

ECM ENGINE CONTROL
AND MONITORING

G100TM

Air-Fuel Ratio Gauge

Instruction Manual

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Introduction

The G100 Air-Fuel Ratio Gauge

The ECM G100 series of Air-Fuel Ratio (AFR) gauges revolutionize vehicle instrumentation, tuning, and engine control by combining four important features into a single system: a true wide-range AFR sensor, a 270-degree sweep gauge, data recording with playback, and a linear 0 to 5 volt analog output. Four G100 kits are available:

- G100C Kit**
- 9.0 to 16.0 AFR (gasoline)
 - Easy calibration in air
 - Built-in self-diagnosis (trouble codes)
 - Accepts Bosch and NTK wide-range AFR sensors
 - Includes 2 1/16" diameter gauge, control module, and AFR sensor

- G100RC Kit**
- 9.0 to 16.0 AFR (gasoline)
 - Easy calibration in air
 - Built-in self-diagnosis (trouble codes)
 - Accepts Bosch and NTK wide-range AFR sensors
 - Record/Playback Control Pod (Option "R")
Recording duration of up to 1 minute triggered either by buttons on the pod or by an external 12 volt signal
 - Includes 2 1/16" diameter gauge, control module, record/playback control pod, and AFR sensor

- G100AC Kit**
- 9.0 to 16.0 AFR (gasoline)
 - Easy calibration in air
 - Built-in self-diagnosis (trouble codes)
 - Accepts Bosch and NTK wide-range AFR sensors
 - 0 to 5V linear analog output (Option "A")
 - Includes 2 1/16" diameter gauge, control module, and AFR sensor

- G100RAC Kit**
- 9.0 to 16.0 AFR (gasoline)
 - Easy calibration in air
 - Built-in self-diagnosis (trouble codes)
 - Accepts Bosch and NTK wide-range AFR sensors
 - Record/Playback Control Pod (Option "R")
Recording duration of up to 1 minute triggered either by buttons on the pod or by an external 12 volt signal
 - 0 to 5V linear analog output (Option "A")
 - Includes 2 1/16" diameter gauge, control module, record/playback control pod, and AFR sensor

G100 Components List

The following items are included with the G100. For pictures visit www.ecm-co.com.

Item No.	Description	Part Number
1a.	Control Module (for G100-C kit)	G100-1C
or		
1b.	Control Module (for G100-RC kit)	G100-1RC
or		
1c.	Control Module (for G100-AC kit)	G100-1AC
or		
1d.	Control Module (for G100-RAC kit)	G100-1RAC
2a.	Black 2 1/16" Gasoline Gauge	G100-2GBS
or		
2b.	White 2 1/16" Gasoline Gauge	G100-2GWS
3a.	AFR Sensor (not included with –SD ¹ kits)	G100-3B
or		
3b.	Adapter cable to allow use of VW production sensor (included with –SD ¹ kits only)	G100-17V
4.	AFR Sensor Cable, 11'	G100-4D
5.	Power Cable, 15'	G100-5
6.	Record/Playback Control Pod with 5' cable (with Option "R" only)	G100-6
7.	Velcro Insulation Kit	G100-10
8.	Analog Output Cable, 8", (with Option "A" only and installed on gauge)	G100-12
9.	Sensor Boss and Plug Kit	G100-13
10.	Calibration Screwdriver	G100-14
11.	Instruction Manual	G100-15

¹ A G100 kit supplied without an AFR sensor is given the suffix "-SD" (sensor delete).

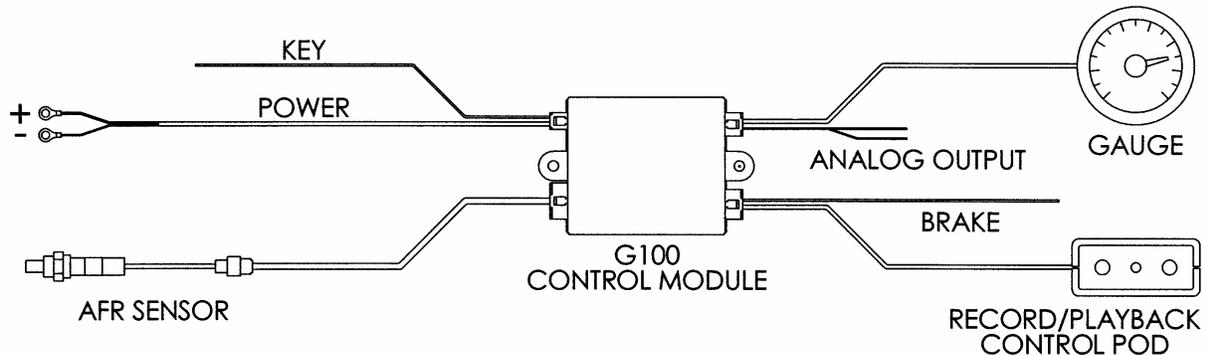
² Optional adapter cable G100-17H allows use of Honda production sensor.

