber	Either one of the following is true: • I/O forces are active (enabled). • I/O force values may or may not exist.
	Flashing amber	One or more input or output addresses have been forced to an On or Off condition, but the forces have not been enabled.
BATT	Off	The battery supports memory.
	Steady red	The battery is in either one of the following states: • Not installed • 95% discharged and should be replaced

Controller Status Indicators

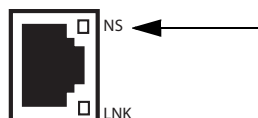| Indicator	Status	Description
I/O	Off	Either one of the following: • There are no devices in the I/O configuration of the packaged controller. • The packaged controller does not contain a project.
	Steady green	The packaged controller is communicating with all the devices in its I/O configuration.
	Flashing green	One or more devices in the I/O configuration of the packaged controller are not responding.
	Flashing red	Either one of the following: • The packaged controller is not communicating with any devices. • The packaged controller is faulted.
OK	Off	No power is applied.

	Flashing red	One of the following conditions exists:
		• The packaged controller requires a firmware update.
		• A major recoverable fault occurred on the packaged controller. To clear the fault, perform this procedure.
		• Turn the packaged controller keyswitch from PROG to RUN to PROG.
		• Go online with RSLogix 5000 software.
		• A nonrecoverable major fault occurred on the packaged controller. In this case, the packaged controller:
		  a. OK indicator initially displays steady red.
		  b. Resets, clearing the project from memory.
		  c. Sets the OK indicator to flashing red.
		  d. Produces a major recoverable fault.
		  e. Generates a fault code in the RSLogix 5000 project.
		The fault code displayed in RSLogix 5000 software and the subsequent fault recovery method depends upon your system.

	Steady red	Upon power-up, the OK indicator is steadily red for a few moments. This is normal behavior and is not a fault. If the OK indicator is steadily red for more than a few moments or changes to steadily red while in use, then a nonrecoverable major fault has occurred and project memory has been cleared. To recover from a major fault, cycle power to the packaged controller, re-download the project, and put the packaged controller in Run mode. If the OK indicator remains steadily red, contact your Rockwell Automation representative or local distributor.
	Steady green	Packaged controller is OK.
	Flashing green	The packaged controller is storing or loading a project to or from nonvolatile memory.

Module Status (MS) Indicator

The Module Status (MS) indicator is located under the space provided for you to write the IP address of the packaged controller and is one of the Ethernet/IP network status indicators.
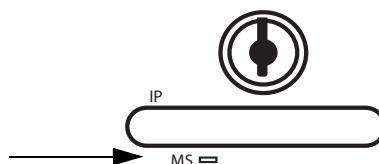
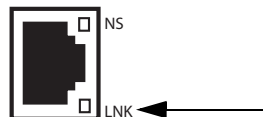| Status	Description	Action
Off	The packaged controller does not have power.	Check the controller power supply.
Flashing green	The port is in standby mode; it does not have an IP address and is operating in BOOTP mode.	Verify that the BOOTP server is running.
Steady green	The port is operating correctly.	Normal operation - no action is required.
Steady red	The packaged controller is holding the port in reset or the packaged controller has faulted.	Clear the fault. If the fault will not clear, replace the packaged controller.
	The port is performing its power-up self test.	Normal operation - no action is required.
	A nonrecoverable fault has occurred.	Cycle power to the controller. If the fault will not clear, replace the packaged controller.
Flashing red	The port firmware is being updated.	Normal operation - no action is required.

Network Status (NS) Indicator

The Network Status (NS) indicator is located to the right of the Ethernet port and is one of the EtherNet/IP status indicators.

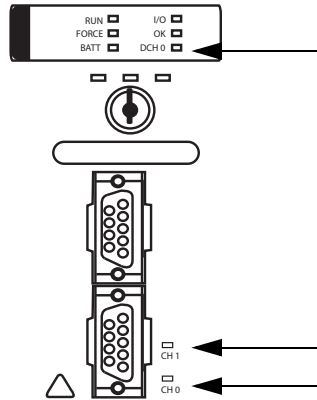| Status	Description	Action
Off	The port is not initialized; it does not have an IP address and is operating in BOOTP mode.	Verify that the BOOTP server is running.
Flashing green	The port has an IP address, but no CIP connections are established.	If no connections are configured, no action is required. If connections are configured, check connection originator for connection error code.
Steady green	The port has an IP address and CIP connections (Class 1 or Class 3) are established.	Normal operation - No action is required.
Steady red	The port has detected that the assigned IP address is already in use.	Verify that all IP addresses are unique.
Flashing red/green	The port is performing its power-up self test.	Normal operation - No action is required.

Link Status (LNK) Indicator

The Link (LNK) status indicator is also located to the right of the Ethernet port, below the NS indicator. It is also an EtherNet/IP network status indicator.

| Status	Description	Action
Off	The port is not connected to a powered Ethernet device. Therefore, the port cannot communicate on the Ethernet network.	Verify that all Ethernet cables are connected. Verify that Ethernet switch is powered.
Flashing green	The port is performing its power-up self-test.	Normal operation - no action is required.
	The port is communicating on the Ethernet network.	
Steady green	The port is connected to a powered Ethernet device. Therefore, the port can communicate on the Ethernet network.	

RS-232 Serial Port Status Indicators

Two serial port status indicators (the 1769-L23-QBFC1B has three) are present on the left side
of each CompactLogix packaged controller.

Indicator	Status	Description
DCH0	Off	Channel 0 configuration differs from the default serial configuration.
	Steady green	Channel 0 has the default serial configuration.
CH0	Off	No RS-232 activity.
	Flashing green	RS-232 activity.
CH1 (1769-L23-QBFC1B only)	Off	No RS-232 activity.
	Flashing green	RS-232 activity.

I/O Status Indicators
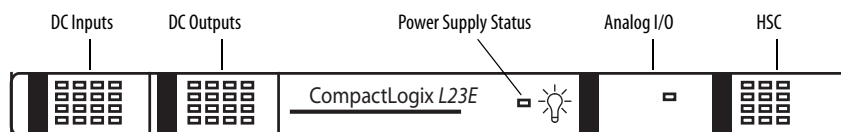
Digital Inputs Status Indicators

There is one status indicator for each digital input point of the CompactLogix packaged controller. When an input is ON, the corresponding input light is on (amber).

Digital Outputs Status Indicators

There is one status indicator for each digital output point of the CompactLogix packaged controller. When an output is ON, the corresponding output light is on (amber).

Analog I/O Status Indicator

The analog I/O have one status indicator - the OK status indicator. If the indicator is green, the analog I/O have power, have passed internal diagnostics, and are communicating properly. If analog I/O OK indicator is off, a fault is present.

High-speed Counter Status Indicators

The high-speed counters have 12 status indicators.

Indicator	Status	Description
0,1,2, and 3	Amber	The corresponding output is ON.
A0, A1, B0, B1, Z0, and Z1	Amber	The corresponding input is ON (amber).
FUSE	Red	An overcurrent condition is present.
OK	Off	No power to the HSC.
	Flashing red, brief	The HSC is testing itself (this usually occurs at start-up).
	Steady green	The HSC is operating normally.
	Flashing green	The HSC is not in Run mode.
	Steady red	A fault has occurred.
	Flashing red, continuous	A HSC configuration error exists.

Additional Resources

These documents contain additional information concerning related Rockwell Automation products.

Resource	Description
CompactLogix Controllers Specifications Technical Data, publication 1769-TD005	Controller specifications
CompactLogix Packaged Controllers Quick Start and User Manual, publication IASIMP-QS010	Procedures for using your CompactLogix packaged controller as well as additional reference information
Logix5000 Controllers Common Procedures, publication 1756-PM001	Developing projects for Logix5000 controllers
ControlFLASH Firmware Upgrade Kit, publication 1756-QS105	Information and procedures for upgrading your packaged controller firmware using the ControlFLASH utility
Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1	Ground and wire Allen-Bradley programmable controllers

You can view or download publications at http://www.rockwellautomation.com/literature/. To order paper copies of technical documentation, contact your local Allen-Bradley distributor or Rockwell Automation sales representative.

Notes:

Rockwell Automation Support

Rockwell Automation provides technical information on the Web to assist you in using its products.
At http://www.rockwellautomation.com/support, you can find technical manuals, technical and application notes, sample code and links to software service packs, and a MySupport feature that you can customize to make the best use of these tools. You can also visit our Knowledgebase at http://www.rockwellautomation.com/knowledgebase for FAQs, technical information, support chat and forums, software updates, and to sign up for product notification updates.

For an additional level of technical phone support for installation, configuration and troubleshooting, we offer TechConnect[SM] support programs. For more information, contact your local distributor or Rockwell Automation representative, or visit http://www.rockwellautomation.com/support/.

