PULSAR®
R86 RADAR

SIL Safety Manual for Pulsar Model R86

Software v1.x

Functional Safety Manual

Model R86
26 GHz Pulse Burst Radar
Level Transmitter

This manual complements and is intended to be used with the Pulsar® Model R86 Installation and Operating manual (Bulletin 58-603).

Benefits

The PULSAR Model R86 (HART®) Pulse Burst level transmitter can be applied in most indoor and outdoor process or storage vessels. The PULSAR Model R86 can be used in liquids or slurries to meet the safety system requirements of IEC 61508/IEC 61511-1.

Benefits

The Magnetrol® Model R86 (HART) transmitter provides the following benefits to your operation:

- Protection up to SIL2 as independently assessed (hardware assessment) by exida as per IEC 61508/ IEC 61511-1. Safe Failure Fraction:
  - 93.2% (intrinsically safe)
  - 93.0% (explosion-proof)
- Antenna designs to +750 °F (+400 °C), 2320 psig (160 bar)
- IS, XP and Non-Incendive approvals
- Quick connect / disconnect antenna coupling
- Performance not process dependent (changing specific gravity and dielectric have no effect).

Magnetrol®

Pulsar® Model R86 Pulse Burst Radar Level Transmitter

SIL 2 Suitable

Table of Contents

1.0 Introduction

1.1 Product Description

The Pulsar® Model R86 Pulse Burst Radar Level Transmitter is a loop-powered, 24 VDC level transmitter based on Pulse Burst Radar technology. For Safety Instrumented Systems usage, it is assumed that the 4–20 mA output is used as the primary safety variable. The analog output meets NAMUR NE 43 (3.8 mA to 20.5 mA usable), and the transmitter contains self-diagnostics and can be programmed to send its output to a user-selected failure state, either low or high upon internal detection of a failure. The device can be equipped with or without an LCD display. Table 1 lists the versions of the PULSAR Model R96 that have been considered for the hardware assessment.

Table 1
Pulsar® Model Number

R86-51XX-aXX (a=0, 1, A, C or D)	**Intrinsically Safe** R86 is energy limited but not isolated from current loop.
R86-51XX-aXX (a=3 or B)	**Explosion Proof** R86 is galvanically isolated from current loop.

The R86 is classified as a Type B[2] element according to IEC 61508, having a hardware fault tolerance of 0)

1.2 Theory of Operation

PULSAR Model R86 is a top-mounted, downward-facing pulse burst radar transmitter operating at 26 GHz. Unlike true pulse devices that transmit a single, sharp (fast rise-time) waveform of wide-band energy, the PULSAR Model R86 emits short bursts of 26 GHz energy and measures the transit time of the signal reflected off the liquid surface. Distance is calculated utilizing the equation:

Distance = C × Transit time/2, then developing the Level value by factoring in application-specific configuration.

The PULSAR Model R86 is classified as a Type B device according to IEC 61508.

1.3 Determining Safety Integrity Level (SIL)

Tables 2 & 3 define the criteria for the achievable SIL against the target mode of operation in Demand Mode Operation.

Table 2 shows the relationship between the Safety Integrity Level (SIL) and the Probability of Failure on Demand Average (PFDavg).

Table 3 can be used to determine the achievable SIL as a function of the Hardware Fault Tolerance (HFT) and the Safe Failure Fraction (SFF) for the complete safety system (type B – complex components as per IEC 61508 Part 2) of which the level transmitter is one component.

Table 2
SIL vs. PFDavg

Safety Integrity Level (SIL)	Target Average probability of failure on demand (PFDavg)
4	$\geq 10^{-5}$ to $<10^{-4}$
3	$\geq 10^{-4}$ to $<10^{-3}$
2	$\geq 10^{-3}$ to $<10^{-2}$
1	$\geq 10^{-2}$ to $<10^{-1}$

Table 3
Minimum hardware fault tolerance
Type B sensors, final elements and non-PE logic solvers

SFF	Hardware Fault Tolerance (HFT)		
	0	1	2
None: <60%	Not Allowed	SIL 1	SIL 2
Low: 60% to <90%	SIL 1	SIL 2	SIL 3
Medium: 90% to <99%	SIL 2	SIL 3	
High: ≥99%	SIL 3		

