Technical Bulletin

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Title: Design Study on Dual Traffic-Loop type Vehicle Detector for AEI Applications

Summary

Southern Technologies Corporation (STC) conducted a design study with the Reno S-1300-R-24D Dual Channel Vehicle Detector, which is referred to in this document as "Vehicle Detector." The Vehicle Detector utilizes two sensing-loops positioned under the track to detect train presence. We directed our work to determine a locomotive's relative position while moving over the sensing-loop at the instant the Vehicle Detector indicates train presence.

Equipment such as the STC 2600-020 AEI System requires a short period to activate in preparation for scanning a train. So, a thorough understanding of the Vehicle Detector's activation characteristics and the STC 2600-020 AEI system start-up timing is necessary for correct sensing-loop placement in applications for rail traffic at given speeds.

☐ **Critical (Affects safe operation of the system)** ☑ **Informational**
Distribution List:

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Testing Hardware Configuration

Figure 1 illustrates the hardware configuration constructed at our test site, which is composed of a 7’ x 20’, four turns, sensing-loop, and two STC wheel sensing transducers. The wheel sensing transducers are positioned to indicate a wheel passing over the ends of the sensing-loop. All signals were recorded using a chart recorder.

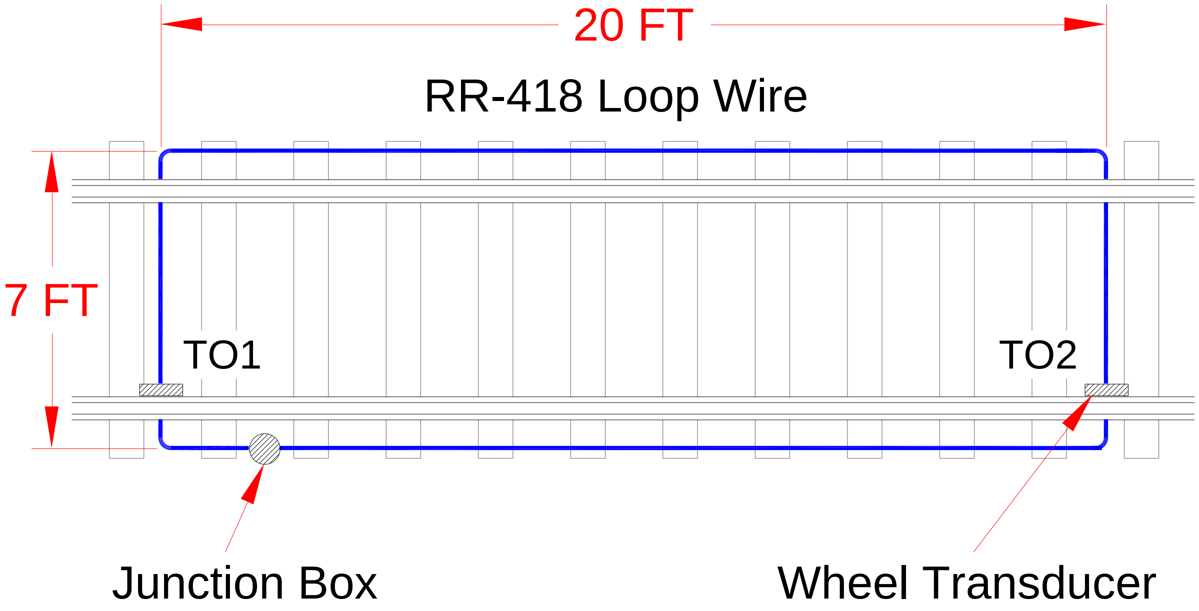

Figure 1 - Sensing-loop and two 2100-591 single element transducers as installed at our test site.

The timing between the following two events is of particular interest regardless of the order in which they occur.

- The first wheel of the lead locomotive crosses the leading end of the sensing-loop
- Vehicle Detector indicates train presence

Converting the recorded elapsed time between these two signals into a distance measurement reveals the locomotive’s relative position to the sensing-loop when the Vehicle Detector senses train presence.

We use this information to determine the placement of the sensing-loop, given the maximum expected train speed. A correctly dimensioned sensing-loop provides enough startup time for a system such as the 2600-020 AEI Reader to power-up and read the RFID tags on the lead locomotive while traveling at maximum speed for a given site.