Installation Assistance

If you experience a problem within the first 24 hours of installation, please review the information that's contained in this manual. You can also contact a special Customer Support number for initial help in getting your product up and running.

United States or Canada	1.440.646.3434
Outside United States or Canada	Use the Worldwide Locator at http://www.rockwellautomation.com/rockwellautomation/support/overview.page, or contact your local Rockwell Automation representative.

New Product Satisfaction Return

Rockwell Automation tests all of its products to help ensure that they are fully operational when shipped from the manufacturing facility. However, if your product is not functioning and needs to be returned, follow these procedures.

United States	Contact your distributor. You must provide a Customer Support case number (call the phone number above to obtain one) to your distributor to complete the return process.
Outside United States	Please contact your local Rockwell Automation representative for the return procedure.

Documentation Feedback

Your comments will help us serve your documentation needs better. If you have any suggestions on how to improve this document, complete this form, publication RA-DU002, available at http://www.rockwellautomation.com/literature/.

TEXAS INSTRUMENTS

LM35

SNIS159G – AUGUST 1999 – REVISED AUGUST 2016

LM35 Precision Centigrade Temperature Sensors

1 Features

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated for Full −55°C to 150°C Range
- Suitable for Remote Applications
- Low-Cost Due to Wafer-Level Trimming
- Operates from 4 V to 30 V
- Less than 60-μA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Non-Linearity Only ±¼°C Typical
- Low-Impedance Output, 0.1 Ω for 1-mA Load

2 Applications

- Power Supplies
- Battery Management
- HVAC
- Appliances

3 Description

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor package. The LM35D device is available in an 8-lead surface-mount small-outline package and a plastic TO-220 package.
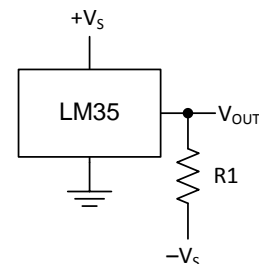
Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM35	TO-CAN (3)	4.699 mm × 4.699 mm
	TO-92 (3)	4.30 mm × 4.30 mm
	SOIC (8)	4.90 mm × 3.91 mm
	TO-220 (3)	14.986 mm × 10.16 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

Basic Centigrade Temperature Sensor (2°C to 150°C)

+V$_S$ (4 V to 20 V)

LM35

OUTPUT
0 mV + 10.0 mV/°C

Full-Range Centigrade Temperature Sensor

+V$_S$

LM35

V$_{OUT}$

R1

−V$_S$
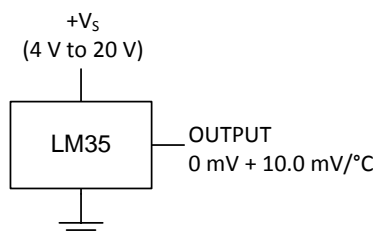
Choose R$_1$ = −V$_S$ / 50 μA
V$_{OUT}$ = 1500 mV at 150°C
V$_{OUT}$ = 250 mV at 25°C
V$_{OUT}$ = −550 mV at −55°C

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4 Revision History

Changes from Revision F (January 2016) to Revision G   **Page**

- Equation 1, changed From: 10 mV/°F To: 10mv/°C 13
- *Power Supply Recommendations*, changed From: "4-V to 5.5-V power supply" To: "4-V to 30-V power supply: 19

Changes from Revision E (January 2015) to Revision F   **Page**

- Changed NDV Package (TO-CAN) pinout from Top View to Bottom View 3

Changes from Revision D (October 2013) to Revision E   **Page**

- Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section 1

Changes from Revision C (July 2013) to Revision D   **Page**

- Changed *W* to *Ω* 1
- Changed *W* to *Ω* in *Abs Max* tablenote. 4
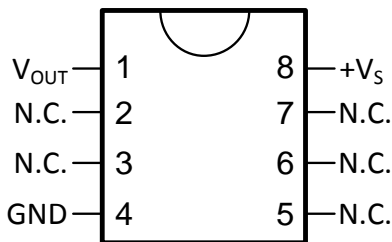
5 Pin Configuration and Functions

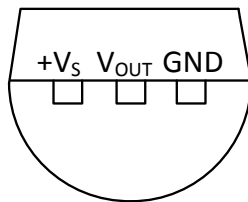**NDV Package**
3-Pin TO-CAN
(Bottom View)
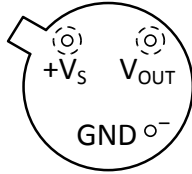
Case is connected to negative pin (GND)
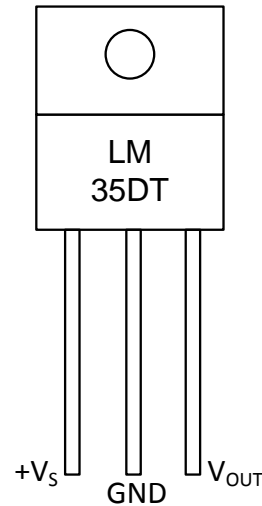
D Package
8-PIN SOIC
(Top View)

N.C. = No connection

LP Package
3-Pin TO-92
(Bottom View)

NEB Package
3-Pin TO-220
(Top View)

Tab is connected to the negative pin (GND).

NOTE: The LM35DT pinout is different than the discontinued LM35DP

Pin Functions

PIN					TYPE	DESCRIPTION
NAME	TO46	TO92	TO220	SO8		
V$_{OUT}$	—	—	—	1	O	Temperature Sensor Analog Output
N.C.	—	—	—	2	—	No Connection
	—	—	—	3		
GND	—	—	—	4	GROUND	Device ground pin, connect to power supply negative terminal
N.C.	—	—	—	5	—	No Connection
	—	—	—	6		
	—	—	—	7		
+V$_S$	—	—	—	8	POWER	Positive power supply pin

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1][2]

		MIN	MAX	UNIT
Supply voltage		−0.2	35	V
Output voltage		−1	6	V
Output current			10	mA
Maximum Junction Temperature, $T_J$max			150	°C
Storage Temperature, T_{stg}	TO-CAN, TO-92 Package	−60	150	°C
	TO-220, SOIC Package	−65	150	

(1) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
(2) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±2500	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
Specified operating temperature: T_{MIN} to T_{MAX}	LM35, LM35A	−55	150	°C
	LM35C, LM35CA	−40	110	
	LM35D	0	100	
Supply Voltage (+V_S)		4	30	V

6.4 Thermal Information

THERMAL METRIC[1][2]		LM35				UNIT
		NDV	LP	D	NEB	
		3 PINS		8 PINS	3 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	400	180	220	90	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	24	—	—	—	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.
(2) For additional thermal resistance information, see *Typical Application*.

6.5 Electrical Characteristics: LM35A, LM35CA Limits

Unless otherwise noted, these specifications apply: −55°C ≤ T_J ≤ 150°C for the LM35 and LM35A; −40°C ≤ T_J ≤ 110°C for the LM35C and LM35CA; and 0°C ≤ T_J ≤ 100°C for the LM35D. V_S = 5 Vdc and I_{LOAD} = 50 µA, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

PARAMETER	TEST CONDITIONS	LM35A			LM35CA			UNIT
		TYP	TESTED LIMIT[1]	DESIGN LIMIT[2]	TYP	TESTED LIMIT[1]	DESIGN LIMIT[2]	
Accuracy[3]	T_A = 25°C	±0.2	±0.5		±0.2	±0.5		°C
	T_A = −10°C	±0.3			±0.3		±1	
	T_A = T_{MAX}	±0.4	±1		±0.4	±1		
	T_A = T_{MIN}	±0.4	±1		±0.4		±1.5	
Nonlinearity[4]	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C	±0.18		±0.35	±0.15		±0.3	°C
Sensor gain (average slope)	T_{MIN} ≤ T_A ≤ T_{MAX}	10	9.9		10		9.9	mV/°C
	−40°C ≤ T_J ≤ 125°C	10	10.1		10		10.1	
Load regulation[5] 0 ≤ I_L ≤ 1 mA	T_A = 25°C	±0.4	±1		±0.4	±1		mV/mA
	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C	±0.5		±3	±0.5		±3	
Line regulation[5]	T_A = 25°C	±0.01	±0.05		±0.01	±0.05		mV/V
	4 V ≤ V_S ≤ 30 V, −40°C ≤ T_J ≤ 125°C	±0.02		±0.1	±0.02		±0.1	
Quiescent current[6]	V_S = 5 V, 25°C	56	67		56	67		µA
	V_S = 5 V, −40°C ≤ T_J ≤ 125°C	105		131	91		114	
	V_S = 30 V, 25°C	56.2	68		56.2	68		
	V_S = 30 V, −40°C ≤ T_J ≤ 125°C	105.5		133	91.5		116	
Change of quiescent current[5]	4 V ≤ V_S ≤ 30 V, 25°C	0.2	1		0.2	1		µA
	4 V ≤ V_S ≤ 30 V, −40°C ≤ T_J ≤ 125°C	0.5		2	0.5		2	
Temperature coefficient of quiescent current	−40°C ≤ T_J ≤ 125°C	0.39		0.5	0.39		0.5	µA/°C
Minimum temperature for rate accuracy	In circuit of Figure 14, I_L = 0	1.5		2	1.5		2	°C
Long term stability	T_J = T_{MAX}, for 1000 hours	±0.08			±0.08			°C

(1) Tested Limits are ensured and 100% tested in production.
(2) Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.
(3) Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).
(4) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.
(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.
(6) Quiescent current is defined in the circuit of Figure 14.

