Series 7100

B/W Controls™

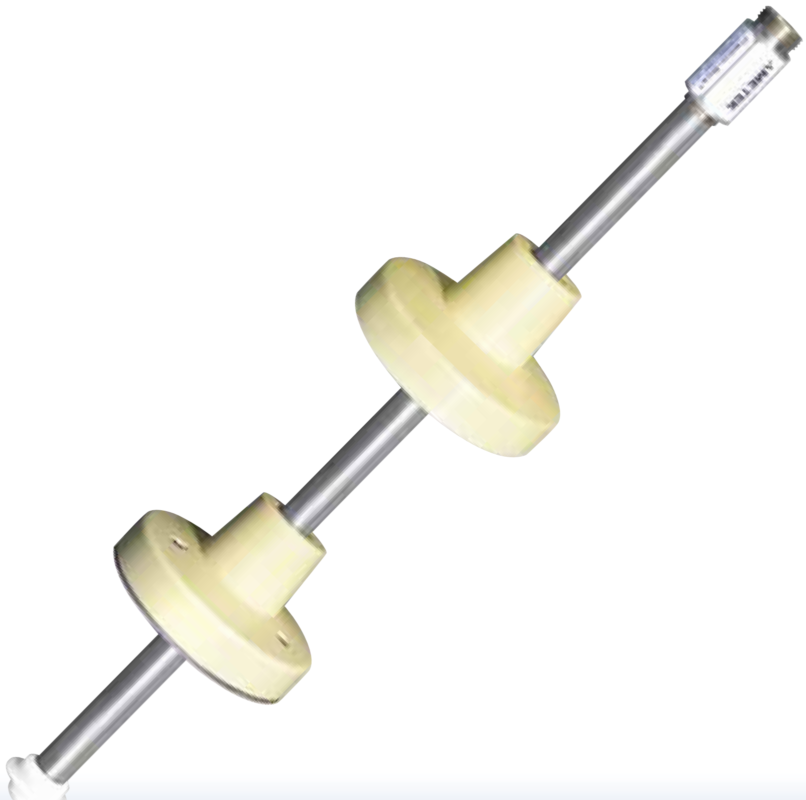
LIQUID LEVEL TECHNOLOGY

# INTERFACE MANUAL

CONTINUOUS LEVEL CONTROLS

# 7100 Leak Detect Stik

## MAGNETOSTRICTIVE LEVEL SYSTEM

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# Contents



AMETEK APT has checked the accuracy of this manual at the time it was printed. Any comments you may have for the improvement of this manual are welcomed.

# Chapter 1: Description of Probe

The 7100 liquid level probe uses a proprietary data transmission technique providing a compact information format for level and temperature data, and a signal pattern which is very easily recognizable at the console.

## 1.1: Data Protocol

Transmission consists of a sequence of similarly formatted frames of data, each frame in turn, consisting of 15 pulse pairs and a pause period. The pause period, as well as the 15 pulse pairs, each occupy 1 of 16 equal time slots of approximately 4.5 milliseconds[1].

Time slot #1 is the pause period and carries no signals. This pause is used by the console to synchronize with the signal sequence. After this pause is found, no further recognition operations are necessary; the console can simply follow the sequence described below. Each of the remaining 15 time slots carries two pulses. The time interval between the pulses in each pair is equal to a value of the parameter assigned to the corresponding time slot. (See Figure 1)

Even numbered pulse pairs #2, 4, 6, 8, 10, 12, 14, & 16 carry temperature related data.

The time interval between the pulses in time slot #3 is proportional to the water level (the lower float position).

The six remaining odd numbered pulse pairs #5, 7, 9, 11, 13, & 15 carry signals related to the product signal. Thus, information on the product level collected during one frame increases the initial resolution (determined by the frequency of the clock advancing the high speed counters in the console) by a factor of about 2.5 (square root of 6). See footnote[2].

The entire message, including time slot #1 through #16, is referred to as a Frame of data throughout this document.

**NOTE:** The first pulse pair in a frame is in time slot #2 and is hence referred to as pulse pair #2. As stated above, the eight even pulse pairs #2, 4, 6, 8, 10, 12, 14, & 16 carry temperature data. #2 through #10 correspond to the lowest to the highest temperature sensors in the probe rod, respectively. #12 corresponds to the temperature sensor in the head electronics. #14 and #16 are references. The five sensors are spaced apart equally in the probe rod. (See Chapter 5 for more information on computing the temperature).

[1] For probes over 18 feet in length, the frame duration should be doubled. This is due to the longer wire propagation time.

[2] Since the magnetostrictive wire velocity is about 9 microseconds per inch, a 110 MHz. clock would provide a single level readout resolution of 0.001”. Since the 7100 probe utilizes the patented resolution-doubling reflection method, the resolution would be 0.0005”. If a more practical 40 MHz. clock is used, the resolution is 0.001375”.

| Specifications | |
|---|---|
| Input Voltage | 16 to 31 VDC |
| Sensor Length | Stainless Steel up to 24’<br>PVDF up to 50’ |
| Enclosure Rating | Material 316 SS or PVDF, IP 68 |
| Typical Level Resolution (Controller Dependent) | 0.010” Inventory Mode<br>0.001” Leak Detection Mode |
| Linearity | +/- 0.01% of Full Scale<br>+/- 0.010”, whichever is greater |
| Repeatability | +/- 0.001% of Full Scale<br>+/- 0.00025”, whichever is greater |
| Temperature Measurement | Up to 5 along the sensor span |
| Temperature Accuracy, Absolute | +/- 2°F |
| Typical Temperature Resolution (Controller Dependent) | +/- 0.01°F |
| Temperature Sensing Range | - 4°F to +158°F or -20°C to 70°C |
| Operating Temperature Range | - 4°F to +158°F or -20°C to 70°C |
| Sensor Output | Pulse Position Modulated |
| Distance to Monitor | Over 1000’ using twisted pair wire |
| Floats (not included) | Specs based on 4” standard floats |
| Approvals | Ex II 1G EEx ia IIB T4 (7100 M/R)<br>Ex II 1G EEx ia IIA T4 (7100 K/V)<br>CE 0344 Ex II 1G<br>DEMKO 03 ATEX 0319425<br>UL 913, CSA C22.2 No. 157-92 c UL us |
| Specifications are subject to change without notice. Patented. | |

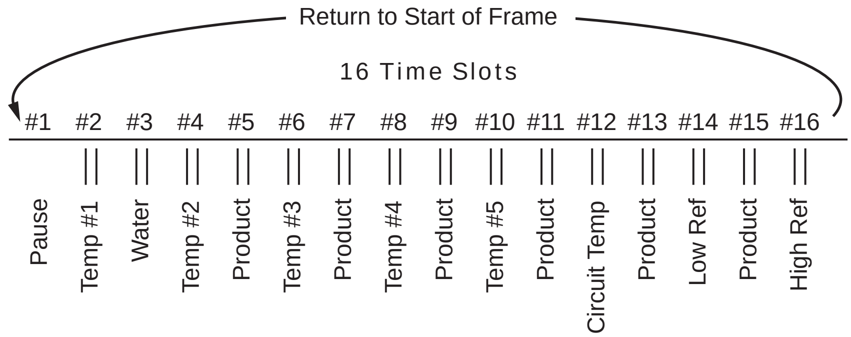



Figure 1: One frame of Data

## 1.2: Frame Protocol

All 7100 probes transmit data in the same general format. In this format, information is conveyed during a discrete period of time called a frame. The duration of a frame varies depending on the probe type. Table 1 specifies the frame periods for various probe types.