Recording Data

We recorded signals from our test hardware representing 17 trains. Figure 2 shows a chart recording as a lead locomotive enters the testing area. The top trace of the chart shows the output signals from wheel sensing transducer TO1; the middle trace is the wheel sensing transducer TO2, and the bottom trace represents the output from the Vehicle Detector. Note that the high to low signal transition is where the Vehicle-Detector indicates train presence.

Before we can convert the signal timing into the physical distance, we have to calculate the train speed. The following equation calculates speed by plugging in the known distance between the two wheel sensing transducers and the elapsed time between the transducers signals.

$$\left(\frac{\boldsymbol{feet}}{\mathbf{5,280}}\right)\Big/\left(\frac{\boldsymbol{milliseconds}}{\mathbf{3,600,000}}\right) = \boldsymbol{MPH}$$

Where: ***feet*** is a constant of 20 that represents the distance measured from center-to-center of the wheel sensing transducers*.*

The ***milliseconds*** variable represents elapsed time for a wheel to travel from one wheel sensing transducer to the other.

The constants ***5,280*** and ***3,600,000*** represent the number of feet in one mile and the number of milliseconds in one hour, respectively.

Figure 2 indicates a timing measurement of 300 milliseconds (mS) for the locomotive's first wheel to travel from one wheel transducer to the other. Plugging 20 feet and 300 mS into the equation reveals a train speed of 45.45 miles per hour.

$$\left(\frac{\mathbf{20}}{\mathbf{5,280}}\right)\Big/\left(\frac{\mathbf{300}}{\mathbf{3,600,000}}\right) = \mathbf{45.45}\ \boldsymbol{MPH}$$

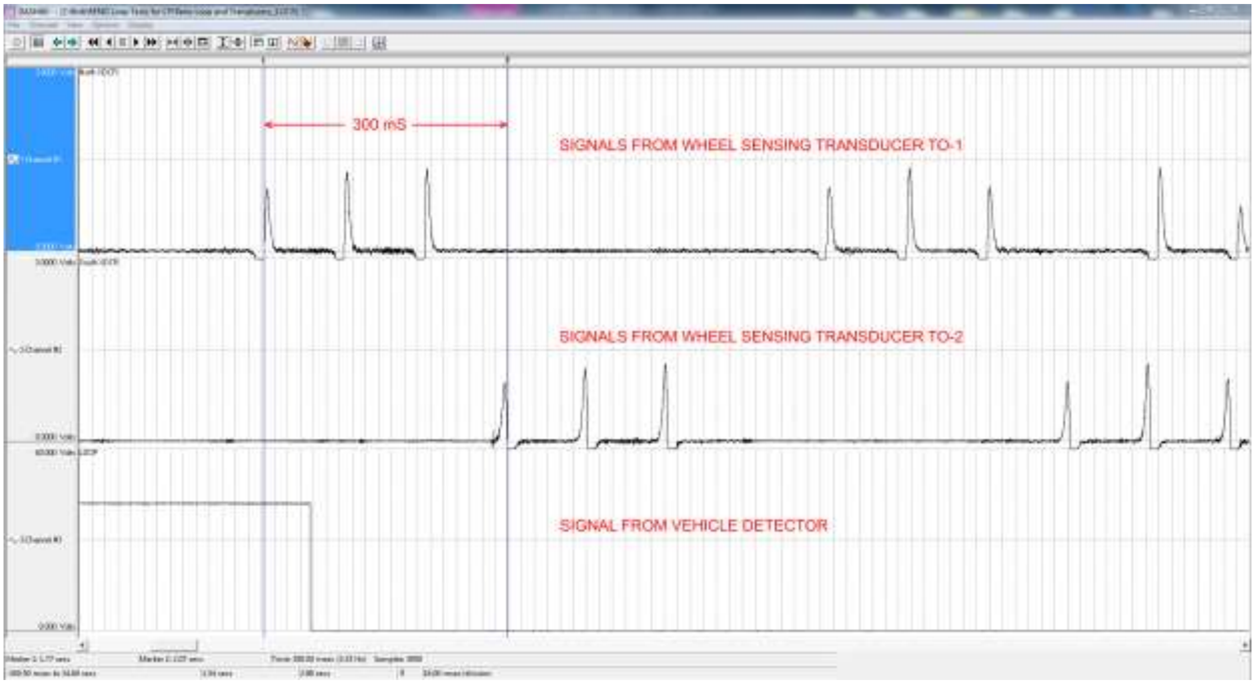

Figure 2 – Chart recorder representation showing the time measurement of the first locomotive wheel to move between the TO-1 to the TO-2 wheel sensing transducer.