6.6 Electrical Characteristics: LM35A, LM35CA

Unless otherwise noted, these specifications apply: −55°C ≤ T_J ≤ 150°C for the LM35 and LM35A; −40°C ≤ T_J ≤ 110°C for the LM35C and LM35CA; and 0°C ≤ T_J ≤ 100°C for the LM35D. V_S = 5 Vdc and I_{LOAD} = 50 µA, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

PARAMETER	TEST CONDITIONS		LM35A			LM35CA			UNIT
			MIN	TYP	MAX	TYP	TYP	MAX	
Accuracy[1]	T_A = 25°C			±0.2			±0.2		°C
		Tested Limit[2]			±0.5			±0.5	
		Design Limit[3]							
	T_A = −10°C			±0.3			±0.3		
		Tested Limit[2]							
		Design Limit[3]						±1	
	T_A = T_{MAX}			±0.4			±0.4		
		Tested Limit[2]			±1			±1	
		Design Limit[3]							
	T_A = T_{MIN}			±0.4			±0.4		
		Tested Limit[2]			±1				
		Design Limit[3]						±1.5	
Nonlinearity[4]	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C			±0.18			±0.15		°C
		Tested Limit[2]							
		Design Limit[3]			±0.35			±0.3	
Sensor gain (average slope)	T_{MIN} ≤ T_A ≤ T_{MAX}			10			10		mV/°C
		Tested Limit[2]			9.9				
		Design Limit[3]						9.9	
	−40°C ≤ T_J ≤ 125°C			10			10		
		Tested Limit[2]			10.1				
		Design Limit[3]						10.1	
Load regulation[5] 0 ≤ I_L ≤ 1 mA	T_A = 25°C			±0.4			±0.4		mV/mA
		Tested Limit[2]			±1			±1	
		Design Limit[3]							
	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C			±0.5			±0.5		
		Tested Limit[2]							
		Design Limit[3]			±3			±3	
Line regulation[5]	T_A = 25°C			±0.01			±0.01		mV/V
		Tested Limit[2]			±0.05			±0.05	
		Design Limit[3]							
	4 V ≤ V_S ≤ 30 V, −40°C ≤ T_J ≤ 125°C			±0.02			±0.02		
		Tested Limit[2]							
		Design Limit[3]			±0.1			±0.1	

(1) Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).
(2) Tested Limits are ensured and 100% tested in production.
(3) Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.
(4) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.
(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Product Folder Links: LM35

Electrical Characteristics: LM35A, LM35CA (continued)

Unless otherwise noted, these specifications apply: −55°C ≤ T_J ≤ 150°C for the LM35 and LM35A; −40°C ≤ T_J ≤ 110°C for the LM35C and LM35CA; and 0°C ≤ T_J ≤ 100°C for the LM35D. V_S = 5 Vdc and I_{LOAD} = 50 µA, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

PARAMETER	TEST CONDITIONS		LM35A			LM35CA			UNIT
			MIN	TYP	MAX	TYP	TYP	MAX	
Quiescent current[6]	V_S = 5 V, 25°C			56			56		µA
		Tested Limit[2]			67			67	
		Design Limit[3]							
	V_S = 5 V, −40°C ≤ T_J ≤ 125°C			105			91		
		Tested Limit[2]							
		Design Limit[3]			131			114	
	V_S = 30 V, 25°C			56.2			56.2		
		Tested Limit[2]			68			68	
		Design Limit[3]							
	V_S = 30 V, −40°C ≤ T_J ≤ 125°C			105.5			91.5		
		Tested Limit[2]							
		Design Limit[3]			133			116	
Change of quiescent current[5]	4 V ≤ V_S ≤ 30 V, 25°C			0.2			0.2		µA
		Tested Limit[2]			1			1	
		Design Limit[3]							
	4 V ≤ V_S ≤ 30 V, −40°C ≤ T_J ≤ 125°C			0.5			0.5		
		Tested Limit[2]							
		Design Limit[3]			2			2	
Temperature coefficient of quiescent current	−40°C ≤ T_J ≤ 125°C			0.39			0.39		µA/°C
		Tested Limit[2]							
		Design Limit[3]			0.5			0.5	
Minimum temperature for rate accuracy	In circuit of Figure 14, I_L = 0			1.5			1.5		°C
		Tested Limit[2]							
		Design Limit[3]			2			2	
Long term stability	T_J = T_{MAX}, for 1000 hours			±0.08			±0.08		°C

(6) Quiescent current is defined in the circuit of Figure 14.

Product Folder Links: LM35

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6.7 Electrical Characteristics: LM35, LM35C, LM35D Limits

Unless otherwise noted, these specifications apply: −55°C ≤ T_J ≤ 150°C for the LM35 and LM35A; −40°C ≤ T_J ≤ 110°C for the LM35C and LM35CA; and 0°C ≤ T_J ≤ 100°C for the LM35D. V_S = 5 Vdc and I_{LOAD} = 50 µA, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

PARAMETER	TEST CONDITIONS	LM35			LM35C, LM35D			UNIT
		TYP	TESTED LIMIT[1]	DESIGN LIMIT[2]	TYP	TESTED LIMIT[1]	DESIGN LIMIT[2]	
Accuracy, LM35, LM35C[3]	T_A = 25°C	±0.4	±1		±0.4	±1		°C
	T_A = −10°C	±0.5			±0.5		±1.5	
	T_A = T_{MAX}	±0.8	±1.5		±0.8		±1.5	
	T_A = T_{MIN}	±0.8		±1.5	±0.8		±2	
Accuracy, LM35D[3]	T_A = 25°C				±0.6	±1.5		°C
	T_A = T_{MAX}				±0.9		±2	
	T_A = T_{MIN}				±0.9		±2	
Nonlinearity[4]	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C	±0.3		±0.5	±0.2		±0.5	°C
Sensor gain (average slope)	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C	10	9.8		10		9.8	mV/°C
		10	10.2		10		10.2	
Load regulation[5] 0 ≤ I_L ≤ 1 mA	T_A = 25°C	±0.4	±2		±0.4	±2		mV/mA
	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C	±0.5		±5	±0.5		±5	
Line regulation[5]	T_A = 25°C	±0.01	±0.1		±0.01	±0.1		mV/V
	4 V ≤ V_S ≤ 30 V, −40°C ≤ T_J ≤ 125°C	±0.02		±0.2	±0.02		±0.2	
Quiescent current[6]	V_S = 5 V, 25°C	56	80		56	80		µA
	V_S = 5 V, −40°C ≤ T_J ≤ 125°C	105		158	91		138	
	V_S = 30 V, 25°C	56.2	82		56.2	82		
	V_S = 30 V, −40°C ≤ T_J ≤ 125°C	105.5		161	91.5		141	
Change of quiescent current[5]	4 V ≤ V_S ≤ 30 V, 25°C	0.2	2		0.2	2		µA
	4 V ≤ V_S ≤ 30 V, −40°C ≤ T_J ≤ 125°C	0.5		3	0.5		**3**	
Temperature coefficient of quiescent current	−40°C ≤ T_J ≤ 125°C	0.39		0.7	0.39		0.7	µA/°C
Minimum temperature for rate accuracy	In circuit of Figure 14, I_L = 0	1.5		2	1.5		2	°C
Long term stability	T_J = T_{MAX}, for 1000 hours	±0.08			±0.08			°C

(1) Tested Limits are ensured and 100% tested in production.
(2) Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.
(3) Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).
(4) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.
(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.
(6) Quiescent current is defined in the circuit of Figure 14.