7100 series probe data consists of a series of pulses that are transmitted along the wire pair that provides power to the probe. Pulses are grouped in pairs called readings. Position and temperature information can be determined by measuring the period between the two pulses that comprise a reading.

A frame consists of a sync. period followed by 15 readings. The sync. period is a period of time during which no pulses occur. An external device that is attempting to synchronize with the probe data should start looking for the first pulse in reading 1 after detecting a period greater than sync. period during which no pulses occur. Table 1 lists the recommended sync period for various probe types.

| Table 1 - 7100 Probe parameters by probe type | | | | |
|---|---|---|---|---|
| Probe Type | Overall Length | Frame Period | Sync Period | Reference Magnet |
| Types 1, 4 | 0 M L O 18 | 72 ms | 7 ms | No |
| Types 2, 5 | 18 M L O 24 | 144 ms | 14 ms | No |
| Types 3, 6 | 24 M L | 144 ms | 14 ms | Yes |
| **NOTE**: Probe types 1, 2, and 3 are 5 thermistor probes (R5 designation in part number). Probe types 4, 5, and 6 are 1 thermistor probes (R1 designation in part number). | | | | |

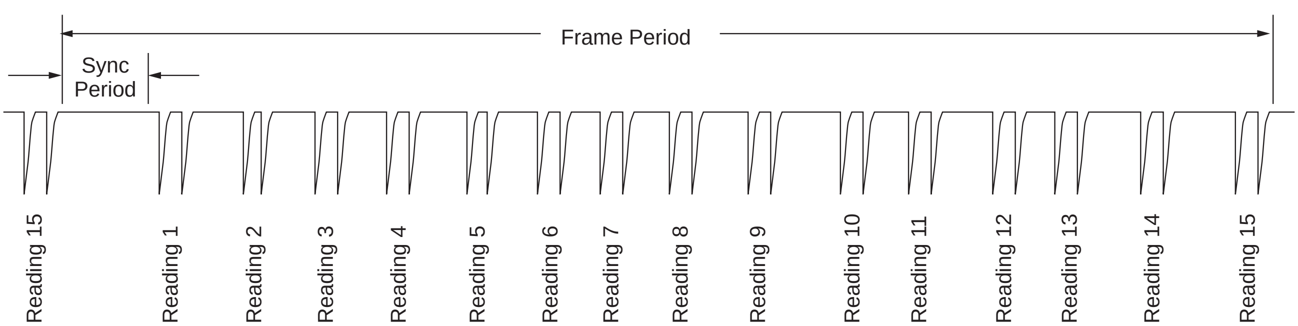



Figure 2: Data Frame Relationship Between the Data Pulses, Sync and Frame Periods

The type of information contained in each reading varies depending on the probe type. Table 2 specifies the data pattern for various probe types.

| Table 2 - Reading Data Type Specification by Probe Type | | |
|---|---|---|
| | Types 1, 2, 3 | Types 4, 5, 6 |
| **Reading 1** | Temp 1 | Temp 1 |
| **Reading 2** | Product or Water* | Product or Water* |
| **Reading 3** | Low Ref Temp | Temp 2 |
| **Reading 4** | Product | Product |
| **Reading 5** | High Ref Temp | Temp 3 |
| **Reading 6** | Product | Product |
| **Reading 7** | Low Ref Temp | Temp 4 |
| **Reading 8** | Product | Product |
| **Reading 9** | High Ref Temp | Temp 5 |
| **Reading 10** | Product | Product |
| **Reading 11** | Circuit Temp | Circuit Temp |
| **Reading 12** | Product | Product |
| **Reading 13** | Low Ref Temp | Low Ref Temp |
| **Reading 14** | Product | Product |
| **Reading 15** | High Ref Temp | High Ref Temp |
| * For single float probes, this frame contains product data. For dual float probes, this frame contains water data. | | |

When calculating Water or Product positions, one must consider whether or not the probe uses a reference magnet. For probes that use a reference magnet (type 3 and type 6), position can be calculated using the following formula:

Position = Measured Period/Wire Speed

Where:

Measured Period = the time between pulses in a reading (µs)
Wire Speed = (µs / inch)
Position = distance from internal reference

For probes that do not use a reference magnet (types 1, 2, 4, and 5), position can be calculated using the following formula:

Position = Measured Period/Wire Speed*2

# 1.3: Installation and Dimension Drawings

## 7100 Flex Stik Installation Drawing

**APPROVED DOCUMENT**
CHANGES TO THIS DOCUMENT REQUIRE AGENCY APPROVAL

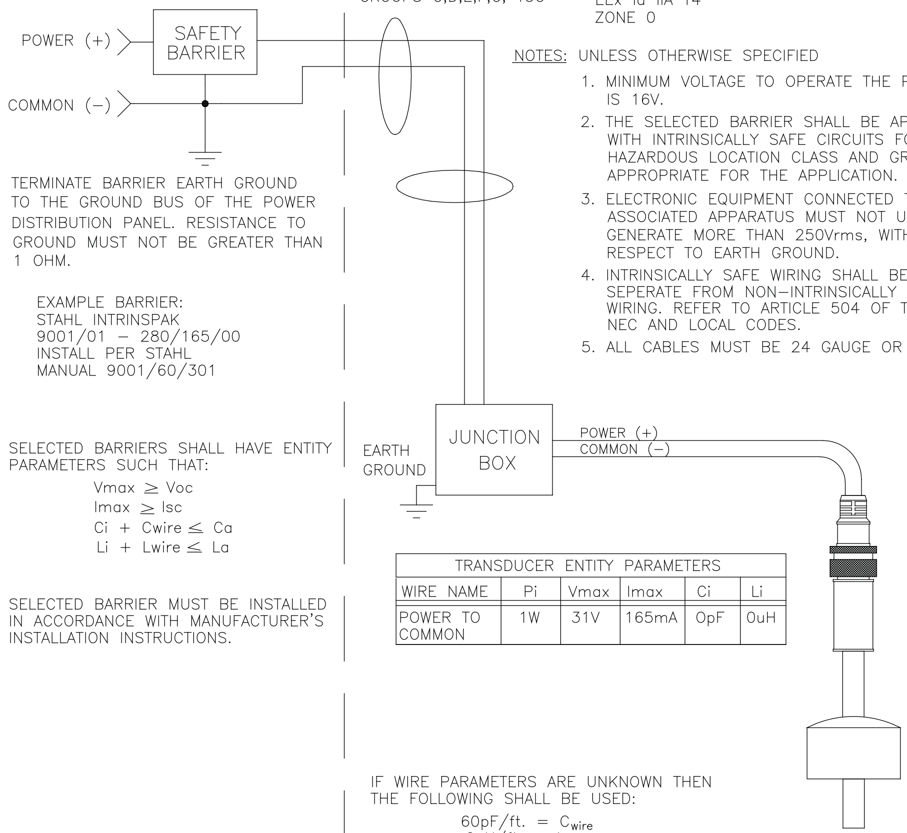
| REVISION | | | |
|---|---|---|---|
| REV. | DESCRIPTION | DATE | BY |
| E | ADDED EUROPEAN UNION CLASSIFICATION | 8/24/07 | WAK |
| | | | |
| | | | |
| | | | |

NON HAZARDOUS AREA

HAZARDOUS AREA

NORTH AMERICA
CLASS I,II,III, DIVISION 1,
GROUPS C,D,E,F,G; T3C

EUROPEAN UNION
Ex II 1 G
EEx ia IIA T4
ZONE 0




NOTES: UNLESS OTHERWISE SPECIFIED

1. MINIMUM VOLTAGE TO OPERATE THE PROBE IS 16V.
2. THE SELECTED BARRIER SHALL BE APPROVED WITH INTRINSICALLY SAFE CIRCUITS FOR THE HAZARDOUS LOCATION CLASS AND GROUP AS APPROPRIATE FOR THE APPLICATION.
3. ELECTRONIC EQUIPMENT CONNECTED TO THE ASSOCIATED APPARATUS MUST NOT USE OR GENERATE MORE THAN 250Vrms, WITH RESPECT TO EARTH GROUND.
4. INTRINSICALLY SAFE WIRING SHALL BE KEPT SEPERATE FROM NON-INTRINSICALLY SAFE WIRING. REFER TO ARTICLE 504 OF THE NEC AND LOCAL CODES.
5. ALL CABLES MUST BE 24 GAUGE OR HEAVIER.