Locomotive's Location Relative to the Sensing-Loop

Now that we know the train speed, we can determine how far the locomotive moves in a given period. For our purposes, we need to calculate the distance the locomotive travels from the point the first wheel crosses the leading end of the sensing-loop to when the Vehicle Detector signals train presence. We do this by measuring the time between the points referenced in Figure 3 and plugging that time into an equation.

The top trace of the chart in Figure 3 shows that the first event recorded was the TO1 wheel sensor pulse. This pulse represents the instant in time the first wheel of the locomotive crossed the first end of the sensing-loop. The bottom trace recorded the second event, which is the Vehicle Detector signaling train presence. We calculate the distance that the wheel moved beyond the end of the sensing-loop to the instant the Vehicle Detector activated using the following equation:

$$\left(\frac{\boldsymbol{MPH} \times \mathbf{5,280} \times \mathbf{12}}{\mathbf{3,600,000}}\right) \times \boldsymbol{mS} = \boldsymbol{Inches}$$

Explanation: The equation above first converts ***MPH*** *to inches per hour and divides that quantity by 3,600,000 to get inches per millisecond. Then it multiplies inches per millisecond by the* ***mS*** *variable to reveal the number of inches traveled for a given elapsed time measured in milliseconds.*

Where:

Variable ***MPH****:* Train speed

Variable ***mS****:* Time in milliseconds between the two points indicated on the chart in Figure 3

Constant ***5,280****:* Number of feet in one mile

Constant ***12****:* Number of inches in one foot

Constant ***3,600,000***: Number of milliseconds in one hour

By plugging in 45.45 MPH and 56.80 mS into this equation, we determine that the first wheel was 45.43 inches past the leading end of the sensing-loop at the instant the Vehicle Detector signaled train presence.

$$\left(\frac{\mathbf{45.45} \times \mathbf{5,280} \times \mathbf{12}}{\mathbf{3,600,000}}\right) \times \mathbf{56.80} = \mathbf{45.43}\ \boldsymbol{Inches}$$