Product Folder Links: LM35

6.8 Electrical Characteristics: LM35, LM35C, LM35D

Unless otherwise noted, these specifications apply: −55°C ≤ T_J ≤ 150°C for the LM35 and LM35A; −40°C ≤ T_J ≤ 110°C for the LM35C and LM35CA; and 0°C ≤ T_J ≤ 100°C for the LM35D. V_S = 5 Vdc and I_{LOAD} = 50 μA, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

PARAMETER	TEST CONDITIONS		LM35			LM35C, LM35D			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Accuracy, LM35, LM35C[1]	T_A = 25°C			±0.4			±0.4		°C
		Tested Limit[2]			±1			±1	
		Design Limit[3]							
	T_A = −10°C			±0.5			±0.5		
		Tested Limit[2]							
		Design Limit[3]						±1.5	
	T_A = T_{MAX}			±0.8			±0.8		
		Tested Limit[2]			±1.5				
		Design Limit[3]						±1.5	
	T_A = T_{MIN}			±0.8			±0.8		
		Tested Limit[2]							
		Design Limit[3]			±1.5			±2	
Accuracy, LM35D[1]	T_A = 25°C						±0.6		°C
		Tested Limit[2]						±1.5	
		Design Limit[3]							
	T_A = T_{MAX}						±0.9		
		Tested Limit[2]							
		Design Limit[3]						±2	
	T_A = T_{MIN}						±0.9		
		Tested Limit[2]							
		Design Limit[3]						±2	
Nonlinearity[4]	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C			±0.3			±0.2		°C
		Tested Limit[2]							
		Design Limit[3]			±0.5			±0.5	
Sensor gain (average slope)	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C			10			10		mV/°C
		Tested Limit[2]	9.8						
		Design Limit[3]				9.8			
				10			10		
		Tested Limit[2]			10.2				
		Design Limit[3]						10.2	
Load regulation[5] 0 ≤ I_L ≤ 1 mA	T_A = 25°C			±0.4			±0.4		mV/mA
		Tested Limit[2]			±2			±2	
		Design Limit[3]							
	T_{MIN} ≤ T_A ≤ T_{MAX}, −40°C ≤ T_J ≤ 125°C			±0.5			±0.5		
		Tested Limit[2]							
		Design Limit[3]			±5			±5	

(1) Accuracy is defined as the error between the output voltage and 10 mv/°C times the case temperature of the device, at specified conditions of voltage, current, and temperature (expressed in °C).
(2) Tested Limits are ensured and 100% tested in production.
(3) Design Limits are ensured (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.
(4) Non-linearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the rated temperature range of the device.
(5) Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Electrical Characteristics: LM35, LM35C, LM35D (continued)

Unless otherwise noted, these specifications apply: −55°C ≤ T_J ≤ 150°C for the LM35 and LM35A; −40°C ≤ T_J ≤ 110°C for the LM35C and LM35CA; and 0°C ≤ T_J ≤ 100°C for the LM35D. V_S = 5 Vdc and I_{LOAD} = 50 µA, in the circuit of Full-Range Centigrade Temperature Sensor. These specifications also apply from 2°C to T_{MAX} in the circuit of Figure 14.

PARAMETER	TEST CONDITIONS		LM35			LM35C, LM35D			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Line regulation[5]	T_A = 25°C			±0.01			±0.01		mV/V
		Tested Limit[2]			±0.1				
		Design Limit[3]						±0.1	
	4 V ≤ V_S ≤ 30 V, −40°C ≤ T_J ≤ 125°C			±0.02			±0.02		
		Tested Limit[2]							
		Design Limit[3]			±0.2			±0.2	
Quiescent current[6]	V_S = 5 V, 25°C			56			56		µA
		Tested Limit[2]			80			80	
		Design Limit[3]							
	V_S = 5 V, −40°C ≤ T_J ≤ 125°C			105			91		
		Tested Limit[2]							
		Design Limit[3]			158			138	
	V_S = 30 V, 25°C			56.2			56.2		
		Tested Limit[2]			82			82	
		Design Limit[3]							
	V_S = 30 V, −40°C ≤ T_J ≤ 125°C			105.5			91.5		
		Tested Limit[2]							
		Design Limit[3]			161			141	
Change of quiescent current[5]	4 V ≤ V_S ≤ 30 V, 25°C			0.2			0.2		µA
		Tested Limit[2]						2	
		Design Limit[3]			2				
	4 V ≤ V_S ≤ 30 V, −40°C ≤ T_J ≤ 125°C			0.5			0.5		
		Tested Limit[2]							
		Design Limit[3]			3			3	
Temperature coefficient of quiescent current	−40°C ≤ T_J ≤ 125°C			0.39			0.39		µA/°C
		Tested Limit[2]							
		Design Limit[3]			0.7			0.7	
Minimum temperature for rate accuracy	In circuit of Figure 14, I_L = 0			1.5			1.5		°C
		Tested Limit[2]							
		Design Limit[3]			2			2	
Long term stability	T_J = T_{MAX}, for 1000 hours			±0.08			±0.08		°C

(6)   Quiescent current is defined in the circuit of Figure 14.

Product Folder Links: LM35

6.9 Typical Characteristics

Figure 1. Thermal Resistance Junction To Air
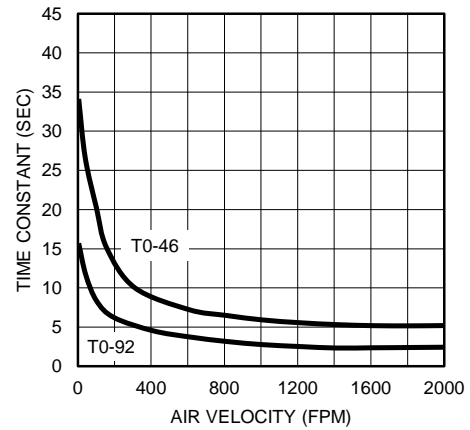
Figure 2. Thermal Time Constant
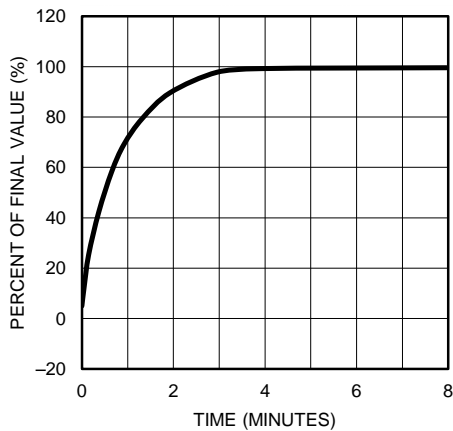
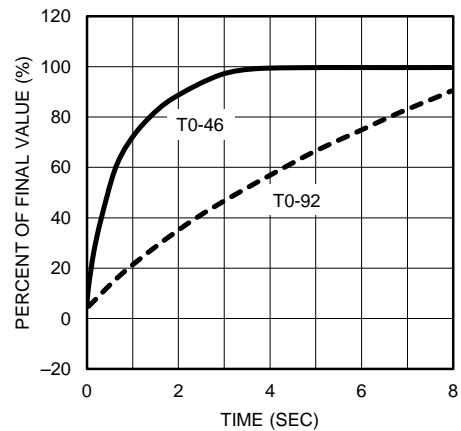**Figure 3. Thermal Response In Still Air**

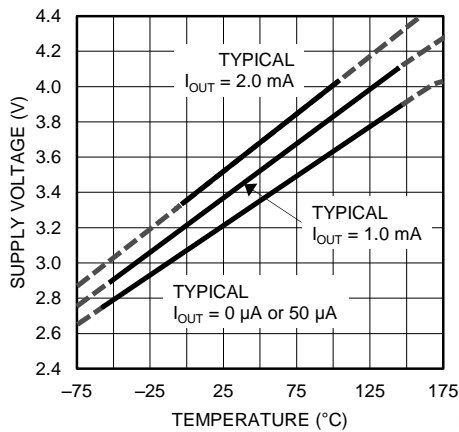**Figure 4. Thermal Response In Stirred Oil Bath**

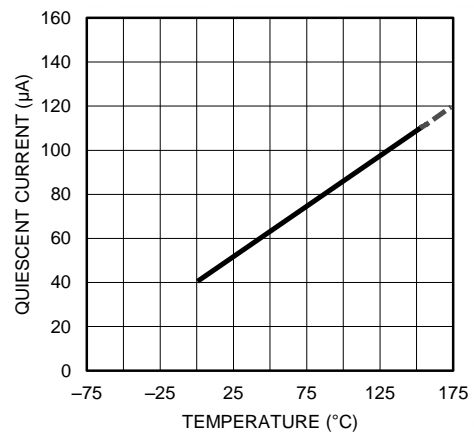**Figure 5. Minimum Supply Voltage vs Temperature**

Figure 6. Quiescent Current vs Temperature (in Circuit of Figure 14)
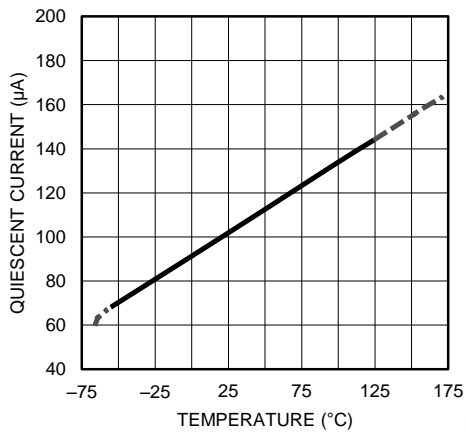
Typical Characteristics (continued)