TERMINATE BARRIER EARTH GROUND TO THE GROUND BUS OF THE POWER DISTRIBUTION PANEL. RESISTANCE TO GROUND MUST NOT BE GREATER THAN 1 OHM.

EXAMPLE BARRIER:
STAHL INTRINSPAK
9001/01 – 280/165/00
INSTALL PER STAHL
MANUAL 9001/60/301

SELECTED BARRIERS SHALL HAVE ENTITY PARAMETERS SUCH THAT:

$V_{max} \geq V_{oc}$
$I_{max} \geq I_{sc}$
$C_i + C_{wire} \leq C_a$
$L_i + L_{wire} \leq L_a$

SELECTED BARRIER MUST BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S INSTALLATION INSTRUCTIONS.

| TRANSDUCER ENTITY PARAMETERS | | | | | |
|---|---|---|---|---|---|
| WIRE NAME | Pi | Vmax | Imax | Ci | Li |
| POWER TO COMMON | 1W | 31V | 165mA | 0pF | 0uH |

IF WIRE PARAMETERS ARE UNKNOWN THEN THE FOLLOWING SHALL BE USED:

$60pF/ft. = C_{wire}$
$.2uH/ft. = L_{wire}$

FOR EXAMPLE: 1000 ft X 60 pF/ft. = 0.06uF

THIRD ANGLE PROJECTION

SURFACE FINISH 63 UNLESS OTHERWISE SPECIFIED

TOLERANCE ALLOWANCE UNLESS OTHERWISE SPECIFIED:
+/− 0.010 ON 2 PLACE DECIMALS
+/− 0.005 ON 3 PLACE DECIMALS
+/− 0.0005 ON 4 PLACE DECIMALS
+/− 30 MIN. ON ALL ANGLES



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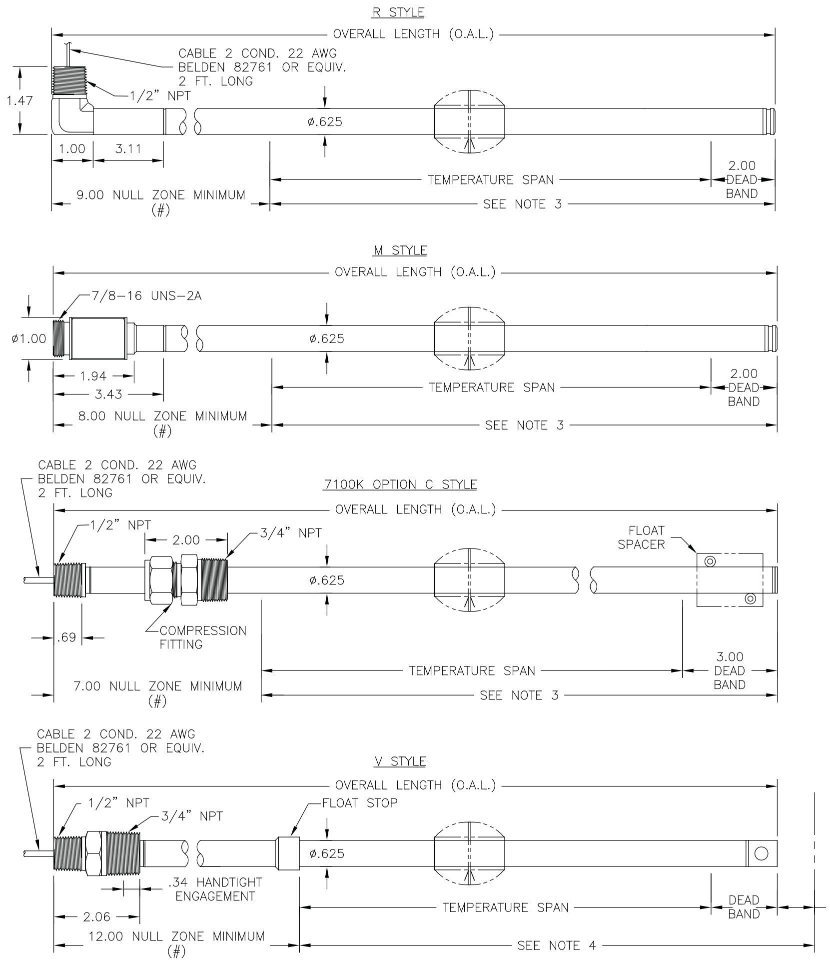
DR. X.W.
DATE 2/26/98
APP.
DATE
SCALE NONE

TITLE
INSTALLATION DRAWING
PETRO/FLEX STIK
SERIES TANK PROBES

| DRAWING NO. | REV. | SIZE |
|---|---|---|
| E0234300 | E | A |




EXPANSION CLEARANCE REQ'D AT BOTTOM OF TANK (V STYLE):
MIN. CLEARANCE = (O.A.L.) X (MAX. OPERATING TEMP(°C) − 20) X (.00014)
OVERALL LENGTH = TANK HEIGHT − CLEARANCE + 1"

| O.A.L. (in) | DEAD BAND(in) | TANK BOTTOM CLEARANCE(in) |
|---|---|---|
| 51−144 | 6.00 | 1.00 |
| 145−288 | 8.00 | 2.00 |
| 289−432 | 12.00 | 3.00 |
| 433−600 | 14.00 | 4.00 |

| REVISION | | | |
|---|---|---|---|
| REV. | DESCRIPTION | DATE | BY |
| F | UPDATED PART NUMBERING DESCRIPTION, SPAN IN 7100R & OAL FOR 7100K−C | 4/19/05 | KTP |
| G | REVISED MAX OAL OF "VB" STYLE PROBE TO 608" | 8/24/06 | KTP |
| H | ADDED "P" TO TANK MOUNTING METHOD IN PART NUMBER | 2/1/08 | MJD |
| J | ADDED NOTE FOR THERMISTOR LOCATION FOR V STYLE PROBES (ECR 1552) | 6/6/08 | KTP |

SAMPLE PART NUMBER

7100 − M − 048 − R5 − X − F2 − L058

XXX = O.A.L. (in)
AFFECTS TOP DIMENSION (#)
O.A.L. BASED ON ACTIVE SENSING SPAN. MIN. O.A.L. = SPAN+10" (M, R & K−C STYLE);
SEE DRAWING (V & VB)

F1 = ONE FLOAT
F2 = TWO FLOATS

TANK MOUNTING METHOD:
C = COMPRESSION FITTING / 0−40° TEMPERATURE
B = FIXED BOTTOM (WITH OPTION R5 & V ONLY)
P = REPLACEMENT PROBE FOR FIXED BOTTOM ONLY
X = STANDARD

R(0−5) = NUMBER OF THERMISTORS
T1 = ONE THERMISTOR (FIXED LOCATION)

048 = TEMPERATURE SPAN (in)