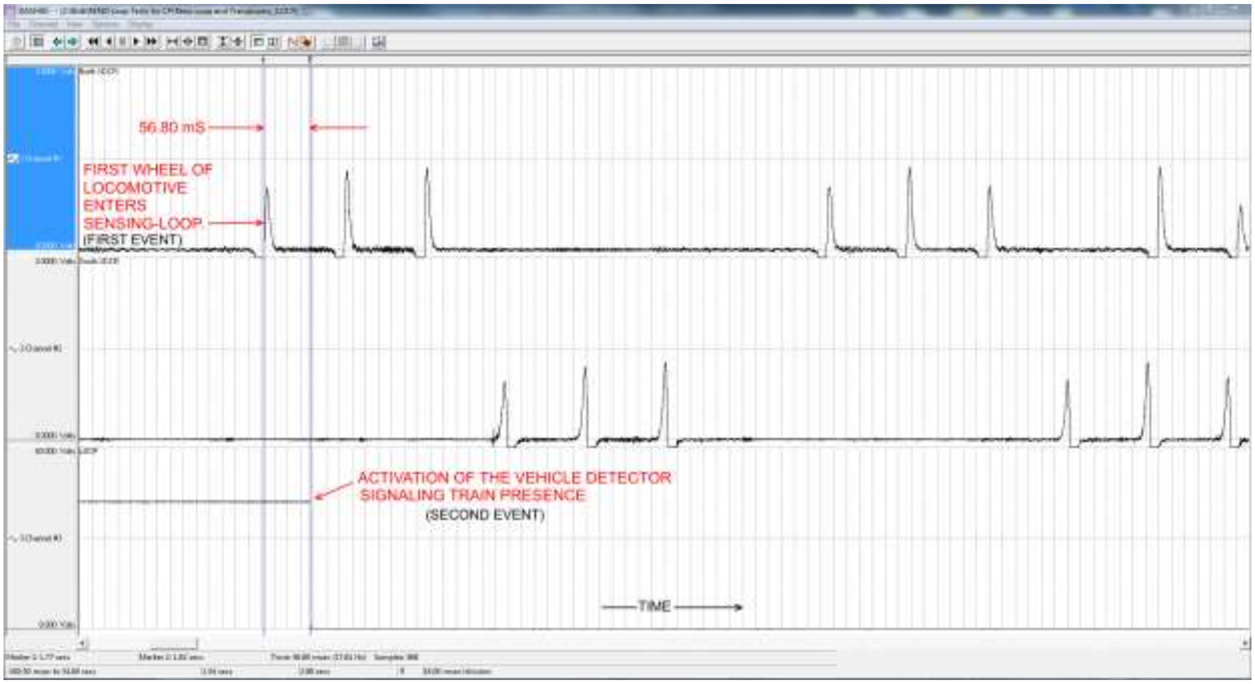

Figure 3 –The period indicated between the two vertical cursors mark the time from when the first wheel crossed the leading end of the sensing loop (top trace) to when the Vehicle Detector signals train presence (bottom trace).

In the example above, the locomotive's first wheel is calculated to be 45.43 inches beyond the leading end of the sensing-loop when the Vehicle Detector signals train presence. This measurement was found to differ with individual trains and thought to be influenced by train speed, locomotive type, and possibly sensor-loop multiplexing[1]. For proposed installations

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[1] The Model S-1300 Series detector employs a loop scanning technique to minimize crosstalk.

where maximum train speeds are faster than the ones recorded during this study, we include a safety margin when calculating sensing-loop location relative to the AEI tag reading antennae to ensure adequate system activation time. These calculations are covered later in the Example Application section.

The chart below lists data collected from all seventeen trains recorded during the study. The Speed column lists the speed of each train, and the right-hand column represents the distance the first wheel was from the leading end of the sensing loop when the Vehicle Detector signaled train presence. The negative numbers in this column indicate presence activation occurred after the first wheel passed the leading end of the sensing loop. The positive number for train 17 was a case when activation occurred before the first wheel reached the sensing loop. The zero recorded for train 16 indicates that the Vehicle Detector signaled presence at the same time the wheel sensing transducer detected the first wheel.

Train Speed versus
Vehicle Detector's Activation Point

Train #	Speed (MPH)	Distance From Leading End of Sensing-Loop to Vehicle Detector's Activation Point (Inches)
1	45.45	-45.6
2	41.32	-43.2
3	45.33	-40.2
4	46.67	-37.2
5	38.74	-37.2
6	37.75	-31.2
7	34.09	-29.76
8	45.15	-24
9	38.56	-23.35
10	37.55	-21.15
11	31.75	-16.33
12	35.51	-11.5
13	33.49	-10.37
14	21.85	-4.6
15	43.04	-3
16	23.72	0
17	37.55	+17.97

Example Application

A customer has an application with the following requirements.

