PULSAR®
R96 RADAR

SIL Safety Manual for Pulsar Model R96

Software v1.x

Functional Safety Manual

Pulse Burst Radar

Level Transmitter

This manual complements and is intended to be used with the Pulsar® Model R96 Installation and Operating manual (Bulletin 58-602 dated January 2015 or later).

Application

The PULSAR Model R96 (HART®) Pulse Burst level transmitter can be applied in most metal and concrete process or storage vessels. The PULSAR Model R96 can be used in liquids or slurries to meet the safety system requirements of IEC 61508/IEC 61511-1.

Benefits

The Magnetrol® Model R96 (HART) transmitter provides the following benefits to your operation:

- Protection up to SIL2 (Safe Failure Fraction = 92.7%) as independently assessed (hardware assessment) by exida as per IEC 61508/ IEC 61511-1.
- Antenna designs to +400 °F (+200 °C), 750 psig (51.7 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 R96 Pulse Burst Radar Level Transmitter

SIL 2 Capable

Table of Contents

1.0 Introduction

1.1 Product Description

The Pulsar® Model R96 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). The transmitter contains self-diagnostics and is 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

Model R96, R96-511*-*** (HART)

1.2 Theory of Operation

PULSAR Model R96 is a top-mounted, downward-looking pulse burst radar operating at 6 GHz. Unlike true pulse devices that transmit a single, sharp (fast rise-time) waveform of wide-band energy, PULSAR Model R96 emits short bursts of 6 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 R96 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		

2.0 Level Measuring System

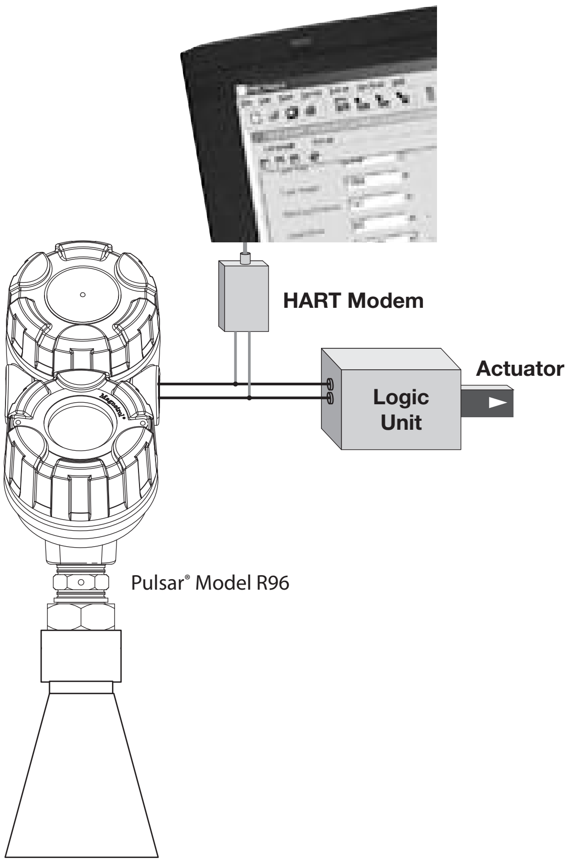


Figure 1
Typical System

The diagram shows the structure of a typical measuring system incorporating the MAGNETROL PULSAR Model R96 Pulse Burst radar transmitter.

This SIL rated device is only available with an analog signal (4–20 mA) with HART communications. 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 R96 is available with FOUNDATION fieldbus™ output, it does not presently meet the FF-SIS standard.

2.1 Applicable Models

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

R96-511x-xxx (SIL 2, HFT 0)

2.2 Miscellaneous Electrical Considerations

Following are miscellaneous electrical issues to be considered.

2.2.1 Pollution Degree 2

The PULSAR system is designed for use in Category II, Pollution Degree 2 installations.

A nonconductive pollution of the sort where occasionally a temporary conductivity caused by condensation must be expected. This is the usual pollution degree used for equipment being evaluated to IEC/EN 61010.

2.2.2 Overvoltage

The MAGNETROL Model R96 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 R96 is based on a MTTR of 24 hours.

4.0 Supplementary Documentation

The PULSAR Model R96 Installation and Operating Manual Bulletin 58-602 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 0x56
Model R96 1.x Device ID 0x56DE, 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 must be observed to avoid systematic failures.