M = ST. STEEL TUBE W/MINI CONNECTOR, CATHODIC PROTECTIVE BOOT & FOOT (BOOT & FOOT NOT SHOWN)
R = ST. STEEL TUBE W/RIGHT ANGLE NPT CONNECTOR & 2 FT. LEADS
K = FLEXIBLE PVDF TUBE W/MALE NPT PVDF CONNECTOR, 2 FT. POTTED TEFLON CABLE, NYLON COMPRESSION FITTING, & OPERATING TEMPERATURE RANGE 0−40 °C (32−104°F) "K" STYLE PROBE AVAILABLE WITH "C" OPTION ONLY
V = FLEXIBLE PVDF TUBE W/MALE NPT PVDF CONNECTOR & 2 FT. POTTED TEFLON CABLE

STANDARD PROBE LENGTHS:

| PROBE TYPE | MAXIMUM O.A.L. (in) | MINIMUM O.A.L. (in) |
|---|---|---|
| 7100R (R5) | 288 | 36 |
| 7100R (R1) | 288 | 31 |
| 7100R (T1) | 288 | 17 |
| 7100M (R5) | 288 | 36 |
| 7100M (R1) | 288 | 31 |
| 7100M (T1) | 288 | 17 |
| 7100V (R5) | 600 | 51 |
| 7100V (R1&T1) | 600 | 44 |
| 7100K−C (R5) | 192 | 64 |
| 7100K−C(R1&T1) | 192 | 22 |

THERMISTOR SPACING

SINGLE THERMISTOR PROBES:

| PROBE TYPE | OVERALL PROBE LENGTH | THERMISTOR SPACING @ 24°C |
|---|---|---|
| 7100 M & R (R1) | ALL STD. LENGTHS | 18" |
| 7100 M & R (T1) | ALL STD. LENGTHS | 4" |
| 7100 V (R1 & T1) | L □ 144" | 27" |
| 7100 V (R1 & T1) | 145" □ L □ 288" | 30" |
| 7100 V (R1 & T1) | 289" □ L □ 432" | 35" |
| 7100 V (R1 & T1) | 433" □ L □ 600" | 38" |
| 7100 K−C (R1 & T1) | L □ 192" | 5 1/2" |

MULTIPLE THERMISTOR PROBES:

| PROBE TYPE | OVERALL PROBE LENGTH | THERMISTOR SPACING @ 24°C |
|---|---|---|
| 7100 M & R (R5) | ALL STD. LENGTHS | (TEMP. SPAN+2")/6 |
| 7100 V ** (R5) | L □ 144" | (TEMP. SPAN+7")/6 |
| 7100 V ** (R5) | 145" □ L □ 288" | (TEMP. SPAN+10")/6 |
| 7100 V ** (R5) | 289" □ L □ 432" | (TEMP. SPAN+15")/6 |
| 7100 V ** (R5) | 433" □ L □ 600" | (TEMP. SPAN+18")/6 |
| 7100 K−C (R5) | L □ 192" | (TEMP. SPAN+3")/6 |

** THERMISTORS LOCATED WITH REFERENCE TO TANK BOTTOM.

NOTES: UNLESS OTHERWISE SPECIFIED

1. OPERATING TEMPERATURE OF K−C STYLE PROBE IS 0−40°C (32−104°F)
2. ALL DIMENSIONS ARE FOR REFERENCE ONLY.
3. THERMISTORS ARE SPACED EQUALLY OVER RANGE SPECIFIED.
4. THERMISTORS ARE SPACED EQUALLY OVER TEMPERATURE SPAN + DEAD BAND + TANK BOTTOM CLEARANCE

SHEET 1 OF 2

THIRD ANGLE PROJECTION

SURFACE FINISH 63
UNLESS OTHERWISE SPECIFIED

TOLERANCE ALLOWANCE
UNLESS OTHERWISE SPECIFIED:
+/− 0.010 ON 2 PLACE DECIMALS
+/− 0.005 ON 3 PLACE DECIMALS
+/− 0.0005 ON 4 PLACE DECIMALS
+/− 30 MIN. ON ALL ANGLES



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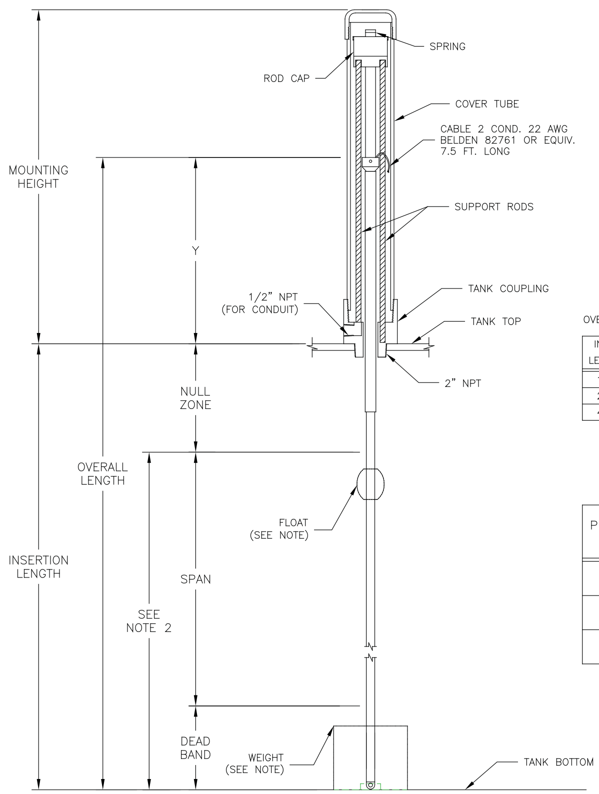
DR. K.P.
DATE 09/28/01
APP.
DATE
SCALE NONE

TITLE
DIMENSION DRAWING
7100 SERIES STIK
TANK PROBES (2 SHEETS)

DRAWING NO. D0247300
REV. J
SIZE B

# 7100 Dimension Drawing, Page 2

| REVISION | | | |
|---|---|---|---|
| REV. | DESCRIPTION | DATE | BY |
| F | UPDATED PART NUMBERING DESCRIPTION, SPAN IN 7100R & OAL FOR 7100K-C | 4/19/05 | KTP |
| G | REVISED MAX OAL OF "VB" STYLE PROBE TO 608" | 8/24/06 | KTP |
| H | ADDED "P" TO TANK MOUNTING METHOD IN PART NUMBER | 2/1/08 | MJD |
| J | ADDED NOTE FOR THERMISTOR LOCATION FOR V STYLE PROBES (ECR 1552) | 6/6/08 | KTP |




OVERALL LENGTH = INSERTION LENGTH + Y

| INSERTION LENGTH (in) | OVERALL LENGTH (in) | NULL ZONE @24°C (in) | DEAD BAND (in) | Y (in) | MOUNTING HEIGHT (in) |
|---|---|---|---|---|---|
| 192–288 | 209–305 | 10 | 3.65 | 17 | 25 |
| 289–432 | 309–452 | 12 | 6.25 | 20 | 29 |
| 433–588 | 453–608 | 15 | 6.25 | 20 | 30 |

THERMOMETER SPACING:

| PROBE TYPE | OVERALL PROBE LENGTH | THERMISTOR SPACING @ 24°C (FROM TANK BOTTOM) |
|---|---|---|
| 7100 VB (R5) | 209" □ L □ 305" | (SPAN+3.65")/6 |
| 7100 VB (R5) | 309" □ L □ 452" | (SPAN+6.25")/6 |
| 7100 VB (R5) | 453" □ L □ 608" | (SPAN+6.25")/6 |

NOTES: 1. FLOAT AND WEIGHT TYPE & GEOMETRY ARE DEPENDANT ON APPLICATION.
2. TEMPERATURE SENSORS ARE SPACED EQUALLY OVER RANGE SPECIFIED.