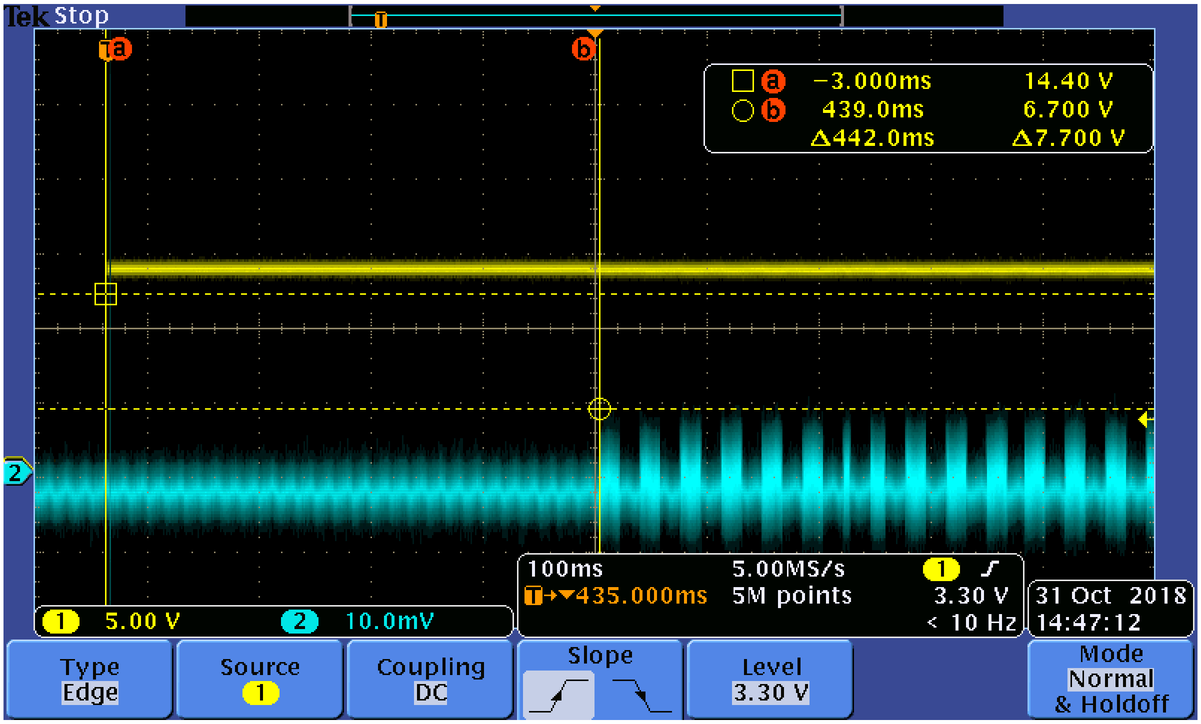
- SmartScan 2600-020 AEI Reader utilizing a TransCore MPRX Tag Reader
- Highest speed rail traffic expected is 70 MPH
- Main-Line location

- Reno Vehicle Detector to provide system activation

Determining 2600-020/MPRX Activation Time

We now have a feel for the locomotive location relative to the sensing-loop when the Vehicle Detector activates, and we have the maximum train speed parameter for an application. Now we need to know how long it takes for the 2600-020 AEI Tag Reader system to activate after it receives a presence signal from the Vehicle Detector. We used a Tektronix MSO3012 oscilloscope for this purpose,

Referring to Figure 4, channel one (yellow) triggered on the presence input activation signal (in this case it is active high), and channel two (blue) shows the RF output from the tag reading antenna connected to the MPRX. The existence of the RF signal was detected by connecting the channel two scope probe tip to its grounding clip to create a small loop antenna and placing it near the AEI antenna.[2]



☐ a −3.000ms 14.40 V
○ b 439.0ms 6.700 V
Δ442.0ms Δ7.700 V

1 5.00 V 2 10.0mV

100ms 5.00MS/s 1 ⨍
T→▼435.000ms 5M points 3.30 V
< 10 Hz

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Type Edge
Source 1
Coupling DC
Slope
Level 3.30 V
Mode Normal & Holdoff

Figure 4 - Activation time for the 2600-020 AEI and MPRX (the time between cursors a&b is 442 mS)

We found that the 2600-020 AEI / MPRX system requires approximately 442 mS of activation time in preparation to read the first AEI RFID tag. The distance a train moves in 442 mS while traveling at 70 MPH is calculated using the equation below.

$$(MPH \times 5,280) \times \left(\frac{ms}{3,600,000}\right) = ft$$

Where:

Variable ***MPH:*** Train speed

Variable ***mS:*** Time in milliseconds that the train travels at the given speed in MPH

Constant ***5,280:*** Number of feet in one mile

Constant ***3,600,000***: Number of milliseconds in one hour

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[2] As additional information we observed that the RF signal represented by channel two indicated evidence of antenna multiplexing from the MPRX with a switching rate of approximately 36 mS.