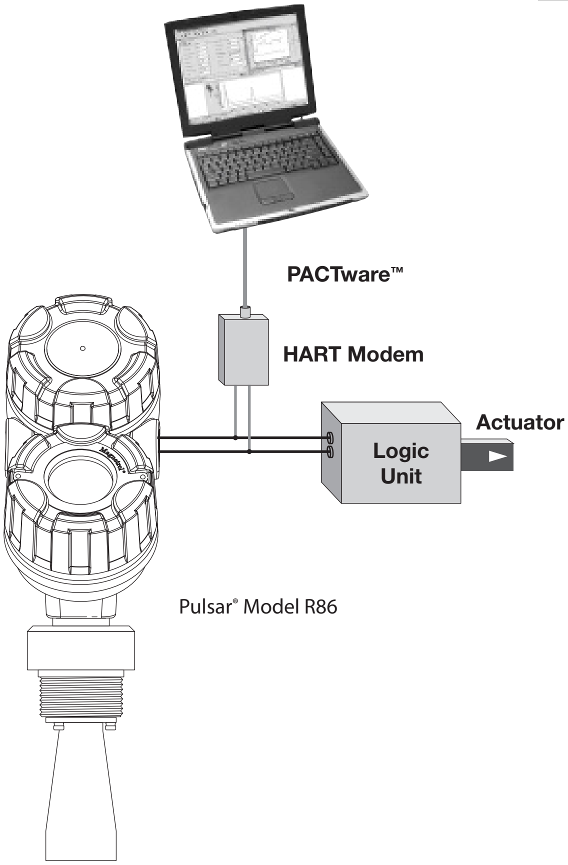

Figure 1
Typical System

2.0 Level Measuring System

The diagram shows the structure of a typical measuring system incorporating the MAGNETROL PULSAR Model R86 Pulse Burst radar transmitter.

This SIL rated device is only available with an analog signal (4–20 mA) with HART digital communication. (The measurement signal used by the logic solver must be the analog 4– 20 mA signal proportional to the level generated).

For fault monitoring, the logic unit must recognize both high alarms (21.5 mA) and low alarms (3.6 mA). If the logic solver loop uses intrinsic safety barriers, caution must be taken to ensure the loop continues to operate properly under the low alarm condition.

The only unsafe mode is when the unit is reading an incorrect level within the 4–20mA range (> ±2% deviation). MAGNETROL defines a safe failure as one in which the 4–20 mA current is driven out of range (i.e., less than 3.8 mA or greater than 20.5 mA).

2.0.1 FOUNDATION fieldbus™

Although the PULSAR Model R86 is available with FOUNDATION fieldbus™ output, it does not presently meet the FF-SIS standard.

2.1 Applicable Models

This manual is applicable to the following PULSAR Pulse Burst Radar transmitters:

R86-51XX-aXX (a=0, 1, 3, A, B, C or D)

2.2 Miscellaneous Electrical Considerations

Following are miscellaneous electrical issues to be considered.

2.2.1 Pollution Degree 3

The PULSAR system is designed for use in Category II, Pollution Degree 3 installations.

The typical pollution degree used for equipment being evaluated to IEC/EN 61010 is a nonconductive pollution of the sort where a temporary conductivity caused by condensation might be expected.

2.2.2 Overvoltage

The MAGNETROL Model R86 has over-voltage protection per CE requirements. When considering Hi-pot, Fast Transients and Surge, this protection is to 1000 volts. Therefore, there should be no unsafe failure modes up to 1 KV.

Overvoltage Category II is a local level, covering appliances, portable equipment, etc., with smaller transient overvoltages than those characteristic of Overvoltage Category III. This category applies from the wall plug to the power-supply isolation barrier (transformer). The typical plant environment is Overvoltage Category II, so most equipment evaluated to the requirements of IEC/EN 61010 are considered to belong in that classification.

3.0 Mean Time To Repair (MTTR)

SIL determinations are based on a number of factors including the Mean Time To Repair (MTTR). The analysis for the PULSAR Model R86 is typically based on a MTTR of 24 hours.

4.0 Supplementary Documentation

The PULSAR Model R86 Installation and Operating Manual Bulletin 58-603 must be available for installation of the measuring system.