SHEET 2 OF 2

THIRD ANGLE PROJECTION

SURFACE FINISH 63
UNLESS OTHERWISE SPECIFIED

TOLERANCE ALLOWANCE
UNLESS OTHERWISE SPECIFIED:
+/- 0.010 ON 2 PLACE DECIMALS
+/- 0.005 ON 3 PLACE DECIMALS
+/- 0.0005 ON 4 PLACE DECIMALS
+/- 30 MIN. ON ALL ANGLES



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DATE
SCALE NONE

TITLE
DIMENSION DRAWING
7100 SERIES STIK
TANK PROBES (2 SHEETS)

DRAWING NO. D0247300 | REV. J | SIZE B

# Chapter 2: Interfacing to Probe

The pulse signals coming from the probe are superimposed onto the nominal 24 VDC power supply connections. As shown in Figure 3, the pulses are negative-going and are large in amplitude, nominally 20 volts peak. The peak is negative going and only a few microseconds in duration. The leading edge is the proper edge to use for timing purposes. The large signal amplitude offers high noise immunity.

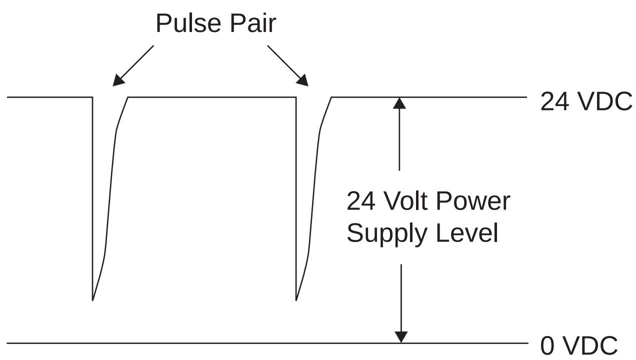


Figure 3: Pulse Signals

A simple approach to getting 5 volt logic levels from the input signal is to simply set a comparator level as shown in Figure 6. The comparator output can then be used to create a gate signal for a counter circuit. The circuit example in Section 2.1 (page10) has a variation of this concept using a 5:1 pulse transformer to eliminate the reference to 24 VDC and make the comparison relative to circuit common (with inverted polarity).

Probe power supply impedance will have an effect on pulse amplitude. Wire lengths will vary the pulse amplitude. Wire has an associated inductance, resistance and capacitance which will change the amplitude of the coupled pulse. Users may wish to load their circuit to minimize wire effects.

The chart below gives relative times by which a user can distinguish timing for various probe lengths.

| Length | Float Position | Tstart | Tstop | ∆t=Position |
|---|---|---|---|---|
| **12"** | 1" | 160µsec | 180µsec | 20µsec |
| **12"** | 12" | 50µsec | 290µsec | 240µsec |
| **30"** | 1" | 340µsec | 360µsec | 20µsec |
| **30"** | 30" | 50µsec | 650µsec | 600µsec |
| **100"** | 1" | 1040µsec | 1060µsec | 20µsec |
| **100"** | 100" | 50µsec | 2050µsec | 2000µsec |
| **200"** | 1" | 2040µsec | 2060µsec | 20µsec |
| **200"** | 200" | 50µsec | 4050µsec | 4000µsec |

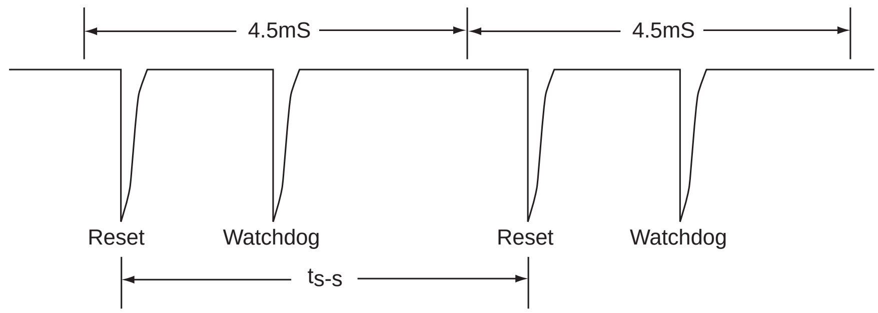


Figure 4: Start Pulse

**NOTE 1:** $t_{S-S}$ = time from 1st start pulse in one frame to next start pulse in the next frame.

**NOTE 2:** Start pulse can start anywhere in the 4.5 ms frame. The stop pulse will follow at the correct time. The $t_{S-S}$ is <u>not</u> consistent. The user does not have the 4.5 ms frame as a reference. The user must use the watchdog timeout during the pause frame to “sync up”. The watchdog timer should be reset on both the start and stop pulse.

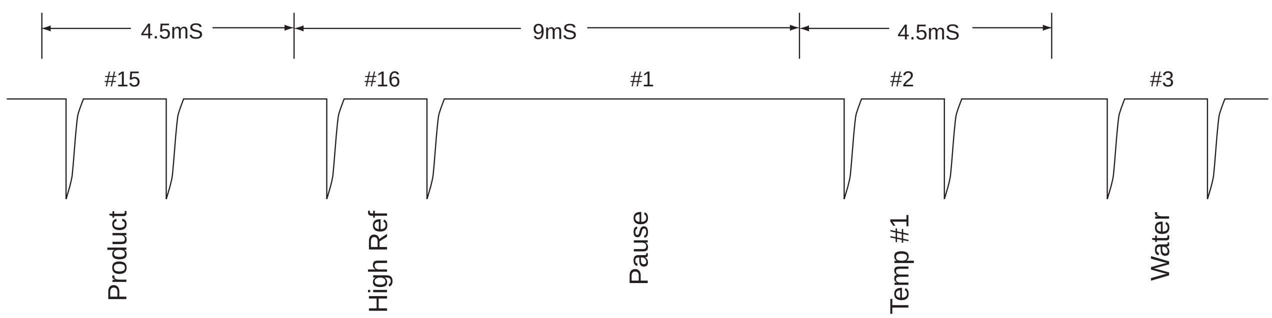


Figure 5: Pause Period Timing

**NOTE:** Although the timebase is generated with a crystal oscillator, the times shown are NOT exact times. Also, the initial pulse within a window of the frame does not start at the beginning of the window. See Section 3.1: Synchronizing with a Watchdog Timer and footnote 3 for more information.

## 2.1: Interface Hardware

A typical console has the following sub-systems:

1. Probe Mulitplexer
2. Intrinsic Safety Barrier
3. Pulse Discriminator
4. Gate Circuit
5. High Speed Counter

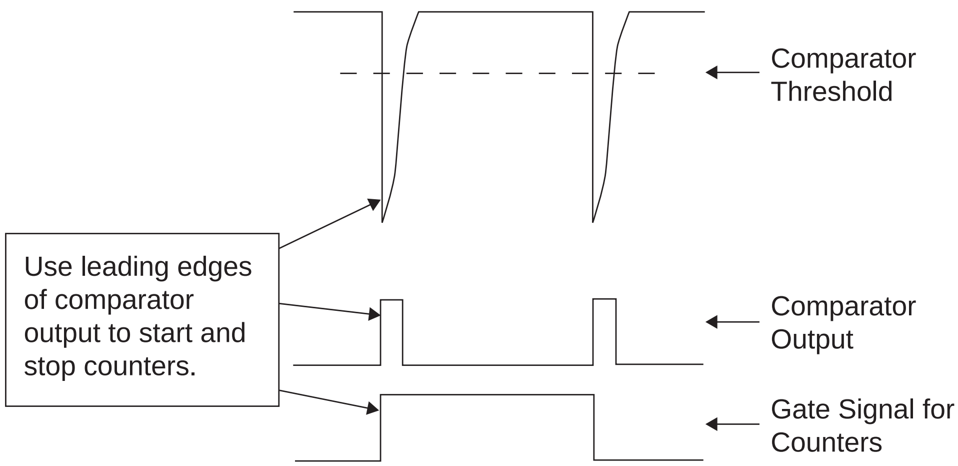


Figure 6: Start and Stop Counters

Figure 7 shows typical means of achieving each of these sub-systems. The multiplexing is achieved with the use of a PNP-style bipolar driver IC. where only one output is turned on at a given time. The output that is turned on serves two functions; it couples power to the corresponding probe, and it conducts the probes output pulses back to the pulse discriminator.