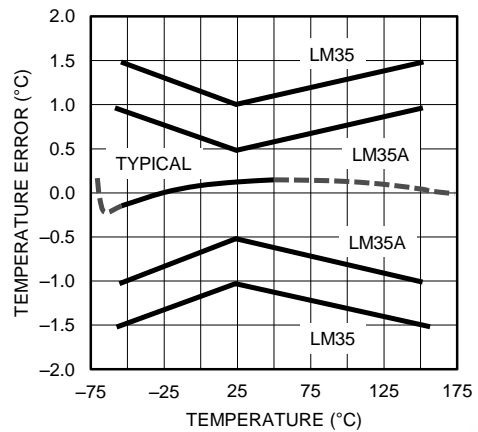**Figure 7. Quiescent Current vs Temperature (in Circuit of Full-Range Centigrade Temperature Sensor)**

Figure 8. Accuracy vs Temperature (Ensured)
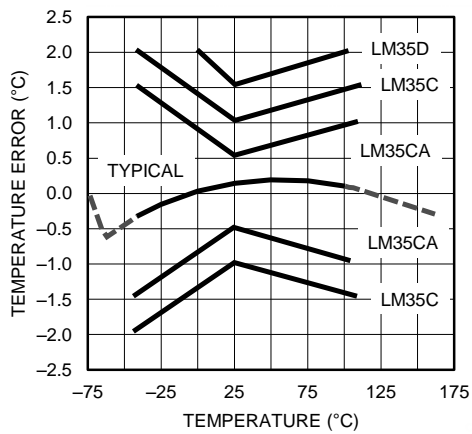
Figure 9. Accuracy vs Temperature (Ensured)
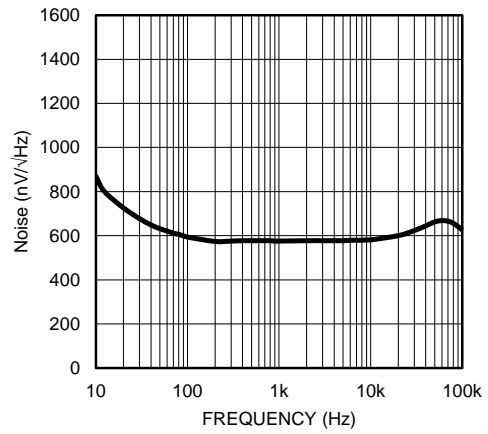
Figure 10. Noise Voltage
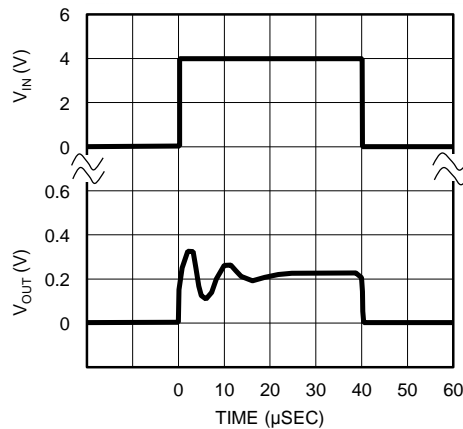
Figure 11. Start-Up Response

Product Folder Links: *LM35*

7 Detailed Description

7.1 Overview

The LM35-series devices are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ± ¼ °C at room temperature and ± ¾ °C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The temperature-sensing element is comprised of a delta-V BE architecture.

The temperature-sensing element is then buffered by an amplifier and provided to the VOUT pin. The amplifier has a simple class A output stage with typical 0.5-Ω output impedance as shown in the *Functional Block Diagram*. Therefore the LM35 can only source current and it's sinking capability is limited to 1 μA.

7.2 Functional Block Diagram
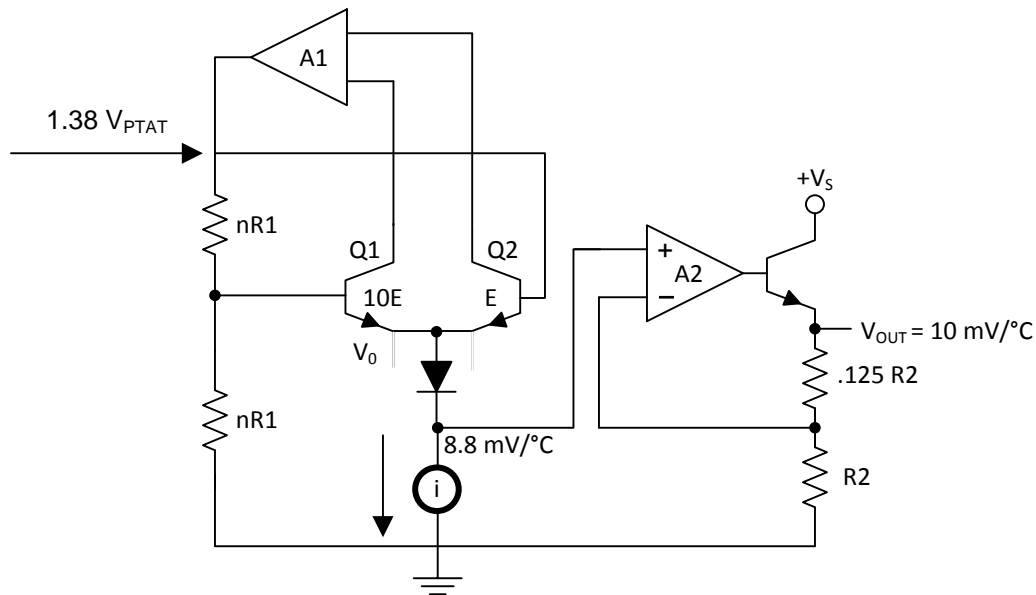
7.3 Feature Description

7.3.1 LM35 Transfer Function

The accuracy specifications of the LM35 are given with respect to a simple linear transfer function:

$$V_{OUT} = 10 \text{ mv/°C} \times T$$

where

- V_{OUT} is the LM35 output voltage
- T is the temperature in °C   (1)

7.4 Device Functional Modes

The only functional mode of the LM35 is that it has an analog output directly proportional to temperature.

8 Application and Implementation

> **NOTE**
>
> Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The features of the LM35 make it suitable for many general temperature sensing applications. Multiple package options expand on it's flexibility.

8.1.1 Capacitive Drive Capability

Like most micropower circuits, the LM35 device has a limited ability to drive heavy capacitive loads. Alone, the LM35 device is able to drive 50 pF without special precautions. If heavier loads are anticipated, isolating or decoupling the load with a resistor is easy (see Figure 12). The tolerance of capacitance can be improved with a series R-C damper from output to ground (see Figure 13).

When the LM35 device is applied with a 200-Ω load resistor as shown in Figure 16, Figure 17, or Figure 19, the device is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input and not on the output. However, as with any linear circuit connected to wires in a hostile environment, performance is affected adversely by intense electromagnetic sources (such as relays, radio transmitters, motors with arcing brushes, and SCR transients), because the wiring acts as a receiving antenna and the internal junctions act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper, such as 75 Ω in series with 0.2 or 1 μF from output to ground, are often useful. Examples are shown in Figure 13, Figure 24, and Figure 25.

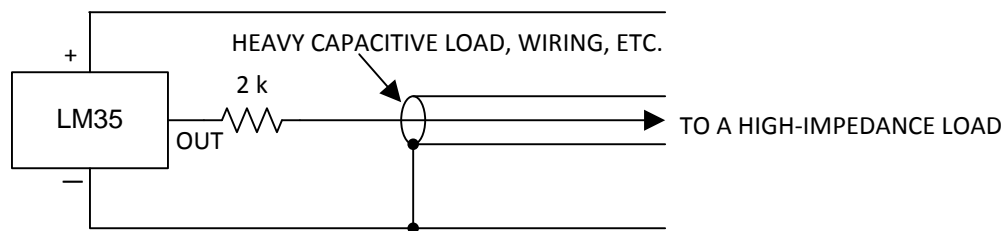**Figure 12. LM35 with Decoupling from Capacitive Load**