Important Operation Notes

1. Before installing the AFR sensor, apply a small amount of non-lead containing antiseize compound to its threads. Do not get the compound on the sensor's tip.
2. Do not operate an engine for more than three minutes with the AFR sensor in the exhaust and the control module's power disconnected or the "KEY" wire not at 12V. If the sensor is off in a running engine for a longer period, soot and water will condense in the sensor and may reduce its life.
3. Do not use the AFR sensor in exhaust systems in which water is sprayed into the exhaust. Water striking the sensor may thermally shock the sensor and cause permanent sensor damage.
4. Do not put the AFR sensor in a heavily sooting or oil-burning engine.
5. Use of the AFR sensor with leaded fuels over time may reduce the life of the sensor.
6. Do not use the AFR sensor in a location where the temperature is greater than 950 deg. C (1742 deg. F) or if the pressure is not between 0.8 to 1.3 atm (23.9 to 38.9 inches Hg, 81 to 132 kPa).
7. Route and cable-tie all cables away from hot or moving objects and ignition wires.
8. Do not remove or attach the AFR sensor from the AFR cable when the control module is powered.
9. Do not drop the AFR sensor onto a hard surface.
10. Do not expose the AFR sensor to flammable substances.
11. Do not attempt to wash the AFR sensor with any solvent or compressed air.

Installing the G100

The G100 is graphically illustrated below. Installation should proceed in the following order: gauge and record/playback control pod (Option “R”), control module and power cable, AFR sensor and cable, and analog output (Option “A”). Do not modify any of the cables. After installation, the G100 should be calibrated. The following sections describe the recommended installation and calibration.



Gauge and Record/Playback Control Pod (Option “R”)

The gauge can be mounted in a bracket, a gauge cup, a pillar, or a dashboard. When choosing the gauge location, keep in mind that the gauge must be within 3’ of the control module (due to the gauge cable length). The two spade connectors on the back of the gauge are for backlighting. Connect one of these spade connectors to dashlight power (often available at the fuse panel) and the other to chassis ground. There is no specific polarity of the spades. Make sure that the spades and terminals on the back of the gauge do not touch anything metallic (i.e. the case of a metal mounting cup) and cause a short.

The record/playback control pod (Option “R”) can be mounted using the supplied velcro or can have its circuit board removed and mounted in a dashboard. The record/playback control pod must be within 5’ of the control module (due to the cable length). The recording of AFR can be triggered by simultaneously pressing and releasing both buttons on the control pod or by a 12V to 0V (or open circuit) transition on the wire labeled “BRAKE” in the control pod cable. Probably the easiest place to get a brake signal is from the brake switch under the dash. Using a voltmeter, probe the wires to the brake switch and find the wire that is at 12V when the brake is pressed and 0V (or open circuit) when the brake is released. Splice the “BRAKE” wire in the control pod cable to this brake wire. Alternatively, a transmission brake signal or another signal can be used as long as it has the 12V to 0V (or open circuit) transition. If you don’t want to use your brake pedal (or another external 12V signal) to trigger the recording, do not connect the “BRAKE” wire to anything.

Control Module and Power Cable

The control module should be located where it will not be exposed to liquids, excessive heat, or mechanical shock. In addition, the control module must be located so that it can be reached by the 3' gauge cable, the 5' record/playback control pod cable, the 11' AFR cable, and the 15' power cable. Lastly, the control module should be accessible so that G100 can be calibrated using the potentiometer and LED light in the module.