Plugging in the variables, we see that the theoretical minimum distance from the outside edge of the sensing loop to the AEI antennae must be at least 45.17 FT.

$$(\mathbf{70} \times \mathbf{5,280}) \times \left(\frac{\mathbf{442}}{\mathbf{3,600,000}}\right) = \mathbf{45.38}\ \boldsymbol{FT} \quad [converting\ to\ inches\text{: } 544.54"]$$

It is necessary to add enough distance to allow for the worst-case Vehicle Detector activation point. Referring to the **Train Speed versus Vehicle Detector's Activation Point** chart above we see that the maximum recorded distance is train # 1 at 45.6 inches past the leading end of the sensing-loop, traveling at 45.45 MPH. However, the trains at the proposed site can be moving at 70 MPH. So, doubling the 45.6-inch figure will more than allow for the difference in speed. This leaves us with 544.54" + (45.6" x 2) = 635.74 inches (52.97 feet). We add 40% to this distance for a measure of reliability to arrive at approximately 74 feet and round up to 75 feet. Now we have the distance from the leading end of the sensing coil to the AEI antennae at 75 FT.

For this application, we have specified the Reno S-1300-R-24D dual channel Vehicle Detector, which utilizes two sensing-loops as shown in Figure 5. Each loop is 16 FT in length and has the same sensing height as the 20-FT loop used in our tests.[3] The location of the loops is at a distance sufficient to activate the AEI system with trains traveling up to 70 MPH, and only a single 100-FT spool of cable is required to construct both loops.

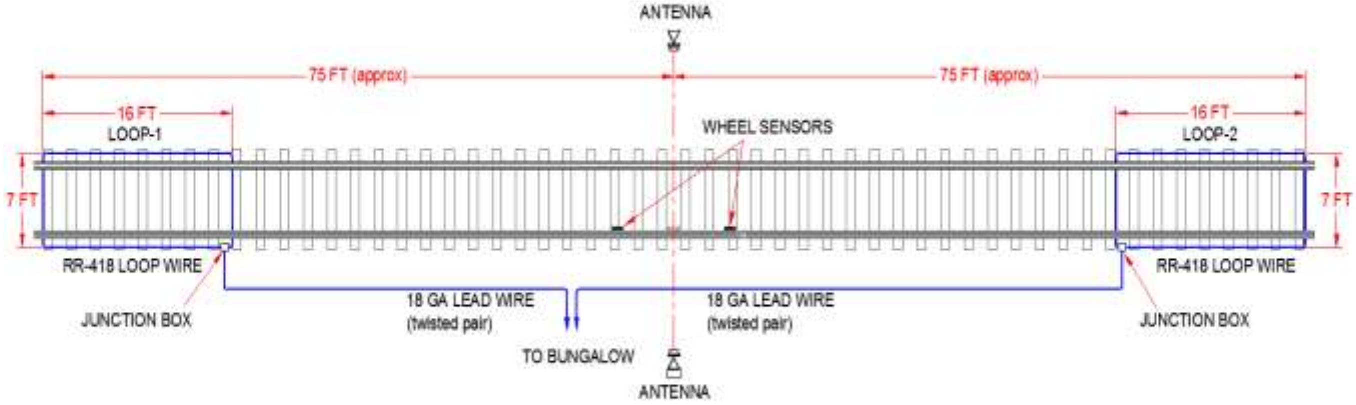

Figure 5 - Application of dual sensing-loop Vehicle Detector train speeds up to 70 MPH

Wiring

The S-1300-R-24D Dual Channel Vehicle Detector has a Form C relay output for each of its two channels. We wire these relays for normally-closed and in series as shown below in Figure 6. Activation of either relay opens the circuit resulting in system activation of the 2600-020 AEI system. Resistor R1 represents a technique to help maintain relay contact conductivity. The resistor provides enough additional current flow to meet the minimum contact current rating of the Vehicle Detector's internal relays.[4] Figure 7 provides a detailed system wiring diagram.

As a side note, an *external relay* is not needed to interface with the 2600-020 AEI Controller. So, we connect the Vehicle Detector's output directly to the Presence Input (Pin 7) on the 2600-020 AEI. However, it is worth pointing out that adding an external relay would delay the presence signal from reaching the 2600-020 AEI System. This lag would be due to the external relay's activation time. In our case, this represents approximately 20 mS,

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[3] The sensing height is determined by the dimension of the shortest leg of the loop (7 FT x (2/3) = 4.66 FT) Model S-1300 Series Operation Manual, p29 of 29.