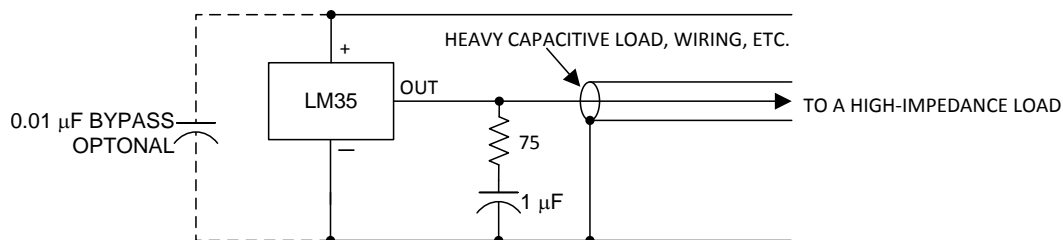**Figure 13. LM35 with R-C Damper**

Product Folder Links: *LM35*

8.2 Typical Application

8.2.1 Basic Centigrade Temperature Sensor

$+V_S$
(4 V to 20 V)
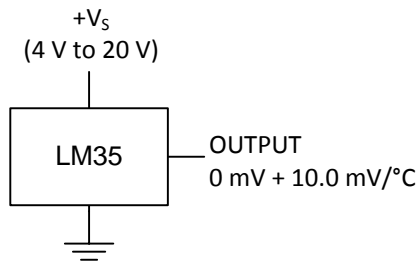
LM35

OUTPUT
0 mV + 10.0 mV/°C

Figure 14. Basic Centigrade Temperature Sensor (2 °C to 150 °C)

8.2.1.1 Design Requirements

Table 1. Design Parameters

PARAMETER	VALUE
Accuracy at 25°C	±0.5°C
Accuracy from –55 °C to 150°C	±1°C
Temperature Slope	10 mV/°C

8.2.1.2 Detailed Design Procedure

Because the LM35 device is a simple temperature sensor that provides an analog output, design requirements related to layout are more important than electrical requirements. For a detailed description, refer to the *Layout*.

8.2.1.3 Application Curve
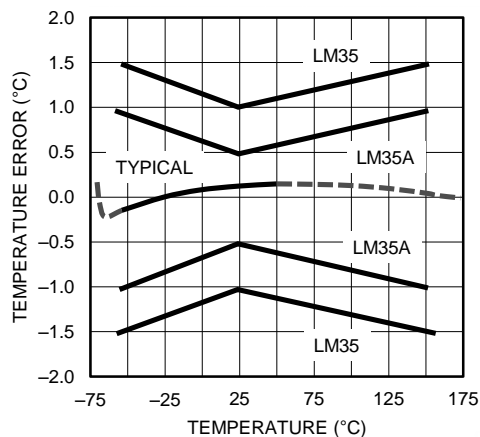
Figure 15. Accuracy vs Temperature (Ensured)

8.3 System Examples

Figure 16. Two-Wire Remote Temperature Sensor (Grounded Sensor)

V_{OUT} = 10 mV/°C ($T_{AMBIENT}$ = 1 °C) FROM + 2 °C TO + 40 °C

Figure 17. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

V_{OUT} = 10 mV/°C ($T_{AMBIENT}$ = 1 °C) FROM + 2 °C TO + 40 °C

Figure 18. Temperature Sensor, Single Supply (−55° to +150°C)

Figure 19. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

V_{OUT} = 10 mV/°C ($T_{AMBIENT}$ = 10 °C) FROM − 5 °C TO + 40 °C

Product Folder Links: *LM35*

System Examples (continued)

Figure 20. 4-To-20 mA Current Source (0°C to 100°C)
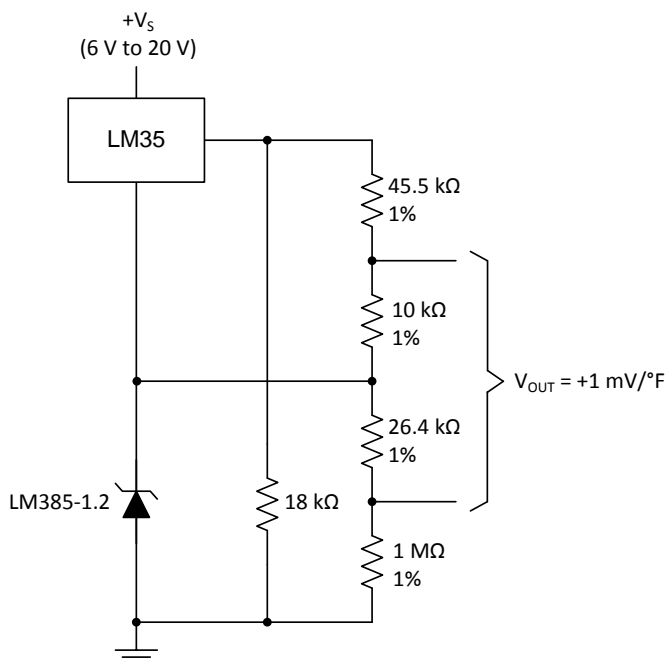
Figure 21. Fahrenheit Thermometer
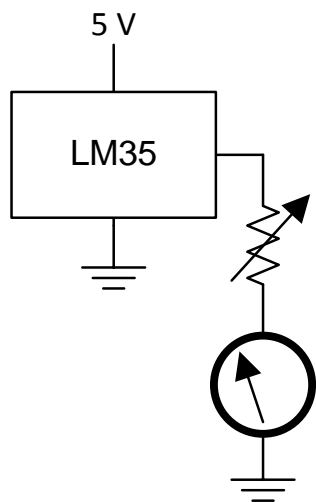
Figure 22. Centigrade Thermometer (Analog Meter)
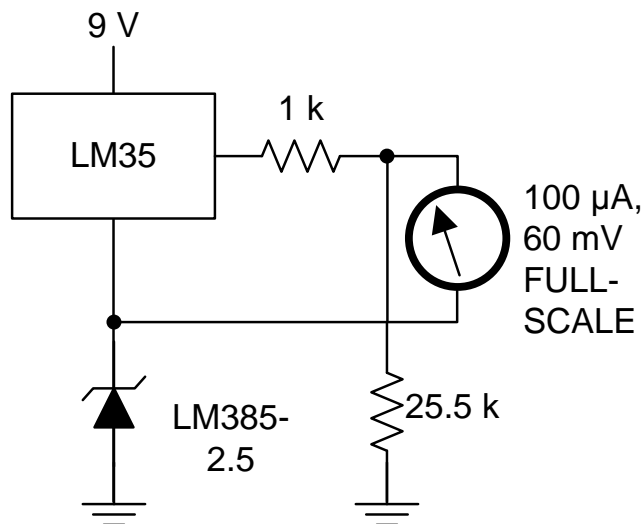
Figure 23. Fahrenheit Thermometer, Expanded Scale Thermometer (50°F to 80°F, for Example Shown)

System Examples (continued)

Figure 24. Temperature to Digital Converter (Serial Output) (128°C Full Scale)

Figure 25. Temperature to Digital Converter (Parallel TRI-STATE Outputs for Standard Data Bus to μP Interface) (128°C Full Scale)

*=1% or 2% film resistor

Trim R_B for V_B = 3.075 V

Trim R_C for V_C = 1.955 V

Trim R_A for V_A = 0.075 V + 100 mV/°C × $T_{ambient}$

Example, V_A = 2.275 V at 22°C

Figure 26. Bar-Graph Temperature Display (Dot Mode)

Figure 27. LM35 With Voltage-To-Frequency Converter and Isolated Output (2°C to 150°C; 20 to 1500 Hz)

9 Power Supply Recommendations

The LM35 device has a very wide 4-V to 30-V power supply voltage range, which makes it ideal for many applications. In noisy environments, TI recommends adding a 0.1 µF from V+ to GND to bypass the power supply voltage. Larger capacitances maybe required and are dependent on the power-supply noise.

10 Layout

10.1 Layout Guidelines

The LM35 is easily applied in the same way as other integrated-circuit temperature sensors. Glue or cement the device to a surface and the temperature should be within about 0.01°C of the surface temperature.

The 0.01°C proximity presumes that the ambient air temperature is almost the same as the surface temperature. If the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature; this is especially true for the TO-92 plastic package. The copper leads in the TO-92 package are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

Ensure that the wiring leaving the LM35 device is held at the same temperature as the surface of interest to minimize the temperature problem. The easiest fix is to cover up these wires with a bead of epoxy. The epoxy bead will ensure that the leads and wires are all at the same temperature as the surface, and that the temperature of the LM35 die is not affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V− terminal of the circuit will be grounded to that metal. Alternatively, mount the LM35 inside a sealed-end metal tube, and then dip into a bath or screw into a threaded hole in a tank. As with any IC, the LM35 device and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as a conformal coating and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 device or its connections.