The intrinsic safety barrier is achieved where the dotted line is shown.

The pulse discriminator is comprised of a 5:1 pulse transformer that is capacitively coupled to the intrinsically safe power supply (where the probe pulses are found) and used to invert the pulses, amplify them, and remove the 24 VDC. offset. Finally, a comparator is used to generate the final output used to drive the gate circuit. The comparison is done with a nominal threshold voltage of approximately 1 VDC.

The gate and counter circuits are shown only in block diagram form. The clock feeding the counters should be selected to yield the resolution required (see footnote 2, page 2). The gate circuit should enable the counters upon the first pulse in a pulse pair and disable the counters on the second after which the counter values are taken. The gate signal is also used to alert the resident computer that it is time to take the data.

For clock frequencies above 35Mhz., it is recommended that all analog comparators and digital gating circuit components be relatively high speed. (If FAST or ACT logic is used for the counters, then also use it for the gating circuits.)

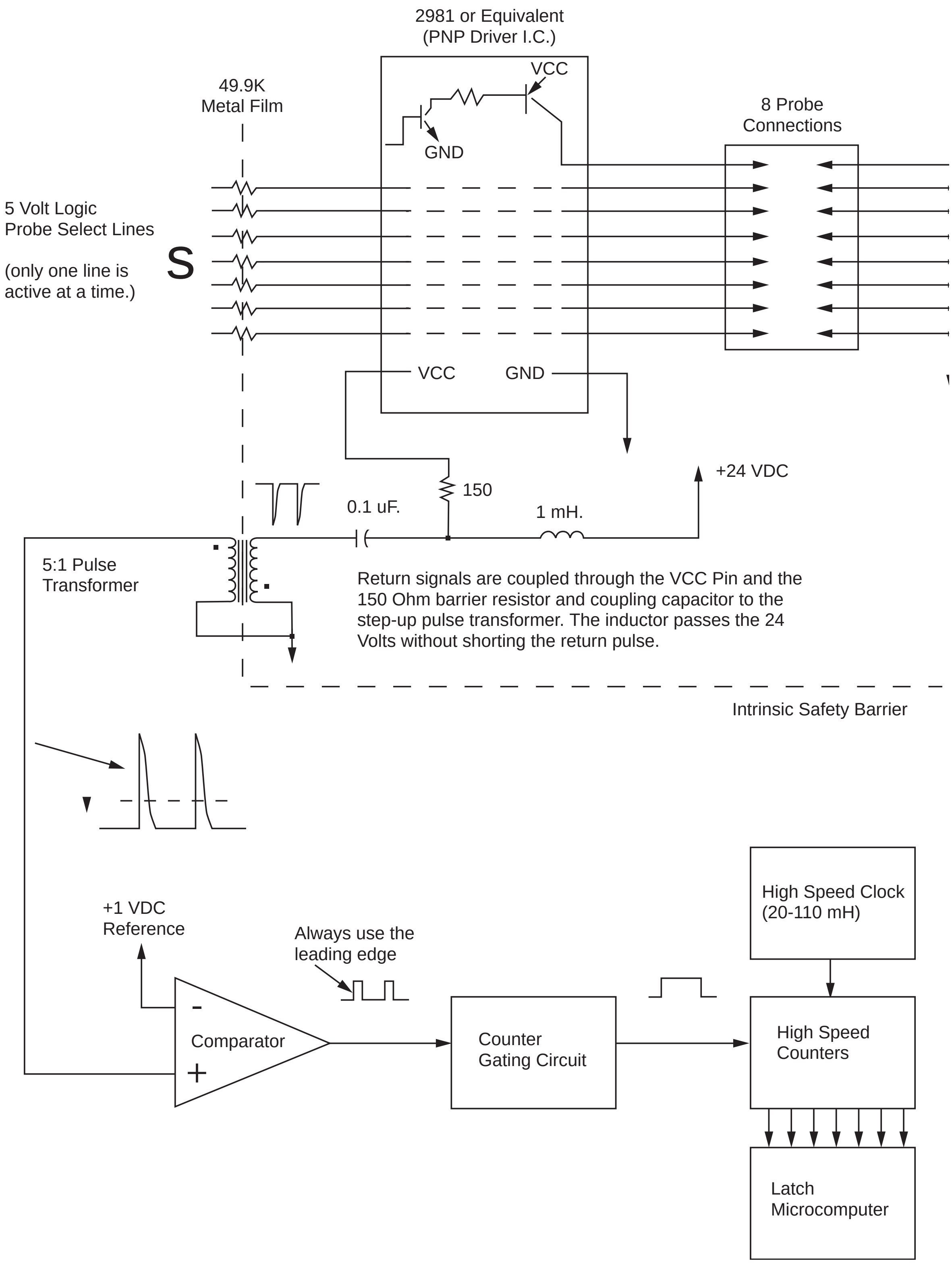


Figure 7: Typical Console Circuitry

# Chapter 3: Getting the Data

The method that data is communicated between the probe and the console is described in Section 1.1: Data Protocol. The user should understand the data protocol scheme before attempting to process the data.

## 3.1: Synchronizing with a Watchdog Timer

Referring to Figures 1 and 5, note that there is only one pause period per frame and therefore, only one time during the sequence when no pulses will be received for approximately 9 milliseconds. A hardware or software watchdog timer may be implemented to time-out after 7 milliseconds (for probes > 18', this time should be 14 milliseconds) which will occur only during frame #1, the pause frame. The next 15 pulse pairs may then be recorded in the sequence shown in Figure 1.

**NOTE:** The times depicted in Figure 5 are not exact times[3]. A watchdog timer setting of 7 milliseconds should generally be used.

## 3.2: System Hardware Setup

Before discussing signal processing, a brief review of the console hardware is in order. Refer to Section 2 as required.

Based on a 16 foot maximum probe length, the number of bits required for the probe counter circuit is the duration of the low reference temperature pulse pair. With a 3 ms low reference pulse duration and a 100 MHz clock frequency, the number of bits can be calculated. Dividing the low reference pulse pair duration by the period of the clock yields 300,000 counts. Converting this number to hexadecimal will show the number of required bits. In this case, 19.

[3] Although the time between adjacent frames is generated with an internal crystal oscillator, the actual pulse pair for a temperature frame is delayed a few hundred microseconds nominally. This is independent of any temperature data. The product and water float pulse pairs may be delayed as much as 2 milliseconds. This delay is affected by the corresponding float position. The longest delay is experienced with a long probe with the float near the bottom.

## 3.3: System Software Setup

Although one frame of data is sufficient to obtain valid product, water, and temperature readings, averaging multiple frames is generally much more appropriate. This is because all elements in the system are subject to slight uncertainties and/or the effects of electrical noise or mechanical vibration. This includes the magnetostrictive wire in the probe, the probe electronics, the transmission wire between the probe and the console, and the console electronics.