[4] Importance of Minimum Contact Current rating specification Military Standard MIL-STD-1346B, RELAYS SELECTION AND APPLICATION, p.15: section k

which equates to about 2 feet of train movement at 70 MPH. So, an additional relay in the presence signal path would have necessitated locating the sensing-loops two feet farther out from the AEI tag reading antennae.

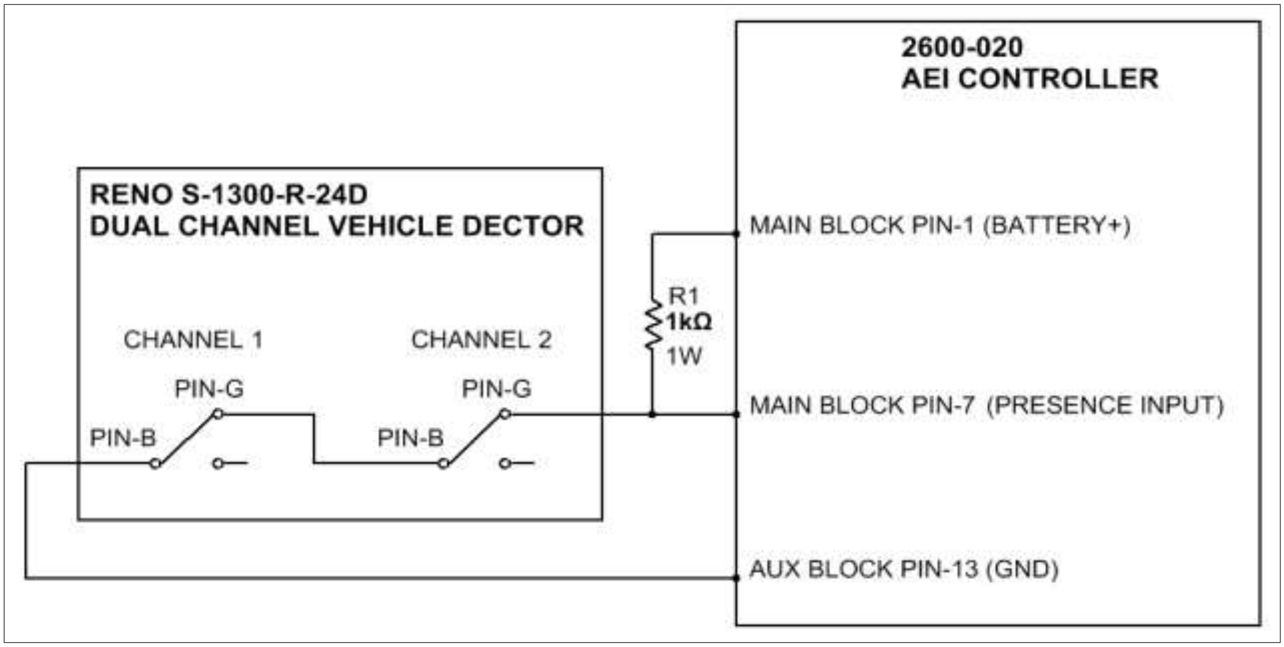

Figure 6 - Train presence wiring between the Vehicle Detector and the 2600-020 AEI Controller