These devices are sometimes soldered to a small light-weight heat fin to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

Table 2. Temperature Rise of LM35 Due To Self-heating (Thermal Resistance, $R_{\theta JA}$)

	TO, no heat sink	TO[1], small heat fin	TO-92, no heat sink	TO-92[2], small heat fin	SOIC-8, no heat sink	SOIC-8[2], small heat fin	TO-220, no heat sink
Still air	400°C/W	100°C/W	180°C/W	140°C/W	220°C/W	110°C/W	90°C/W
Moving air	100°C/W	40°C/W	90°C/W	70°C/W	105°C/W	90°C/W	26°C/W
Still oil	100°C/W	40°C/W	90°C/W	70°C/W	—	—	—
Stirred oil	50°C/W	30°C/W	45°C/W	40°C/W	—	—	—
(Clamped to metal, Infinite heat sink)	(24°C/W)		—	—	(55°C/W)		—

(1)   Wakefield type 201, or 1-in disc of 0.02-in sheet brass, soldered to case, or similar.
(2)   TO-92 and SOIC-8 packages glued and leads soldered to 1-in square of 1/16-in printed circuit board with 2-oz foil or similar.

10.2 Layout Example

Figure 28. Layout Example

Product Folder Links: *LM35*

11 Device and Documentation Support

11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on A*lert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document

11.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community.* Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.3 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.4 Electrostatic Discharge Caution

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

11.5 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGE OPTION ADDENDUM

TEXAS INSTRUMENTS

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM35AH	ACTIVE	TO	NDV	3	500	TBD	Call TI	Call TI	-55 to 150	(LM35AH ~ LM35AH)	Samples
LM35AH/NOPB	ACTIVE	TO	NDV	3	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-55 to 150	(LM35AH ~ LM35AH)	Samples
LM35CAH	ACTIVE	TO	NDV	3	500	TBD	Call TI	Call TI	-40 to 110	(LM35CAH ~ LM35CAH)	Samples
LM35CAH/NOPB	ACTIVE	TO	NDV	3	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-40 to 110	(LM35CAH ~ LM35CAH)	Samples
LM35CAZ/LFT4	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM35 CAZ	Samples
LM35CAZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-40 to 110	LM35 CAZ	Samples
LM35CH	ACTIVE	TO	NDV	3	500	TBD	Call TI	Call TI	-40 to 110	(LM35CH ~ LM35CH)	Samples
LM35CH/NOPB	ACTIVE	TO	NDV	3	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-40 to 110	(LM35CH ~ LM35CH)	Samples
LM35CZ/LFT1	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM35 CZ	Samples
LM35CZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	-40 to 110	LM35 CZ	Samples
LM35DH	ACTIVE	TO	NDV	3	1000	TBD	Call TI	Call TI	0 to 70	(LM35DH ~ LM35DH)	Samples
LM35DH/NOPB	ACTIVE	TO	NDV	3	1000	Green (RoHS & no Sb/Br)	Call TI | POST-PLATE	Level-1-NA-UNLIM	0 to 70	(LM35DH ~ LM35DH)	Samples
LM35DM	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	0 to 100	LM35D M	
LM35DM/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 100	LM35D M	Samples
LM35DMX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	0 to 100	LM35D M	
LM35DMX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 100	LM35D M	Samples
LM35DT	NRND	TO-220	NEB	3	45	TBD	Call TI	Call TI	0 to 100	LM35DT	
LM35DT/NOPB	ACTIVE	TO-220	NEB	3	45	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	0 to 100	LM35DT	Samples

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM35DZ/LFT1	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM35 DZ	Samples
LM35DZ/LFT4	ACTIVE	TO-92	LP	3	2000	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type		LM35 DZ	Samples
LM35DZ/NOPB	ACTIVE	TO-92	LP	3	1800	Green (RoHS & no Sb/Br)	CU SN	N / A for Pkg Type	0 to 100	LM35 DZ	Samples
LM35H	ACTIVE	TO	NDV	3	500	TBD	Call TI	Call TI	-55 to 150	(LM35H ~ LM35H)	Samples
LM35H/NOPB	ACTIVE	TO	NDV	3	500	Green (RoHS & no Sb/Br)	Call TI	Level-1-NA-UNLIM	-55 to 150	(LM35H ~ LM35H)	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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

PACKAGE MATERIALS INFORMATION

TAPE AND REEL INFORMATION

REEL DIMENSIONS

TAPE DIMENSIONS

A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM35DMX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LM35DMX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM35DMX	SOIC	D	8	2500	367.0	367.0	35.0
LM35DMX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0

∅ 4.95 / 4.55

0.76 MAX

2.67 MAX

0.64 MAX
UNCONTROLLED
LEAD DIA

3X
12.7 MIN

3X ∅ 0.483 / 0.407

∅ 5.32-5.56

2

1   3

45°

(∅ 2.54)

1.16
0.92

1.22
0.72
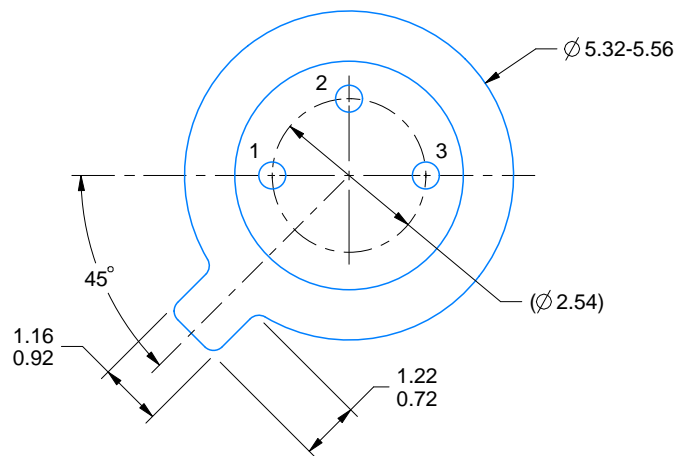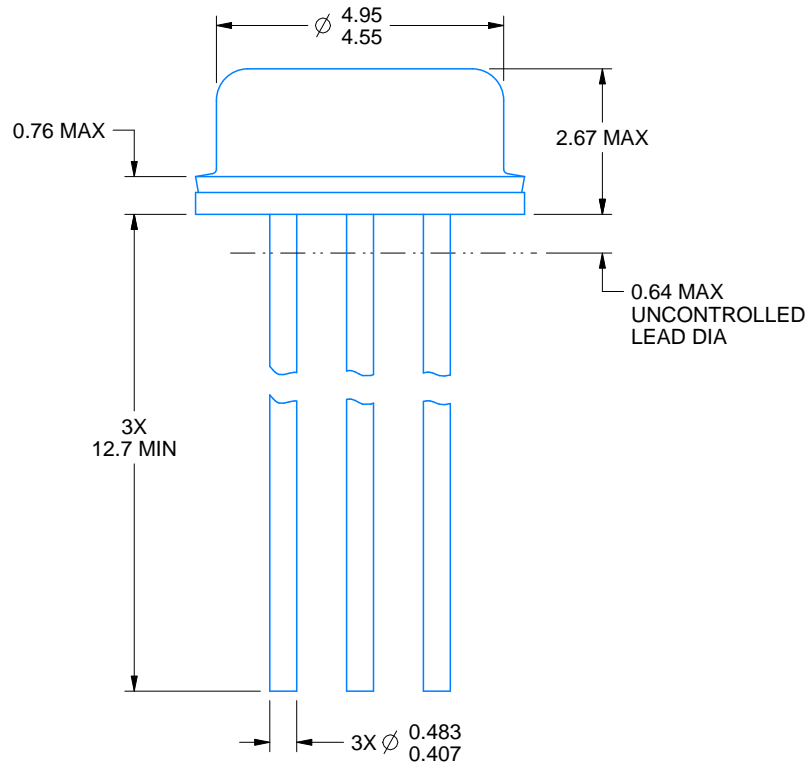
4219876/A   01/2017

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing
   per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration TO-46.

