*Technical Description*

*For*

# Model 330 Weigh-In-Motion System

*Including*

## Doppler Radar, Loop, Weigh-In-Motion Sensors and Processor

**TRANSPORT DATA SYSTEMS**

# Table of Contents

# 1.0 INTRODUCTION/SUMMARY

The purpose of this document is to define the design of the Model 330 WIM Classification Equipment. This system provides the capability of classifying vehicles into a complex class structure based on vehicle length, axle location and weight.

# 2.0 CUSTOMER REQUIREMENTS

## 2.1 Vehicle Classes

The following is a generalized list of vehicle classes. The final product will be customized to meet the customer class table.

i) Two axle vehicles within a given weight range

ii) Three axle vehicles within a given weight range

iii) Four axle vehicles within given weight ranges

iv) Five axle vehicles within given weight ranges

v) Six axle vehicles within given weight ranges

## 2.2 Accuracy

The WIM shall determine classes to an accuracy of at least 98%.

## 2.3 WIM Vehicle Separation Performance

The WIM system will differentiate between vehicles separated by a minimum of 2 meter at speeds of less than 60 kilometers per hour.

## 2.4 Interfaces

Sending vehicle's presence and class from the WIM to the host computer. Presence information can be used for vehicle separation.

# 3.0 SYSTEM DESIGN

The WIM system consists of the loop, Doppler radar and twin quartz sensors. This system is capable of providing the classification accuracy to meet the requirements defined in Section 3.

The block diagram of the WIM is shown in Figure 3.0-1 below:

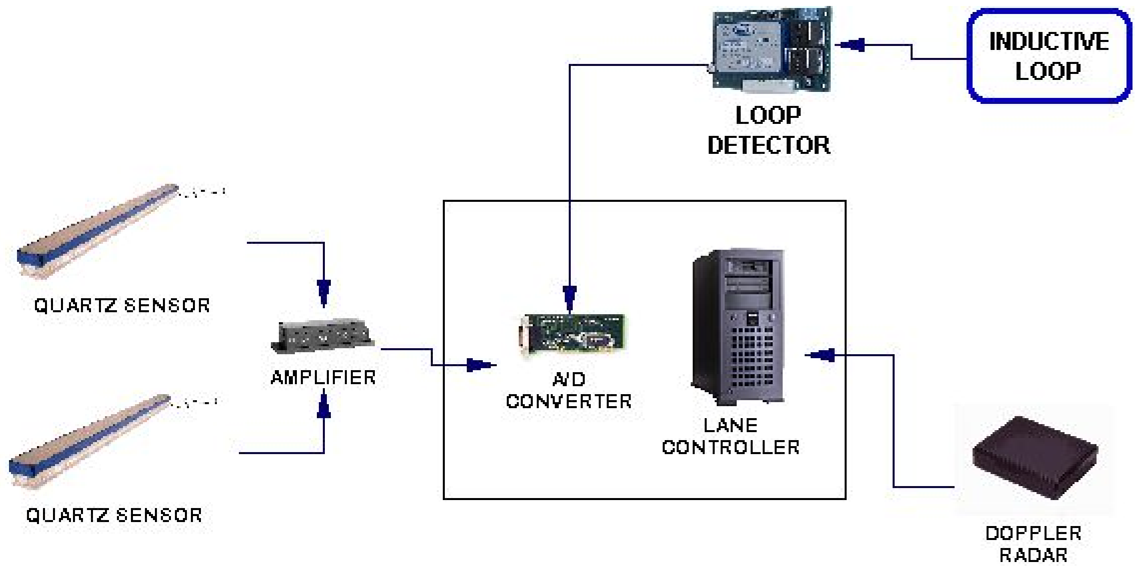


**Figure 3.0-1; WIM Block Diagram**

The lane layout for the WIM lane is shown in Figure 3.0-2 below:

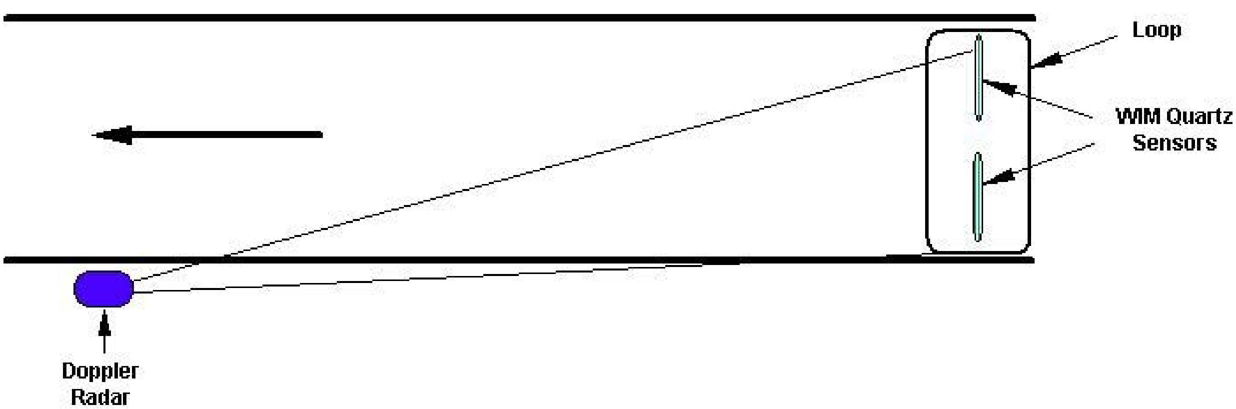


**Figure 3.0-2; WIM Lane Sensor Layout**

The vehicle class types will be detected according to a set of rules similar to those described below in Table 3.0-1.