The power cable requires three connections: one to +12V power, one to the – terminal of the battery, and one that is at 12V when the vehicle's ignition key is in the "Run" position. +12V power should be fused for 5A (slow blow) before being attached to the red wire on the power cable. Due to the high current draw of the AFR sensor during start-up, it is recommended that +12V power be tapped directly from the battery (through the fuse). There are two ground wires in the power cable (black and clear) and they both must be connected directly (i.e. not with an extension wire) to the – terminal of the battery (preferred) or the chassis of the vehicle (if the negative terminal of the battery has a good external connection to the chassis). If these two ground wires are not connected directly this way then you may damage the G100's control module and other electronics in your vehicle. The wire labeled "KEY" in the power cable is used to turn the G100 on and off. Connect the "KEY" wire to a wire from the ignition switch that is at 12V when the ignition key is in the "Run" position and 0V (or open circuit) when the vehicle's ignition key is in the "Off" position. Do not be tempted to connect the "KEY" wire directly to the + terminal of the battery or the G100 will run continuously and drain the battery when the engine is off.

Do not modify the power cable and replace the cable if it becomes damaged.

Air-Fuel Ratio Sensor and Cable

Location of the AFR Sensor

The AFR sensor should be located from 12" to 48" from the exhaust valve(s) of the engine. A location further from the engine may be used as long as it is at least ten times the exhaust pipe diameter upstream of the end of the exhaust system. For example, with a 2 1/2" diameter exhaust pipe, the sensor should be at least 25" upstream of the end of the exhaust. The problem with locations less than ten diameters upstream is that reversion air may be trapped in the exhaust giving leaner than actual readings. This especially occurs at low exhaust flowrates (i.e. idle). Locating the AFR sensor far from the engine exposes the sensor to more liquid water during both start-up and normal operation and is not recommended.

When choosing an AFR sensor location, take into consideration engine movement, ground clearance, and AFR cable routing.

Mount the AFR sensor in a location where the sensor's wires are pointing upward (9 o'clock to 3 o'clock). Do not mount the sensor where liquid inside the exhaust may collect in the sensor or its threads.

Install the AFR sensor by lightly coating its threads with a non-lead containing antiseize compound and tighten it to 30 ± 3 ft-lbf (40 ± 4 Nm). Attach the sensor to the AFR cable and route the cable to where the control module is to be located. Use cable ties to keep the cable away from hot or moving objects and ignition wires.

Do not modify the AFR cable. Replace the cable if it becomes damaged.

Installation of the Sensor Mounting Boss

The AFR sensor is mounted in the engine's exhaust by threading it into a M18X1.5mm boss that is cast, welded, or brazed onto the engine's exhaust pipe. This thread size is identical to that of most exhaust oxygen sensors (O₂ sensors) used in production automobiles with 3-way exhaust catalyts.

The sensor boss provided has a M18X1.5mm thread. To mount the boss, first drill a 3/4" diameter hole in the desired location. Clean the area around the hole with a wire brush and clamp the boss over the hole. Weld or braze the boss to the exhaust pipe. After the boss is attached to the exhaust, tap the treads to straighten them (they will deform during welding or brazing) and file the top of the boss to provide a flat surface for sealing.

If the AFR sensor is removed, use the supplied plug (with some anti-seize) to plug the hole. Do not use the AFR sensor to plug the hole during engine operation when the control module is not powered-up.

Analog Output (Option "A")

If your G100 has the analog output option then an 8" red wire ("signal") and an 8" black wire ("ground") will be installed in the gauge cable connector. The signal measured across these two wires will be from 0 to 5V and linear in AFR from 9 to 16 AFR. This signal is suitable for input into any data acquisition system or engine controller and can be used to provide closed-loop wide-range AFR control. If the G100's power cable was properly connected, then the ground wire (black) of the analog output should be within 0.020 V of battery ground when the G100 is on. Use a voltmeter to make sure this is true when the G100 is on. Also measure the voltage between what the ground wire (black) is about to be connected to (i.e. the data acquisition system or engine controller) and the battery ground before connecting it. This voltage should also be within 0.020 V of battery ground when the data acquisition system and engine are running. If this is not the case, the data acquisition system or engine controller was improperly wired and damage to the G100 and the data acquisition system or engine controller may result if they are connected.