One of the following Electronic Device Description Files is also required if HART is used:

Manufacturer Code 0x0056
Model R86 1.x Device ID 0x56DD, device revision 1, DD revision 1.

For device installations in a classified area, the relevant safety instructions and electrical codes must be followed.

5.0 Instructions

5.1 Systematic Limitations

The following factors must be observed to avoid systematic failures.

5.1.1 Application

Choosing the proper Pulse Burst Radar antenna is the most important step in the application decision process. The antenna configuration establishes fundamental performance characteristics. Therefore, the horn antenna for use with the PULSAR Model R86 should be selected as appropriate for the application.

See Sections 2.3 & 2.4 of Installation and Operating Manual 58-603 for more detailed application information and limitations.

5.1.2 Environmental

See Section 3.7 of Installation and Operating Manual 58-603 for environmental limitations.

5.2 Skill Level of Personnel

Personnel following the procedures of this safety manual should have technical expertise equal to or greater than that of a qualified instrument technician.

5.3 Necessary Tools

Following are the necessary tools needed to carry out the prescribed procedures:

- Open-wrenches or adjustable wrench to fit the process connection size and type.
  - Antenna 2" (50 mm)
  - Transmitter 1½" (38 mm)
  - Torque wrench is highly desirable
- Flat-blade screwdriver
- Digital multimeter
- 24 VDC power supply, 23 mA minimum

5.4 Storage

The device should be stored in its original shipping box and not be subjected to temperatures outside the storage temperature (-50 to +80 °C) shown in the PULSAR Model R86 Installation and Operating Manual and associated specifications.

5.5 Installation

Refer to the PULSAR Model R86 Installation and Operating Manual Bulletin 58-603 for the proper installation instructions.

Section 2.6 of I/O Manual 58-603 contains information on the use, changing and resetting of the password protection function.

Section 2.6 of I/O Manual 58-603 provides menu selection items for configuration of the transmitter as a level sensing device and also contains configuration recommendations.

This SIL evaluation has assumed that the customer will be able to acknowledge an over or under current condition via the Logic Solver.

5.6 Configuration

5.6.1 General

The MAGNETROL PULSAR Model R86 can be configured via the local display, or via HART compatible handheld terminal or personal computer.

Ensure the parameters have been properly configured for the application.

Special consideration should be given to the following configuration parameters:

DIELECTRIC RANGE: Enter the Dielectric Range for the material to be measured:

Above 10 (Water-based media)
3.0 to 10 (Mid-dielectric media)
1.7 to 3.0 (Most typical hydrocarbons)
Below 1.7 (Light Hydrocarbons like Propane and Butane) — (stillwell only)

PV ALARM SELECTION: Do NOT choose HOLD for this parameter as a Fault will not be annunciated on the current loop.

LOOP CURRENT MODE: ensure this is set to ENABLED.

PASSWORD: should be changed to a specific value other than Zero. See Section 5.6.2

5.6.2 Write Protecting / Locking

The PULSAR Model R86 is password protected with a numerical password between 0 and 59999 (Default=0=Password disabled).

Refer to section 2.6 of the PULSAR Model R86 Installation and Operating Manual Bulletin 58-603 for information on password protection.

5.6.3 Write Enabling / Unlocking

Refer to section 2.6 of the PULSAR Model R86 Installation and Operating Manual Bulletin 58-603 for information on password protection.

When the alterations to the system are complete, ensure the menu has been locked with the password to prevent inadvertent changes to the device.

5.7 Site Acceptance Testing

To ensure proper operation after installation and configuration a site acceptance test should be completed. This procedure is identical to the Proof Test Procedure described in Section 6.1.4.

5.8 Recording Results

Results of Site Acceptance Testing must be recorded for future reference.

5.9 Maintenance

5.9.1 Diagnostics

Internal diagnostic testing does a complete cycle approximately four times per minute. A message will appear and the Output current will be driven to 3.6 or 22 mA (customer selectable) upon detection of a Diagnostic Failure. Worst-case internal fault detection time is one minute.

5.9.2 Troubleshooting

Report all failures to MAGNETROL.

Refer to Section 3.4 of the PULSAR Model R86 Installation and Operating Manual Bulletin 58-603 for troubleshooting device errors.

- As there are no moving parts in this device, the only maintenance required is the proof test.
- Firmware can only be upgraded by factory personnel.