(2.54)

0.07 MAX
ALL AROUND

(□ 1.2)
METAL

3

3X (⌀ 0.7) VIA

SOLDER MASK
OPENING

1

(R0.05) TYP

(1.27)

2

2X (⌀ 1.2)
METAL

0.07 MAX
TYP

2X
SOLDER MASK
OPENING
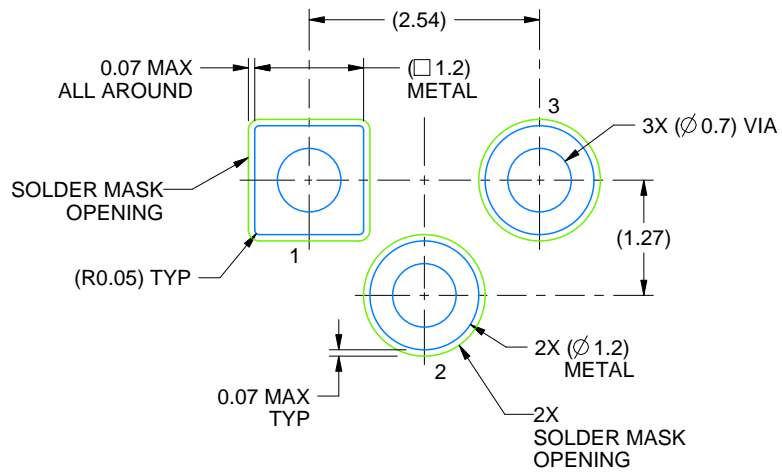
LAND PATTERN EXAMPLE
NON-SOLDER MASK DEFINED
SCALE:12X

4219876/A   01/2017

D (R–PDSO–G8)   PLASTIC SMALL OUTLINE

0.197 (5,00)
0.189 (4,80)
/C\

8   5

0.244 (6,20)
0.228 (5,80)

0.157 (4,00) /D\
0.150 (3,80)

Pin 1
Index Area

1   4

0.050 (1,27)   0.020 (0,51)
                    0.012 (0,31)

⊕ 0.010 (0,25) Ⓜ

0.069 (1,75) Max   0.010 (0,25)
                        0.004 (0,10)

0.010 (0,25)
0.005 (0,13)

⌀ 0.004 (0,10)

Gauge Plane

Seating Plane

0.010 (0,25)   0°–8°

0.050 (1,27)
0.016 (0,40)

4040047–3/M   06/11

NOTES: A.   All linear dimensions are in inches (millimeters).
         B.   This drawing is subject to change without notice.
      /C\   Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall
             not exceed 0.006 (0,15) each side.
      /D\   Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
         E.   Reference JEDEC MS–012 variation AA.

Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

4040001-2/F

5.21
4.44

5.34
4.32

EJECTOR PIN
OPTIONAL

2X
4 MAX

SEATING
PLANE

(2.54)
NOTE 3

(1.5) TYP

SEATING
PLANE

(0.51) TYP

6X
0.076 MAX

3X
12.7 MIN

2X
2.6 ± 0.2

3X 0.55
0.38

2X 1.27 ± 0.13

3X 0.43
0.35

FORMED LEAD OPTION
OTHER DIMENSIONS IDENTICAL
TO STRAIGHT LEAD OPTION

STRAIGHT LEAD OPTION

3X 2.67
2.03

4.19
3.17

3   2   1

3.43 MIN

4215214/B   04/2017

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing
   per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Lead dimensions are not controlled within this area.
4. Reference JEDEC TO-226, variation AA.
5. Shipping method:
   a. Straight lead option available in bulk pack only.
   b. Formed lead option available in tape and reel or ammo pack.
   c. Specific products can be offered in limited combinations of shipping medium and lead options.
   d. Consult product folder for more information on available options.

TEXAS INSTRUMENTS
www.ti.com

FULL R
TYP

0.05 MAX
ALL AROUND
TYP

(1.07)

METAL
TYP

3X (⌀ 0.85) HOLE

(1.5)

2X
METAL

2X (1.5)

2X
SOLDER MASK
OPENING

(R0.05) TYP

1

2

3

SOLDER MASK
OPENING

(1.27)

2X (1.07)

(2.54)
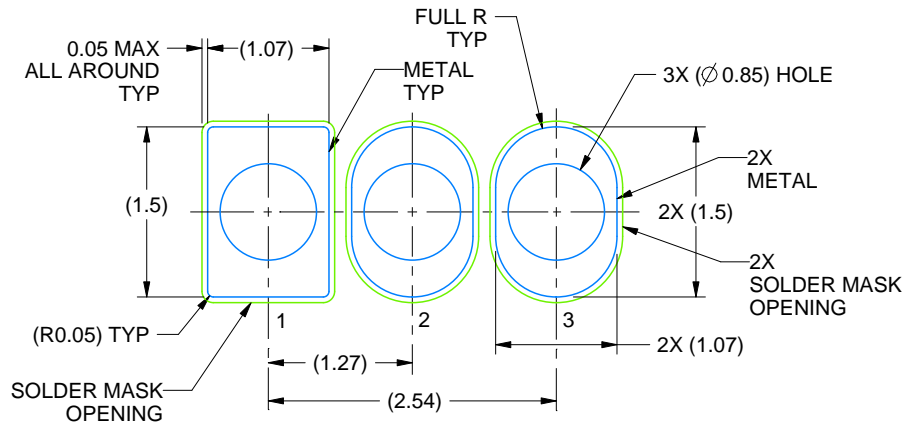
LAND PATTERN EXAMPLE
STRAIGHT LEAD OPTION
NON-SOLDER MASK DEFINED
SCALE:15X

0.05 MAX
ALL AROUND
TYP

(☐ 1.4)

2X (⌀ 1.4)
METAL

3X (⌀ 0.9) HOLE

METAL

(R0.05) TYP

1

2

3

2X
SOLDER MASK
OPENING

SOLDER MASK
OPENING

(2.6)

(5.2)

LAND PATTERN EXAMPLE
FORMED LEAD OPTION
NON-SOLDER MASK DEFINED
SCALE:15X

4215214/B   04/2017

TEXAS
INSTRUMENTS
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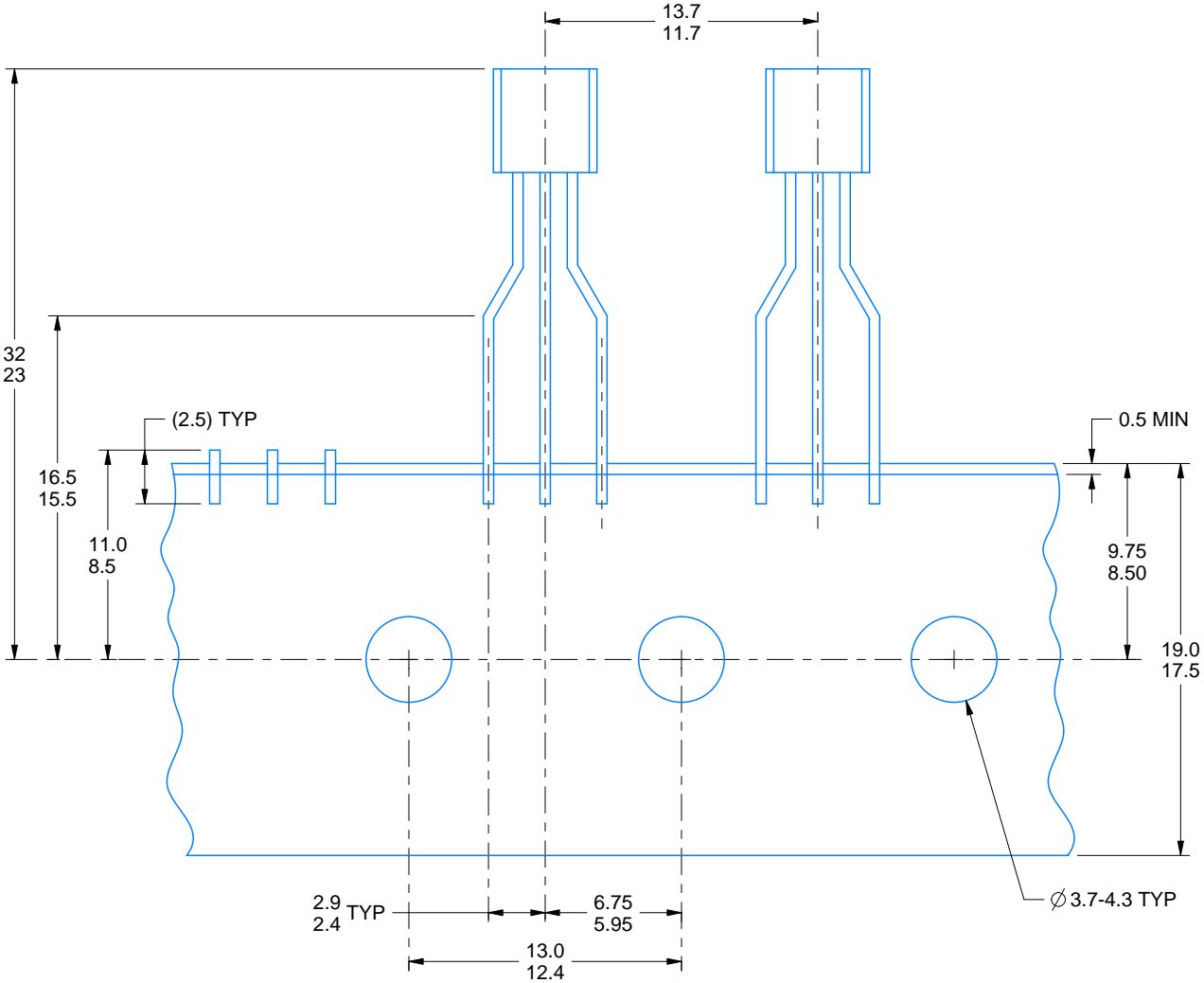
FOR FORMED LEAD OPTION PACKAGE

4215214/B   04/2017

IMPORTANT NOTICE