**Table 3.0-1; WIM Produced Classes - Sample**

| Vehicle Type | Toll Classification | Vehicle Characteristics |
|---|---|---|
| 2 Axle | 1 | Axle Count, Length, Axle Location. Wheel Weight > Max Weight |
| 3 Axle | 2 | Axle Count, Length, Axle Location. Wheel Weight > Max Weight |
| 4 Axle Vehicle | 3 | Axle Count, Length, Axle Location. Wheel Weight > Max Weight |
| 5 Axle Vehicle | 4 | Axle Count, Length, Axle Location. Wheel Weight > Max Weight |
| 6 Axle Trucks | 5 | Axle Count, Length, Axle Location. Wheel Weight > Max Weight |

The TDS WIM Automatic Vehicle Classifier:

- Meets all of the individual classification requirements Section 3.1 fare classes based on axles, vehicle weight and length of the vehicle.
- Allows easy modification of classification categories to readily accommodate future rate structure changes or additional classes.
- Provides accurate vehicle velocity (max and/or average) – accuracy = 1% +/- 0.2 mph.
- Maintains the position of the vehicle at all times while in the collection zone. This includes stop and go operation as well as reverse motion.
- Transmits entry and exit information to the host processor. This information is used by the host processor to augment the lane logic.
- Is composed of off-the-shelf technology from major suppliers.
- Has a system MTBF in excess of 20,000 hours.

### 3.1 WIM Operational Philosophy

The automatic vehicle classification system described herein is a pattern recognition system that relies on special pattern recognition algorithms to categorize vehicles into a number of distinct types. It uses the length of the vehicle, the number, weights and spacing of wheel groups to form a complex pattern. This pattern is then fed to discrimination software that correlates with one of a predetermined set of vehicle types.

Vehicle detection and profiling are accomplished by processing the sensor data from the radar, loop and weigh-in-motion sensors. The WIM processor receives frequent sensor messages from the radar and loop. Each radar message reports the distance and velocity of up to seven targets that the radar is currently sensing in its beam. Each loop message provides a report of the status of the loop. The vehicle detection process begins when the loop reports sufficient penetration concurrent with a radar report of an object moving in the vicinity of the lane in the path of the loop beams. A filter is implemented to eliminate false classifications from being reported due to penetration of the loop by objects other than vehicles.

While the loop is triggered, the processor creates a profile of the vehicle using the Doppler radar velocity information to determine which position in the vehicle profile to store each sample from the weight sensors. This process continues until the loop no longer detects a presence. The vehicle profile is then sent to the correlation process where the classification will be determined.

The correlation process begins with the series of tests to determine the characteristics of the vehicle. These characteristics are the length of the primary vehicle, the number of axles and their weights and the locations of the axles. The test results are then correlated with a table of characteristic values that is configured for the user classification schedule. This table of characteristics is stored in a configuration file that is separate from the WIM application software. This provides an easy method for updating the class schedule should the user require modifications. After the classification has been determined the classification message is transmitted to the lane controller application. The classification message includes the maximum velocity of the vehicle measured during the period that it was within the loop. The message also includes the vehicle weights and length as well as the total axle count.

After the vehicle has been classified the system continues to track the location of the vehicle in the lane.

A key element in this design is the use of the CW Doppler radar. When vehicles are traveling at higher speeds, the problem of resolving two vehicles in close proximity is particularly vexing. However one characteristic that these two vehicles have in common is that their velocities are obviously very nearly the same. Therefore the Doppler return from each of the vehicles is also nearly the same. The loop acts to provide excellent vehicle separation. The current design allows for separating two vehicles that are within 4 foot of each other at a velocity of 100 miles per hour. At more reasonable speeds (60 mph), the vehicles may be within two feet of each other and at manual lane speeds, the vehicles may be within 8 inches of each other. The processor uses the velocity provided by the Doppler radar to determine the positioning of the various samples in the vehicle profile. Since in this particular case the velocities of the two adjacent vehicles and the corresponding Doppler radar outputs are nearly identical, errors in the sampling distance that are due to returns from the adjacent vehicle are negligible.

The output from the Doppler radar provides an excellent measure of the vehicle velocity. This data is used to calculate the weight of each wheel set as the wheel crosses the quartz sensor. This data will be transmitted to the lane controller as part of the primary WIM message.

The WIM software can provide any/all of the following functions:

- Receipt of data from the radar
- Receipt of data from the loop
- Receipt of data from the axle detection and weighing equipment
- Vehicle presence detection
- Vehicle position tracking through the collection zone
- Determination of the vehicle classification
- Vehicle speed
- Lane entry and exit messages
- Vehicle At ACM message for associating coins with a vehicle

- WIM system diagnostics (remote or local)
- Error reporting to the host processor

The processor will be able to handle all types of vehicle motion including negative speeds. It will identify back-outs and terminate the transaction.