5.1.1 Application

Choosing the proper Pulse Burst Radar antenna is the most important decision in the application process. The antenna configuration establishes fundamental performance characteristics. Horn and dielectric rod are the two basic configurations. The antenna for use with the PULSAR Model R96 should be selected as appropriate for the application.

See Section 2.3. of Installation and Operating Manual 58-602 for more detailed application information and limitations.

5.1.2 Environmental

See Section 3.6 of Installation and Operating Manual 58-602 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 °C to +80 °C) shown in the PULSAR Model R96 Installation and Operating Manual and associated specifications.

5.5 Installation

Refer to the PULSAR Model R96 Installation and Operating Manual Bulletin 58-602 for the proper installation instructions.

Section 2.6 of I/O Manual 58-602 contains information on the use, changing and resetting of the password protection function.

Section 2.6 of I/O Manual 58-602 provides menu selection items for configuration of the transmitter as a level sensing device. This section 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 R96 can be configured via the local display, or via HART compatible hand-held terminal or personal computer.

5.6.2 Configuration

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

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 5.6.3

5.6.3 Write Protecting / Locking

The PULSAR Model R96 is password protected with a numerical password between 0 (Default=0=Password disabled) and 59999.

Refer to section 2.6 of the PULSAR Model R96 Installation and Operating Manual Bulletin 58-602 for information on password protection.

5.6.4 Write Enabling / Unlocking

Refer to section 2.6 of the PULSAR Model R96 Installation and Operating Manual Bulletin 58-602 for information on password protection.

When the alterations to the system are complete, insure 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 4 times per second. 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.

5.9.2 Troubleshooting

Report all failures to MAGNETROL.

Refer to Section 3.3 of the PULSAR Model R96 Installation and Operating Manual Bulletin 58-602 for troubleshooting device errors. To assist in finding errors should they occur, complete the Configuration Data Sheets included at the end of the Operating Manual. Be sure to include all device information, including the password. Retain this information in a safe place.

- 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 98.1% of possible DU failures in the Model R96-511*-***.

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 SIL for the Model R96 is based on the assumption that the operator will carry out these tests and inspection at least once (1x) per year. 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

A suggested proof test is described below. This test will detect approximately 85% of possible DU failures in Model R96-511*-*** of the PULSAR Model R96 Pulse Burst Radar Level Transmitter.

1. Bypass the safety PLC or take other appropriate action to avoid a false trip.
2. Send a HART command to the transmitter to go to the high alarm current output and verify that the analog current reaches that value.

   This tests for compliance voltage problems such as low power supply voltage or increased loop wiring resistance. This also tests for other possible failures in the current loop circuitry.
3. Send a HART command to the transmitter to go to the low alarm current output and verify that the analog current reaches that value.

   This tests for possible quiescent current related failures.
4. Reduce the level in the vessel. The Status parameter should say “OK” and the level reading should be equal to the value in the “Bottom Blocking Distance” parameter.
5. Perform a two-point calibration check of the transmitter by applying level at two points and compare the transmitter display reading and the current level value to a known reference measurement.
6. If the calibration is correct, the proof test is complete. Proceed to step 11.
7. If calibration is incorrect, remove the transmitter and antenna from the process. Inspect the antenna for buildup or clogging. Clean the antenna if necessary.

   Perform a bench verification by aiming the antenna at two different distances from a target (such as a wall). First, set the device to measure Distance. Then compare the transmitter display and loop current readings to the actual distances.
8. If the calibration is off by more than 2%, call the factory for assistance.
9. If the calibration is correct, the proof test is complete. Return the transmitter to level mode. Proceed to step 10.
10. Re-install the transmitter and antenna.
11. Restore the loop to full operation.
12. Remove the bypass from the safety PLC or otherwise restore normal operation.

7.0 Appendices

7.1 SIL Declaration of Conformity

Functional safety according to IEC 61508/IEC 61511

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

Pulse Burst Radar (4-20 mA) Model R96-511x-xxx

is suitable for the use in safety instrumented systems according to IEC 61511-1, if the safety instructions and following parameters are observed:

(FIT = Failure in Time (1×10^{-9} failures per hour))

Product	**Model R96-511x-xxx**
SIL	2
Proof Test Interval	1 Year
Device Type	B
SFF	92.7%
PFD_{avg} ①	8.47E-04
λ_{SD}	0 FIT
λ_{SU}	63 FIT
λ_{DD}	972 FIT
λ_{DU}	81 FIT

① As determined in compliance with ANSI/ISA-84.01 clause 9.2.3 for 1oo1 system.