6.0 Recurrent Function Tests

6.1 Proof Testing

6.1.1 Introduction

Following are the procedures utilized to detect Dangerous Undetected (DU) failures. The procedure will detect approximately 90% of possible DU failures in the Model R86.

6.1.2 Interval

To maintain the Safety Integrity Level of a Safety Instrumented System, it is imperative that the entire system be tested at regular time intervals (referred to as TI in the appropriate standards). The onus is on the owner/operator to select the type of inspection and the time period for these tests.

The system check must be carried out to prove that the functions meet the IEC specification and result in the desired response of the safety system as a whole.

This system check can be guaranteed when the response height is approached in the filling process; though, if this is not practical, a suitable method of simulating the level of the physical measurement must be used to make the level sensor respond as if the fill fluid were above the alarm/set point level. If the operability of the sensor/transmitter can be determined by other means that exclude all fault conditions that may impair the normal functions of the device, the check may also be completed by simulating the corresponding output signal of the device.

6.1.3 Recording results

Results of the Proof Test should be recorded for future reference.

6.1.4 Proof Test Procedure

1. Bypass the PLC or take other action to avoid a false trip.
2. Inspect the Unit in detail outside and inside for physical damage or evidence of environmental or process leaks.
   a. Inspect the exterior of the Unit housing. If there is any evidence of physical damage that may impact the integrity of the housing and the environmental protection, the unit should be repaired or replaced.
   b. Inspect the interior of the Unit. Any evidence of moisture, from process or environment, is an indication of housing damage, and the unit should be repaired or replaced.
3. Use the Unit's DIAGNOSTICS menu to observe Present Status, and review EVENT HISTORY in the Event Log. Up to 20 events are stored. The events will be date and time stamped if the internal clock is set and running. It is suggested that the internal clock be set at the time of commissioning of the unit. If the clock is set at the time of the proof test, event times are calculated.
   a. Choose the menu DIAGNOSTICS / Present Status.
      i. Present Status should be OK.
   b. Choose the menu DIAGNOSTICS / EVENT HISTORY / Event Log
      i. Any FAULT or WARNING messages must be investigated and understood.
      ii. Corrective actions should be taken for FAULT messages.
4. Use the DIAGNOSTICS menu to perform a "CURRENT LOOP TEST". Choose the menu DIAGNOSTICS / ADVANCED DIAGNOSTICS / TRANSMITTER TESTS / Analog Output Test to change the output loop current and confirm the actual current matches the value chosen.
   a. Send a HART command to the transmitter (or use the local interface) to go to the high alarm current output, 22mA, and verify that the analog current reaches that value.
      i. This step tests for compliance voltage problems such as low supply voltage or increased wiring resistance.
      ii. This also tests for current loop control circuitry and adjustment problems.
   b. Send a HART command to the transmitter (or use the local interface) to go to the low alarm current output, 3.6mA, and verify that the analog current reaches that value.

i. This step tests for high quiescent current and supply voltage problems.

ii. This also tests for current loop control circuitry and adjustment problems.

c. Exit the "Analog Output Test" and confirm that the output returns to original state, with the proper loop current as indicated and controlled by the unit.

5. Use the DIAGNOSTICS menu to observe the present Echo Curve. Confirm that the ECHO Waveform is normal. The echo curve is dependent on the type of antenna used, the installation conditions and the level of process. Comparison of the present Echo curve to one stored at the time of commissioning the unit gives additional confidence of the normal operation of the unit. Use of the DTM and digital communications is necessary for comparison of echo curves.

   a. Choose the menu DIAGNOSTICS / ECHO CURVES / View Echo Curve

      i. Observe the present Echo Curve, identify the characteristic portions of the waveform related to the Initial Launch, Process level, and other features.

      ii. Confirm that the Initial Launch appears acceptable. Confirm that Initial Launch is located where expected.

      iii. Confirm that the signal from the process level appears normal and is located as expected.

      iv. Compare to Echo curve from commissioning in the Initial Launch area.

6. Perform 2 point calibration check of the transmitter by varying level to two points in the process and compare the transmitter display reading and the current level value to a known reference measurement.