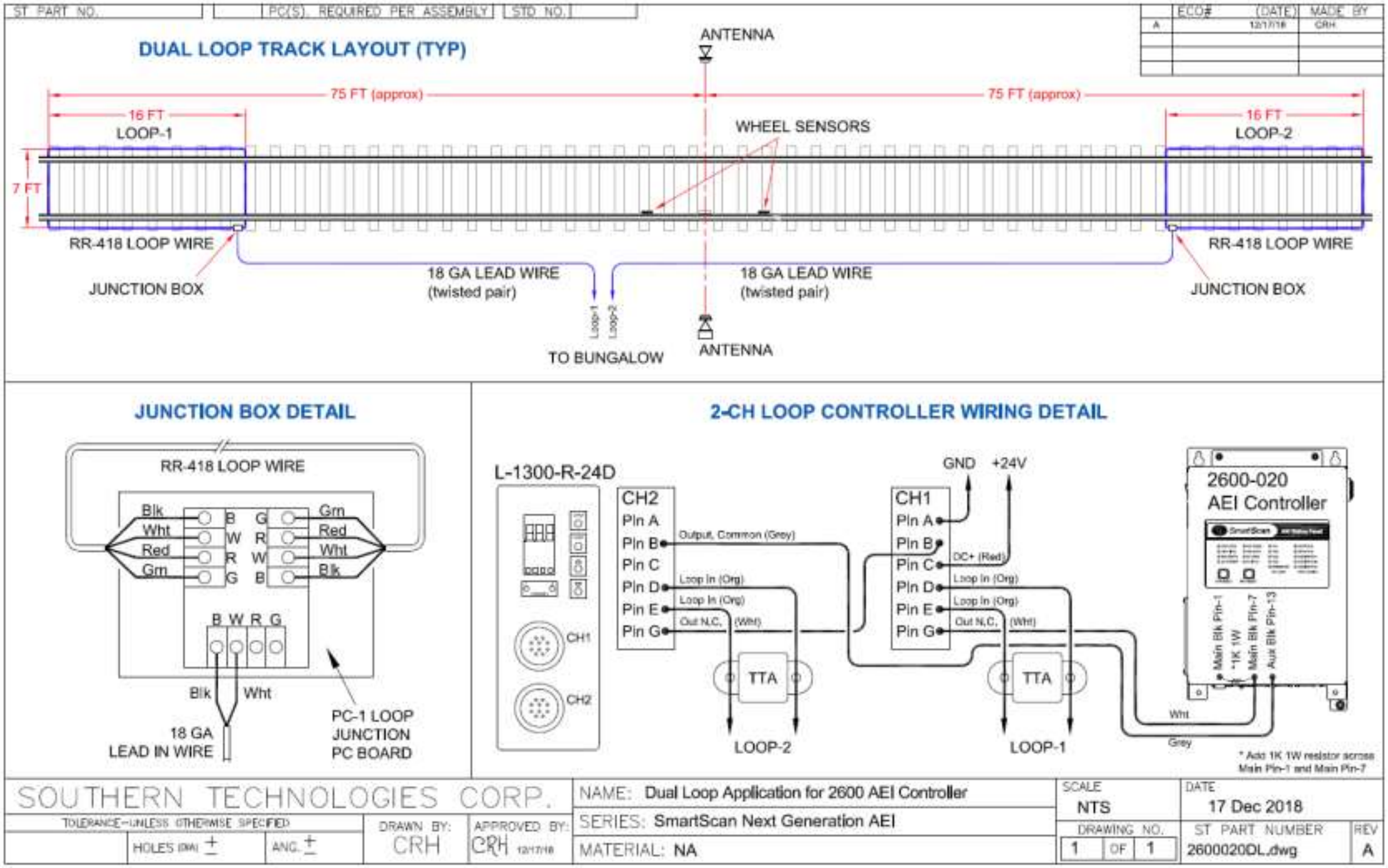

Figure 7 - Wiring Diagram for 2600-020 AEI with Reno L1300-R-14D rated for 70 MPH rail traffic

Reno S-1300-R-24D Parameter Settings

Southern Technologies specifies the following settings for all models of Reno Vehicle Detectors used in our systems. For the S-1300-R-24D, set both channels to the same parameters.

Reno Vehicle Detector Settings

FUNCTION	SETTING
Frequency	2
Sensitivity	**2**
Presence / Pulse Mode	Presence
Call Delay Time	0
Call Extension Time	0
Max Presence Time	OFF
End-of-Green (EOG)	OFF
Option 1 – Loop Inductance (L) Display	OFF
Option 2 – Loop Inductance Change (-ΔL/L) Display	OFF
Option 3 – Call Extension Control	OFF
Option 4 – Noise Filter Disable	OFF
Option 5 – Phase Green Loop Compensation	OFF
Option 11 – Audible Detect Signal	OFF
Option 12 – Detector Disconnect	OFF
Option 13 – True Presence™ Mode	**13.1**
Option 14 – Sensitivity Boost	OFF

Conclusions

In applications where the worst-case train speed exceeds that of normal freight traffic, the dual channel version Vehicle Detector is a viable solution for early system activation. This model simultaneously monitors two sensing-loops that can be positioned a distance to either side of the AEI RFID tag reading antennae. The dual sensing-loop configuration is useful for extending the sensing distance without having a single sensing-loop spanning the entire area.