Calibration

Calibration of the G100 should be performed after installation. To perform a calibration, remove the AFR sensor from the exhaust and turn the ignition key on without starting the engine. After the ignition key is on, the needle on the gauge should point to 16 AFR and then slowly rotate clockwise to 9 AFR as the sensor warms up. After it reaches 9, it should swing clockwise to over 16 AFR. If the needle does not do this or if the AFR sensor does not warm up (be careful when checking, the sensor gets really hot), turn the ignition key off and review your installation before continuing. Three minutes after the ignition key has been turned on, put the calibration screwdriver into the "CAL POT" hole in the side of the control module and turn the potentiometer inside counterclockwise until the "CAL LED" goes out (if it is already out, don't worry). Then slowly turn the "CAL POT" clockwise until the "CAL LED" just turns on. At this point, very slowly turn the "CAL POT" back and forth until the

"CAL LED" turns off and on by just barely rotating the "CAL POT." Leave the "CAL POT" with the "CAL LED" just barely turned on. The G100 is now calibrated.

If the "CAL POT" cannot be turned counterclockwise to turn the "CAL LED" off then the AFR sensor is broken and must be replaced.

After the G100 has been calibrated, turn the ignition key off and wait until the sensor has cooled before installing it back into the exhaust. Your G100 is then ready to be used.

Using the G100

Warm-up

After the ignition key has been turned on, the gauge will point to 16 AFR and then slowly rotate clockwise to 9 AFR. While this is occurring, the AFR ratio sensor is warming up. After the needle reaches 9 AFR it will either: pin at 9 (if the engine is experiencing an extreme cold start), point to an AFR of between 9 and 16 (if the engine is running), pin at 16 (if the engine has just been started and its engine control system is pumping air into the exhaust, or if the engine has been off for a while), or “flick” a trouble code over the “ECM” logo in the lower area of the gauge.

Operation

The AFR displayed by a properly calibrated and warmed-up engine will be between 9 and 16 AFR. Generally speaking, a stoichiometric closed-loop controlled engine will be at approximately 14.6 AFR at all conditions except cold-start, fuel shutoff (during closed-throttle deceleration), and wide-open throttle (WOT) operation.

During cold-start, the AFR is always richer than stoichiometric (i.e. less than 14.6) but this may not be seen on the gauge due to air being pumped into the exhaust upstream of the AFR sensor. This pumping of air will make the gauge pin at 16 AFR and typically stops within 5 minutes of engine start-up. Flick the throttle during this period and you will see the AFR momentarily go below 16 AFR.

Fuel shutoff is programmed into most if not all modern engine control systems and may come as a surprise to you during a “foot-off-the-gas” deceleration. During fuel shutoff, the G100 will be pinned at 16 AFR (the AFR of air is infinity!). Press the throttle during a fuel shutoff and you will see the AFR come below 16 indicating that the engine is firing again.

During WOT operation, the AFR will be programmed between 9 and 14.6. Maximum engine power occurs typically around an AFR of 12 but engines are run richer (i.e. less than 12) for durability reasons. This is common on turbocharged engines where the extra fuel is used to keep the turbocharger from overtemping. Some engine control strategies keep the AFR at about 12 for a while at WOT and then go richer to avoid damaging the engine as it gets hotter. Perhaps the most frustrating AFR that you will see at WOT is stoichiometric (i.e. 14.6). Some modern engine control systems will not go rich at WOT for more power. That’s lost horsepower (but cleaner air).

Record/Playback (Option “R”)

A recording can either be started manually using the buttons on the Record/Playback Control Pod or by a signal to the “BRAKE” wire in the pod cable.

To start a recording manually: press the “SET/STOP” button and “PLAYBACK” button on the pod at the same time. If the “BRAKE” wire is connected, do not press the brake. The recording starts when the two buttons are released.

To start a recording using the signal to the “BRAKE” wire: hold the brake down and press and release the “SET/STOP” button. When the brake is released, the recording will start.

The LED on the control pod flashes during a recording.

The recording stops after 1 minute or when the “SET/STOP” button is pressed. Holding down the “PLAYBACK” button plays the recording back. During playback, the recorded AFR is replayed on the gauge and the analog output. You can play back the recording as many times as you want and the recording is not lost when you turn the G100 off.

If you start another recording, the previous recording is erased.

Analog Output (Option “A”)

When the G100 is first turned on and during the 35 second warm-up period, the analog output is held at 0 V.

After warm-up, the G100 will output 0V to 5V linearized over the range of 9 to 16 AFR. The relationship between the analog output (Vout) and the AFR for gasoline is:

$$\text{AFR} = 1.4 \times \text{Vout} + 9.0$$

For example, if Vout is 1.0 V then the AFR is 10:4. If the AFR is less than 9.0, the analog output will be 0 V. If the AFR is greater than 16.0, the analog output will be 5 V.