7. If the calibration is correct the proof test is complete. Proceed to step 9.

8. If the calibration is incorrect, remove the transmitter and antenna from the process. Inspect the antenna for coating. Clean the antenna, if necessary. Perform a bench calibration check by placing a metal reflector at two points in front of the antenna. Measure the distance of the two points and compare to the transmitter display and current level readings.

   a. If the calibration is off by more than 2%, call the factory for assistance.

   b. Re-install the antenna and transmitter.

9. Restore loop to full operation.

7.0 Appendices

7.1 FMEDA Report: Exida Management Summary

Failure Modes, Effects and Diagnostic Analysis

Project:
Pulsar Model R86

Company:
Magnetrol International, Incorporated
Aurora, IL
USA

Contract Number: Q16/08-077
Report No.: MAG 16/08-077 R001
Version V2, Revision R4, June 1, 2017
Rudolf Chalupa

Table 3 Failure rates R86-51XX-aXX (a=1 or A)

Failure Category	Failure Rate (FIT)	
Fail Safe Undetected		78
Fail Dangerous Detected		953
Fail Detected (detected by internal diagnostics)	820	
Fail High (detected by logic solver)	55	
Fail Low (detected by logic solver)	78	
Fail Dangerous Undetected		75
No Effect		452
Annunciation Undetected		5

Table 4 Failure rates R86-51XX-aXX (a=3 or B)

Failure Category	Failure Rate (FIT)	
Fail Safe Undetected		183
Fail Dangerous Detected		905
Fail Detected (detected by internal diagnostics)	820	
Fail High (detected by logic solver)	40	
Fail Low (detected by logic solver)	45	
Fail Dangerous Undetected		81
No Effect		488
Annunciation Undetected		5

These failure rates are valid for the useful lifetime of the product, see Appendix A.

According to IEC 61508 the architectural constraints of an element must be determined. This can be done by following the 1_H approach according to 7.4.4.2 of IEC 61508 or the 2_H approach according to 7.4.4.3 of IEC 61508 (see Section 5.2).

The 1_H approach involves calculating the Safe Failure Fraction for the entire element.

The 2_H approach involves assessment of the reliability data for the entire element according to 7.4.4.3.3 of IEC 61508.

The analysis shows that the R86 has a Safe Failure Fraction between 90% and 99% (assuming that the logic solver is programmed to detect over-scale and under-scale currents) and therefore meets hardware architectural constraints for up to SIL 2 as a single device.

Table 5 lists the failure rates for the R86 according to IEC 61508.

Table 5 Failure rates according to IEC 61508 in FIT

Device	λ_{SD}	λ_{SU}[3]	λ_{DD}	λ_{DU}	SFF[4]
R86-51XX-aXX (a=1 or A)	0	78	953	75	93.2%
R86-51XX-aXX (a=3 or B)	0	183	905	81	93.0%

[3] It is important to realize that the No Effect failures are no longer included in the Safe Undetected failure category according to IEC 61508, ed2, 2010.
[4] Safe Failure Fraction if needed, is to be calculated on an element level

7.2 SIL Declaration of Conformity

Hardware functional safety according to Section 2.4.4 of IEC 61508-2 (Edition 2.0: 2010).

Magnetrol International, Incorporated 705 Enterprise Street, Aurora, Illinois 60504 declares as the manufacturer, that the level transmitter:

Pulse Burst Radar (4-20 mA) Model R86-511x-xxx

is suitable for use in safety-instrumented loops according to IEC 61508 on condition that “the good practice of engineering rules” as described in the IEC standards, the appropriate parts of IEC 61508/61511, and the following parameters of the instrument are applied.

Product	**Model R96-51xx-axx (a=1 or A)**	**Model R96-51xx-axx (a=3 or B)**
SIL	2	2
Proof Test Interval	1 Year	1 Year
Device Type	B	B
SFF	93.2%	93.0%
λ_{SD}	0 FIT	0 FIT
λ_{SU}	78 FIT	183 FIT
λ_{DD}	953 FIT	905 FIT
λ_{DU}	75 FIT	81 FIT

7.3 Specific Model R86 Values

Specific Model R86

Product	PULSAR R86-51XX-aXX (a=1 or A)	PULSAR R86-51XX-aXX (a=3 or B)
SIL	SIL 2	
HFT	0	
SFF	93.2%	93.0%

Refer to Section 5 and Appendix D of the Model R86 FMEDA report for PFD_{avg} information.