7.2 FMEDA Report: Exida Management Summary

exida®

Failure Modes, Effects and Diagnostic Analysis Review

Project:
R96 Pulse Burst Radar Level Transmitter

Company:
Magnetrol International, Incorporated
Aurora, IL
USA

Contract Number: Q16/01-115
Report No.: MAG 15/07-070 R001
Version V1, Revision R1, February 2, 2016
Rudolf Chalupa

Table 1 Failure rates R96

Failure Category	Failure Rate (FIT)	
Fail Safe Undetected		63
Fail Dangerous Detected		972
Fail Detected (detected by internal diagnostics)	802	
Fail High (detected by logic solver)	85	
Fail Low (detected by logic solver)	85	
Fail Dangerous Undetected		81
No Effect		490
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 R96 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 2 lists the failure rates for the R96 according to IEC 61508.

Table 2 Failure rates according to IEC 61508 in FIT

Device	λ_{SD}	λ_{SU}[3]	λ_{DD}	λ_{DU}	SFF[4]
R96	0	63	972	81	92.7%

[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

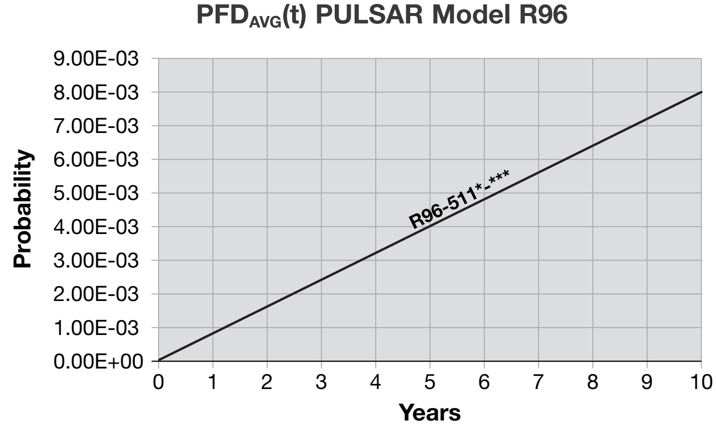
7.3 Specific Model R96 Values

Specific Model R96

Product	PULSAR Model R96-511x-xxx
SIL	SIL 2
HFT	0
SFF	92.7%
PFD_{avg}	8.47E-04
Proof Test Interval	Annually (refer to table below for other periods)

Proof Test Interval (months)	**PFD avg. (SIL 2)**
0	5.47E-04
6	6.97E-04
12	8.47E-04
18	9.98E-04
24	1.15E-03
30	1.30E-03
36	1.45E-03
42	1.60E-03
48	1.75E-03
54	1.90E-03
60	2.05E-03
66	2.20E-03
72	2.35E-03
78	2.50E-03
84	2.65E-03
90	2.80E-03
96	2.95E-03
102	3.10E-03
108	3.25E-03
114	3.40E-03
120	3.56E-03

7.4 PFD Graph



7.5 Report: Lifetime of Critical Components

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 component itself and its operating conditions—temperature in particular (e.g., electrolyte capacitors can be very sensitive).

This assumption of a constant failure rate is based on the bathtub curve, which shows the typical behavior for electronic components.

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.

The table below shows which components are contributing to the dangerous undetected failure rate and therefore to the PFD_{AVG} calculation and what their estimated useful lifetime is.

Useful lifetime of electrolytic capacitors contributing to λ_{DU}

Type	Useful life at +40 °C
Capacitor (electrolytic – Tantalum electrolytic, solid electrolyte	Approximately 500,000 hours

As there are no aluminum electrolytic capacitors used, the tantalum electrolytic capacitors are the limiting factors with regard to the useful lifetime of the system. The tantalum electrolytic capacitors that are used in the PULSAR Model R96 have an estimated useful lifetime of about 50 years. According to section 7.4.7.4 of IEC 61508-2, a useful lifetime, based on experience, should be assumed. According to section 7.4.7.4 note 3 of IEC 61508 experiences have shown that the useful lifetime often lies within a range of 8 to 12 years for transmitters.

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 • Fax 630-969-9489
info@magnetrol.com • www.magnetrol.com

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