During a recording, the voltage output is active and during playback, the analog output will match the replayed AFR.

When there is a fault with the G100 and a trouble code is being “flicked” on the gauge, the analog output will be held at 0 V.

Calibration

Calibration of the G100 is required when: a new AFR sensor is installed, to compensate for sensor aging, or to compensate for large altitude changes. How often to calibrate the G100 depends on the application. Typically, for nominally stoichiometric engines using non-leaded fuel, calibration should be performed once every 6 months or 6000 miles. For racing engines using leaded fuel, calibration should be performed after every race. If the G100 is installed on a stoichiometric closed-loop engine, do not assume that the calibration is okay just because the gauge reads stoichiometric when the engine is operating closed-loop. Due to the G100’s design, it is almost impossible to read inaccurately under stoichiometric exhaust conditions.

The calibration procedure is described in the “Installing the G100” section. Always take the AFR sensor out of the exhaust when performing a calibration. The AFR sensor must be in pure air during a calibration. We have seen exhaust systems where two days after the engine has been turned off, the AFR sensor is still not surrounded by pure air. Take the AFR out of the exhaust to be sure.

If the “CAL POT” cannot be turned counterclockwise to turn the “CAL LED” out then the AFR sensor is broken and must be replaced.

Trouble Codes

Trouble codes are indicated by the G100 by “flicking” the needle over the “ECM” logo in the lower area of the gauge. There are five trouble codes (numbered 1 through 5) and they are indicated by the number of “flicks” of the gauge needle before the trouble code is repeated. One “flick” is one rapid back and forth movement of the needle over the “ECM” logo on the gauge. For example, if the needle flicks back and forth five times, then holds still, and then flicks back and forth five times again, then holds still (and repeats this cycle), then it is indicating trouble code number 5.

Explanations for the trouble codes are as follows:

Trouble Code 1: Battery voltage is less than 11 V, or the AFR cable is damaged, or the AFR sensor’s heater is short circuited. Operating below 11 V may cause inaccurate readings.

Trouble Code 2: Battery voltage is more than 28 V. This may cause permanent damage to the control module and/or sensor. Do not operate the G100 at battery voltages over 28 V.

Trouble Code 3: The AFR cable is damaged, or the AFR sensor’s heater has an open circuit, or the AFR sensor is disconnected.

Trouble Code 4: The AFR sensor is disconnected or the wrong type of AFR sensor is connected.

Trouble Code 5: The AFR cable or the AFR sensor is damaged.

Always check the battery voltage and AFR sensor cable before assuming that the AFR sensor is faulty. A burned, cut, or crushed cable can trigger a trouble code. Only after checking the AFR sensor cable for damage should you suspect the AFR sensor.

If during a calibration the “CAL LED” cannot be turned off by turning the “CAL POT” counterclockwise, the AFR sensor is broken and must be replaced. Sometimes, the G100 will not show a trouble code if this occurs.

Specifications and Limits

Measurement Range and Accuracy

Range: 9 to 16 AFR (gasoline)
Accuracy: $\pm 2\%$

Exhaust Operating Limits

Maximum Exhaust Gas Temperature: 950 deg. C, 1742 deg. F.
Exhaust Gas Pressure Range: 0.8 - 1.3 atm (23.9 to 38.9 inches Hg, 81 to 132 kPa).

Air-Fuel Ratio Sensor Installation

Thread Size: M18X1.5mm. Lightly coat with non-lead containing antiseize.
Hex Size: 22mm.
Tightening Torque: 30 ± 3 ft-lbf, 40 ± 4 Nm.

The AFR sensor's thread size is identical to that of most O₂ sensors used in production vehicles.