7.4 Report: Lifetime of Critical Components

According to section 7.4.9.5 of IEC 61508-2, a useful lifetime, based on experience, should be assumed.

Although a constant failure rate is assumed by the probabilistic estimation method, this only applies provided that the useful lifetime* of components is not exceeded. Beyond their useful lifetime the result of the probabilistic calculation method is therefore meaningless, as the probability of failure significantly increases with time. The useful lifetime is highly dependent on the subsystem itself and its operating conditions.

This assumption of a constant failure rate is based on the bathtub curve. Therefore, it is obvious that the PFD_{avg} calculation is only valid for components that have this constant domain and that the validity of the calculation is limited to the useful lifetime of each component.

It is the responsibility of the end user to maintain and operate the R86 per manufacturer's instructions. Furthermore, regular inspection should show that all components are clean and free from damage.

The R86 has an estimated useful lifetime of about 50 years.

When plant experience indicates a shorter useful lifetime than indicated in this appendix, the number based on plant experience should be used.

* Useful lifetime is a reliability engineering term that describes the operational time interval where the failure rate of a device is relatively constant. It is not a term which covers product obsolescence, warranty, or other commercial issues.

References

- ANSI/ISA-84.00.01-2004 Part 1 (IEC 61511-1Mod) "Functional Safety: Safety Instrumented Systems for the Process Industry Sector – Part 1 Hardware and Software Requirements"
- ANSI/ISA-84.00.01-2004 Part 2 (IEC 61511-2Mod) "Functional Safety: Safety Instrumented Systems for the Process Industry Sector – Part 2 Guidelines for the Application of ANSI/ISA84.00.01-2004 Part 1 (IEC 61511-1 Mod) – Informative"
- ANSI/ISA-84.00.01-2004 Part 3 (IEC 61511-3Mod) "Functional Safety: Safety Instrumented Systems for the Process Industry Sector – Part 3 Guidance for the Determination of the Required Safety Integrity Levels – Informative"
- ANSI/ISA-TR84.00.04 Part 1 (IEC 61511 Mod) "Guideline on the Implementation of ANSI/ISA-84.00.01-2004"

Disclaimer

The SIL values in this document are based on an FMEDA analysis using exida's SILVER Tool. MAGNETROL accepts no liability whatsoever for the use of these numbers of for the correctness of the standards on which the general calculation methods are based.

ASSURED QUALITY & SERVICE COST LESS

Service Policy

Owners of MAGNETROL controls may request the return of a control or any part of a control for complete rebuilding or replacement. They will be rebuilt or replaced promptly. Controls returned under our service policy must be returned by prepaid transportation. MAGNETROL will repair or replace the control at no cost to the purchaser (or owner) other than transportation if:

1. Returned within the warranty period; and
2. The factory inspection finds the cause of the claim to be covered under the warranty.

If the trouble is the result of conditions beyond our control; or, is NOT covered by the warranty, there will be charges for labor and the parts required to rebuild or replace the equipment.

In some cases it may be expedient to ship replacement parts; or, in extreme cases a complete new control, to replace the original equipment before it is returned. If this is desired, notify the factory of both the model and serial numbers of the control to be replaced. In such cases, credit for the materials returned will be determined on the basis of the applicability of our warranty.

No claims for misapplication, labor, direct or consequential damage will be allowed.

Return Material Procedure

So that we may efficiently process any materials that are returned, it is essential that a "Return Material Authorization" (RMA) number be obtained from the factory prior to the material's return. This is available through a MAGNETROL local representative or by contacting the factory. Please supply the following information:

1. Company Name
2. Description of Material
3. Serial Number
4. Reason for Return
5. Application

Any unit that was used in a process must be properly cleaned in accordance with OSHA standards, before it is returned to the factory.

A Material Safety Data Sheet (MSDS) must accompany material that was used in any media.

All shipments returned to the factory must be by prepaid transportation.

All replacements will be shipped F.O.B. factory.

Magnetrol®

705 Enterprise Street • Aurora, Illinois 60504-8149 • 630-969-4000
info@magnetrol.com • www.magnetrol.com

BULLETIN: 58-651.1
EFFECTIVE: July 2017
SUPERSEDES: April 2017