The number of frames of data required for a good probe reading is application dependent. Since the number of frames of data taken is directly proportional to the console update time, the user should review the system criterion before implementing a design. For the sake of discussion, 16 frames of data will be taken. The following table shows the particulars of a console taking in 16 frames of data.

| Parameter | Result | Notes |
|---|---|---|
| Frames Read | 16 | 16 Frames as defined |
| Pulse Pairs Read | 240 | 16 Frames x 15 Pulse Pairs/Frame |
| Product Pulse Pairs | 96 | 16 Frames x 6 Pulse Pairs/Frame |
| Water Pulse Pairs | 16 | 16 Frames x 1 Pulse Pairs/Frame |
| Temp. Pulse Pairs | 128 | 16 Frames x 8 Pulse Pairs/Frame |
| Pause Pulse Pairs | 0 | NO PULSE DURING PAUSE |
| Console Update Time | 1.17 Seconds | See Below |
| Required Memory | 720 Bytes | See Below |

The update time is calculated as:

$$t_{\text{update}} = 16 \text{ Frames x } \left\{ \frac{\text{16 Time Slots}}{\text{1 Frame}} \right\} \text{x} \left\{ \frac{\text{4.57 Milliseconds}}{\text{1 Time Slot}} \right\} = \text{1170 Ms.}$$

**NOTE:** This update time does not include the time required to become synchronized. Up to one additional frame is necessary to synchronize making the total 1.24 seconds.

The required memory is calculated as:

$$\text{Memory Bytes} = 16 \text{ Frames x } \left\{ \frac{\text{15 Pulse Pairs}}{\text{1 Frame}} \right\} \text{x} \left\{ \frac{\text{3 Bytes}}{\text{1 Pulse Pair}} \right\} = \text{720 Bytes}$$

The user will want to configure the system based on individual requirements for update time and memory space. Readings are more precise when more frames are read but more time and memory are required.

# Chapter 4: Processing the Data

Data acquisition was discussed in Section 3 to the degree that memory locations are filled with an array of data from a selected number of frames. It is now appropriate to test for data integrity, average and/or filter the data, and then convert from binary counter values to scaled, meaningful numbers.

## 4.1: Front End Algorithm

A technique for eliminating any possible erroneous data is to discard some of the highest and lowest count values. Lets assume that there is some uncontrolled source of harsh electrical noise causing erroneous data to be received once approximately every 100 to 1000 frames. The table below shows appropriate numbers of High and Low discard values to ensure that no erroneous data is used.

| Parameter | Highs Discarded | Lows Discarded | Probe Reading is the Average of |
|---|---|---|---|
| Product | 12 | 12 | 72 of 96 |
| Water | 2 | 2 | 12 of 16 |
| Temp #1 | 2 | 2 | 12 of 16 |
| Temp #2 | 2 | 2 | 12 of 16 |
| Temp #3 | 2 | 2 | 12 of 16 |
| Temp #4 | 2 | 2 | 12 of 16 |
| Temp #5 | 2 | 2 | 12 of 16 |
| Circuit Temp | 2 | 2 | 12 of 16 |
| LO Reference Temp. | 2 | 2 | 12 of 16 |
| HI Reference Temp. | 2 | 2 | 12 of 16 |

After discarding the Highs and Lows, the remaining data is averaged and the results are referred to as one Probe Reading. These discard numbers are only guidelines. They may be changed to accommodate more or less frequently encountered noise problems, depending upon the installation environment.

One probe reading contains ten values, one for product level, one for water level, and eight for temperature.

# Chapter 5: Computing the Temperature

A probe reading contains 15 values for product, water and temperature. The product and water values are each useful by themselves (a single product or water value may be converted with linear math to represent the float position).

Unlike the product and water values, the temperature values are always accompanied by two reference values. A single temperature sensor value is of no use without its associated reference temperature values. The use of reference values eliminates the effects of circuit drift and produces exceptionally good repeatability.

The 7100 Liquid Level Probe uses thermistors as the temperature sensing elements. All thermistors exhibit known, well defined non-linearity. In our application, the non-linearity of the temperature data is in the range of a few percent. (See Section 5.1: Improving Measurement Accuracy)

As shown in Section 5.1: Improving Measurement Accuracy, the first step in computing the temperature of a given sensor is to use a linear equation to interpolate between the reference temperatures. The above mentioned non-linearity will then be present in the result.

## 5.1: Improving Measurement Accuracy

The temperature measurement circuitry of the 7100 probe generates temperature pulse pairs with the time interval directly proportional to the resistance of a parallel connected thermistor (or reference temperature resistor) and a fixed 37.4 K resistor. The 37.4 K parallel resistor serves to keep the time range of the temperature pulses within reasonable limits over the probe's temperature range.

Variations in parameters of thermistors, time defining capacitors, and other parts of the probe introduce additional error to the temperature measurement. To reduce this error the 7100 probe transmits signals for two reference temperatures: +5 °C (low reference), and +50 °C (high reference). The following sequence of calculations compensates for errors using the reference signals, and takes into account the thermistor plus 37.4 K resistor non-linearity.

**Step 1** - Get reliable time counts for each temperature read, including the temperature references.

Example:

1) Take 16 reads of a temperature.
2) Discard 2 highest and 2 lowest readings.
3) Take average value of the 12 remaining readings.

**Step 2** - Calculate linear approximation of temperature ($T_{LIN}$) using the following formula:

$$T_{LIN} = [(R - L) * (H_{REF} - L_{REF}) / (H - L)] + L_{REF}$$

Where:

R = counts for thermistor,
L = counts for low reference,
H = counts for high reference,
$L_{REF}$ = low reference = 5 °C,
$H_{REF}$ = high reference = 50 °C.

$T_{LIN}$ is a normalized value for temperature that compensates for errors caused by variations of the probe parts' parameters. This is not actual temperature yet. It does not take into account non-linearity of the thermistor-parallel resistor combination.

**Step 3** - Using the attached table, find the linear temperature interval ($T_{LIN1}$, $T_{LIN2}$) and then the actual temperature interval ($T_1$, $T_2$) for $T_{LIN}$.

Example.

$T_{LIN}$ = 15.763 °C,
$T_{LIN1}$ = 15.178 °C,
$T_{LIN2}$ = 16.321 °C,
$T_1$ = 14 °C,
$T_2$ = 15 °C.

**Step 4** - Calculate accurate table interpolated temperature T, using linear interpolation within intervals ($T_{LIN1}$, $T_{LIN2}$) and ($T_1$, $T_2$).

$$T = ((T_{LIN2} - T_{LIN1}) * T_2 - (T_{LIN2} - T_{LIN}) * (T_2 - T_1)) / (T_{LIN2} - T_{LIN1})$$

Example:

$T_{LIN}$ = 15.763 °C,
$T_{LIN1}$ = 15.178 °C,
$T_{LIN2}$ = 16.321 °C,
$T_1$ = 14 °C,
$T_2$ = 15 °C,
T = 14.512 °C

| Temperature Calculation Table | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Actual Temp °C** | **Linear Temp °C** | **Actual Temp °C** | **Linear Temp °C** | **Actual Temp °C** | **Linear Temp °C** | **Actual Temp °C** | **Linear Temp °C** | **Actual Temp °C** | **Linear Temp °C** |
| **-40** | -25.141 | **0** | -0.325 | **40** | 42.332 | **80** | 63.706 | **120** | 70.136 |
| **-39** | -24.884 | **1** | 0.709 | **41** | 43.185 | **81** | 63.984 | **121** | 70.215 |
| **-38** | -24.613 | **2** | 1.759 | **42** | 44.016 | **82** | 64.250 | **122** | 70.296 |
| **-37** | -24.327 | **3** | 2.828 | **43** | 44.824 | **83** | 64.511 | **123** | 70.370 |
| **-36** | -24.030 | **4** | 3.904 | **44** | 45.618 | **84** | 64.766 | **124** | 70.444 |
| **-35** | -23.714 | **5** | 5.000 | **45** | 46.386 | **85** | 65.009 | **125** | 70.524 |
| **-34** | -23.386 | **6** | 6.102 | **46** | 47.155 | **86** | 65.246 | **126** | 70.586 |
| **-33** | -23.038 | **7** | 7.214 | **47** | 47.893 | **87** | 65.477 | **127** | 70.653 |
| **-32** | -22.678 | **8** | 8.331 | **48** | 48.618 | **88** | 65.696 | **128** | 70.719 |
| **-31** | -22.297 | **9** | 9.461 | **49** | 49.317 | **89** | 65.913 | **129** | 70.782 |
| **-30** | -21.900 | **10** | 10.598 | **50** | 50.000 | **90** | 66.121 | **130** | 70.844 |
| **-29** | -21.488 | **11** | 11.738 | **51** | 50.665 | **91** | 66.323 | **131** | 70.905 |
| **-28** | -21.055 | **12** | 12.875 | **52** | 51.320 | **92** | 66.519 | **132** | 70.963 |
| **-27** | -20.601 | **13** | 14.032 | **53** | 51.955 | **93** | 66.711 | **133** | 71.020 |
| **-26** | -20.133 | **14** | 15.178 | **54** | 52.575 | **94** | 66.894 | **134** | 71.075 |
| **-25** | -19.641 | **15** | 16.321 | **55** | 53.177 | **95** | 67.072 | **135** | 71.128 |
| **-24** | -19.126 | **16** | 17.472 | **56** | 53.761 | **96** | 67.245 | **136** | 71.180 |
| **-23** | -18.598 | **17** | 18.629 | **57** | 54.331 | **97** | 67.413 | **137** | 71.231 |
| **-22** | -18.042 | **18** | 19.770 | **58** | 54.882 | **98** | 67.576 | **138** | 71.281 |
| **-21** | -17.466 | **19** | 20.907 | **59** | 55.423 | **99** | 67.734 | **139** | 71.328 |
| **-20** | -16.871 | **20** | 21.974 | **60** | 55.942 | **100** | 67.886 | **140** | 71.375 |
| **-19** | -16.249 | **21** | 23.173 | **61** | 56.451 | **101** | 68.034 | **141** | 71.420 |
| **-18** | -15.611 | **22** | 24.295 | **62** | 56.943 | **102** | 68.180 | **142** | 71.464 |
| **-17** | -14.945 | **23** | 25.419 | **63** | 57.423 | **103** | 68.319 | **143** | 71.507 |
| **-16** | -14.258 | **24** | 26.518 | **64** | 57.890 | **104** | 68.453 | **144** | 71.548 |
| **-15** | -13.554 | **25** | 27.611 | **65** | 58.344 | **105** | 68.583 | **145** | 71.589 |
| **-14** | -12.823 | **26** | 28.695 | **66** | 58.779 | **106** | 68.710 | **146** | 71.629 |
| **-13** | -12.068 | **27** | 29.767 | **67** | 59.205 | **107** | 68.833 | **147** | 71.667 |
| **-12** | -11.291 | **28** | 30.822 | **68** | 59.618 | **108** | 68.954 | **148** | 71.703 |
| **-11** | -10.497 | **29** | 31.866 | **69** | 60.022 | **109** | 69.070 | **149** | 71.740 |
| **-10** | -9.671 | **30** | 32.899 | **70** | 60.410 | **110** | 69.181 | **150** | 71.775 |
| **-9** | -8.832 | **31** | 33.914 | **71** | 60.783 | **111** | 69.290 | | |
| **-8** | -7.968 | **32** | 34.920 | **72** | 61.153 | **112** | 69.396 | | |
| **-7** | -7.078 | **33** | 35.903 | **73** | 61.506 | **113** | 69.498 | | |
| **-6** | -6.178 | **34** | 36.868 | **74** | 61.849 | **114** | 69.597 | | |
| **-5** | -5.252 | **35** | 37.830 | **75** | 62.182 | **115** | 69.694 | | |
| **-4** | -4.297 | **36** | 38.759 | **76** | 62.510 | **116** | 69.789 | | |
| **-3** | -3.332 | **37** | 39.677 | **77** | 62.821 | **117** | 69.879 | | |
| **-2** | -2.347 | **38** | 40.582 | **78** | 63.127 | **118** | 69.968 | | |
| **-1** | -1.345 | **39** | 41.472 | **79** | 63.422 | **119** | 70.053 | | |

**NOTE:** Consult the factory if calculations within a larger temperature range is required.

# EC Declaration of Conformity

**Manufacturer:** AMETEK Automation & Process Technologies
1080 North Crooks Road, Clawson, MI 48017 USA

**Identification of Equipment:**
7100 Stik Series Liquid Level Transducer

**Description of Device:**
The device is a permanently mounted liquid level probe. It determines the level of a liquid based on signal reflections, caused by magnetic floats, in a wire running the length of the probe. These signals are amplified and processed, then relayed via a signal imposed on the input wires to the probe. The probe body and tube may be constructed of stainless steel or of a flexible PVDF polymer. These devices also take liquid level temperature measurements using thermistors located in the probe tube.

**EC type certificate:** DEMKO 03ATEX0319425

**Conformity Specifications:**

Council Directives:

| |
|---|
| Directive 94/9/EC, ATEX |
| Directive 89/336/EEC, EMC |

Other Standards:

| | |
|---|---|
| EN50014:1997 | Electrical apparatus for potentially explosive atmospheres - General requirements |

Harmonized Standards:

| | |
|---|---|
| EN50020:2002 | Electrical apparatus for potentially explosive atmospheres - Intrinsic Safety 'i' |
| EN50284:1999 | Special requirements for construction, test and marking of electrical apparatus of equipment group II, Category 1 G |
| EN55011:1998 | Limits and methods of measurement of radio characteristics of industrial, scientific and medical (ISM) Radio Frequency equipment, Class B, Group 1 |
| EN50082-1:1992 | Electromagnetic compatibility Generic immunity standard Part 1. Residential, commercial and light industry |
| IEC 801-2:1984 | ESD Susceptibility |
| IEC 801-3:1984 | Radiated Susceptibility, Electromagnetic Field |
| IEC 801-4:1988 | Conducted Susceptibility, Burst Interference Transients |
| EN61010-1:1993 | Safety Requirements for Electrical Equipment for Measurement, Control, and laboratory Use |

**Signed:** ______________________

**Name:** Jack Pattee **Dated:** 6/18/2008
**Position:** Director of Engineering **Company:** AMETEK Automation & Process Technologies

| Other Products | | |
|---|---|---|
| GEMCO INDUSTRIAL BRAKES | GEMCO LINEAR DISPLACEMENT TRANSDUCERS<br>PLC INTERFACE PRODUCTS<br>ROTARY POSITION PRODUCTS<br>PROGRAMMABLE LIMIT SWITCHES<br>EXTREME DUTY CABLE REEL PRODUCTS<br>ROTARY LIMIT SWITCHES<br>RESOLVERS<br>MILL DUTY ENCLOSURES<br>ULTRA HIGH SPEED PLS<br>SAFETY PRODUCTS | CATRAC® HEAVY DUTY CABLE AND HOSE CARRIERS |



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