Record/Playback (Option "R")

Period: Up to one minute
Storage: Recording saved even if power is disconnected

Analog Output (Option "A")

Analog Output:

- 0V at 9.0:1 AFR (gasoline)
- 5V at 16.0:1 AFR (gasoline)
- $AFR = 1.4 \times V_{out} + 9.0$ (gasoline)
- Output Impedance: Less than 10 Ohms
- Output Wires: Signal = Red Wire, Ground = Black Wire

General Information

Power: 11 to 28 VDC at 5A (surge), 1.4A (continuous)
Fuse: Use 5 A slow-blow
Mounting: Two $\frac{1}{4}$ " holes spaced $4 \frac{3}{4}$ " apart
Dimensions: 4" x 3.5" x 1",
102mm x 89mm x 25mm (W x H x D)
Weight: 9 oz., 260 gm. (control module only)

Troubleshooting

If the “CAL POT” cannot be turned counterclockwise to where the “CAL LED” goes out then the AFR sensor is broken and must be replaced. This can occur if liquid strikes the AFR sensor when it is on. The liquid thermally shocks the AFR sensor and can cause it to crack. Severe vibration can also crack the AFR sensor.

If the G100’s needle is “flicking” a trouble code, refer to the “Trouble Code” section for more information.

If you think that the G100 is displaying the wrong AFR value then one of five conditions exists:

1. The G100 needs to be calibrated. See the “Calibration” section in “Installing the G100”.
2. The G100 is really displaying the correct AFR. It just isn’t what you guessed it should be.
3. The G100 is being confused by noisy power or operating in an electrically noisy environment. In some situations, a timing light might create a noise problem. Keeping the control module and cables away from the engine’s ignition wires will help avoid this source of electrical noise.
4. The ground wires on the power cable are not attached directly to the ground at the vehicle’s battery. If you connect a single wire from the power cable ground to the vehicle’s battery, a large voltage drop will occur across that wire and cause the analog output signal ground to be elevated above battery ground. Since battery ground is often the data acquisition system or engine controller’s signal ground, if you hook an elevated analog output ground to the ground at the data acquisition system or engine controller then an incorrect voltage (and hence incorrect AFR) will be read.
5. The G100 must be returned to the factory for repair. There are no user-repairable components inside the control module. The warranty is void if the control module is opened or if any cable is modified. Contact ECM before returning the G100 to the factory.

Safety Warnings

In installation and use of this product, comply with the National Electrical Code and any other applicable Federal, State, or local safety codes.

Always wear eye protection when working near engines, vehicles, or machinery.

During installation, disconnect the battery and take all other necessary precautions to prevent injury, property loss, and equipment damage. Do not attach the battery until the installation is completed.

Never work on a running engine.

When installing the G100, it is best to think-out your moves before you make them.

Route and cable-tie all cables away from hot, moving, sharp, high energy (spark), and caustic objects.

Take into consideration the movement of the engine, chassis, and wind buffeting when installing the G100.

Clear tools away from the engine before starting.

Operate the engine only in a well-ventilated area and never when you or one of your co-workers is tired.

When operating the G100, the operator should keep his or her eyes on the road.

One measure of professionalism is how much you and your co-workers can accomplish without an injury. Always be at your professional best. Think and act with safety in mind.

Warranty and Disclaimers

WARRANTY

The products described in this manual, with the exception of the AFR sensor, are warranted to be free from defects in material and workmanship for a period of 365 days from the date of shipment to the buyer. Within the 365 day warranty period, we shall at our option replace such items or reimburse the customer the original price of such items which are returned to us with shipping charges prepaid and which are determined by us to be defective. This warranty does not apply to any item that has been subjected to misuse, negligence or accident; or misapplied; or modified; or improperly installed.

The AFR sensor is considered an expendable part and as such cannot be covered by a warranty.

This warranty comprises the sole and entire warranty pertaining to the items provided hereunder. Seller makes no other warranty, guarantee, or representation of any kind whatsoever. All other warranties, including but not limited to merchantability and fitness for purpose, whether express, implied, or arising by operation of law, trade usage, or course of dealing are hereby disclaimed.

The warranty is void if the control module is opened or if any cable is modified.

LIMITATION OF REMEDY

Seller's liability arising from or in any way connected with the items sold and/or services provided shall be limited exclusively to repair or replacement of the items sold or refund of the purchase price paid by buyer, at seller's sole option. In no event shall seller be liable for any incidental, consequential or special damages of any kind or nature whatsoever, including but not limited to lost profits arising from or in any way connected with items sold and/or services provided to buyer, whether alleged to arise from breach of contract, express or implied warranty, or in tort, including without limitation, negligence, failure to warn or strict liability. In no event shall the company's liability to buyer arising out of or relating to the sale of any product or service exceed the purchase price paid by buyer to the company for such product or service.

PRODUCT CHANGES

We reserve the right to discontinue a particular product or to make technical design changes at any time without notice.

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