## 4.0 DETAILED DESCRIPTION – EQUIPMENT

### 4.1 Eaton Vorad Doppler Radar

The Doppler Radar consists of the following components:

- Radar Antenna assembly
- Power Supply (220/240 VAC)
- Radar Mounting
- Power and communication cables
- RS422 interface to WIM Processor

The Doppler CW radar is a Ku band (24.725 Ghz) radar produced by Eaton Safety Systems. It is designed to provide coarse position and very accurate velocity data on moving vehicles. Coarse position is provided by a 50 kilohertz frequency shift keying applied to the transmitted signal. Velocity data is provided by the Doppler offset of the received signal. The received signal is mixed with a coherent transmitter signal to produce in-phase and quadrature Doppler signals, which are then sampled and fed to a digital signal processor, implemented as a Fast Fourier Transform (FFT). The outputs of the FFT are correlated with the coarse range data to provide data on up to seven separate targets.

The radar was originally designed to be part of a vehicle mounted collision avoidance system that is now being sold in production quantities by Eaton. The radar is a weatherproof unit, packaged to withstand extremes in temperature and humidity. As sold by Eaton, the unit is mounted above the front bumper on a vehicle and provides target information about vehicles directly ahead of the instrumented vehicle. .

The radar is a very low power device (< 5 milliwatts CW). It has complete FCC approval (FCC ID I3L3JC) for operation on the open road and is not an RF hazard to humans under any conditions.

The antenna unit is a planar array. The horizontal beam width is 12 degrees and the vertical beam width is 4 degrees.

The radar processor provides a variable length message containing range and range rate on up to seven targets to the processor. This message is transmitted to the processor every 65 milliseconds. The interface is a 19200 bps RS-422 interface. The resolution of the range is 1 foot and of the range rate is 0.1 foot per second. The accuracy of the range reading has limited value as the phase center tends to move about the vehicle as it passes through the radar beam. On the other hand the accuracy of the range rate is 1% +/- 0.2 miles per hour. The unit will handle velocities up to a maximum of 120 miles per hour and ranges up to 350 feet.

The unit is capable of operating in a temperature range of - 40 degrees to + 85 degrees Centigrade.

The radar requires a maximum of 10 watts of power from a regulated 7.5 VDC source.
As shown below, the Doppler Radar is mounted approximately 35-40 feet “downstream” of the Loop, with the top of the antenna positioned 2-3 feet above the road surface. The unit should be located a maximum of 2 feet from the edge of the lane. The radar antenna should have an unobstructed view of the lane to the loop. The power supply must be located within 6 feet of the radar unit.

## 4.2 Axle Detector

The axle detector will consist of two 1 meter quartz sensors connected to a charge amplifier.

### 4.2.1. Quartz Sensor

Kistler's LINEAS WIM Type 9195C is a force sensor with quartz elements. The sensor is a modular element that is installed into a slot that is saw-cut across an asphalt or concrete road. When a force is applied to the sensor surface, the quartz disks yield an electric charge proportional to the applied force through the piezoelectric effect. The electric charge is converted by a charge amplifier into a proportional voltage which can then be processed as required. Key characteristics include:

- Excellent long term stability.
- Measures very accurately at both walking and freeway speeds.
- Insensitive to temperature changes.
- Frost-resistant and protective against ingress of water.
- Quasistatic and dynamic calibration is possible.
- Wide measuring range.

The sensor is not dislodged from the road and can be reground by up to 10 mm in the event of road deformations.

The sensors are available in 0.75 and 1.0 meter lengths. Two or more sensors can be connected together to make a longer single sensor strip. Several sensors that are installed adjacent to one another can be connected electrically in parallel and operated with a single charge amplifier. The output signal then corresponds to the sum of the forces acting simultaneously on all sensors connected.

### 4.2.2. Charge Amplifier

The industrial charge amplifier (Type 5038A2Y43) is a 2 channel amplifier. Each channel converts the charge output of the Lineas sensor to a proportional voltage. The adjusting potentiometers are designed as plug in units to avoid the need for recalibration when an amplifier is replaced. The unit requires an unregulated 15 to 20 volt DC supply. Its key features include:

- Robust aluminum diecast housing
- Vibration proof

- No adjustments required

4.2.3. Lane Controller Interface

The outputs of the sensor amplifier are brought to the lane controller over special cables capable of extending the distance from the sensor amplifier to over 80 feet. The signals are fed into a digital processing card that contains a 12 bit analog to digital converter.

## 4.3 WIM Processor

The WIM software module will be installed on an WIM Processor. TDS offers a choice of two different WIM processors. One is for installation inside a controlled environment like the plaza and the other is for external installations.

For the inside installation, the processor is a Dell Series 600 server or equivalent. It uses a Celeron processor. It includes 128 megabytes of RAM and a 20 Gb hard drive. It will contain an Ethernet port for LAN connection. The unit will run the Linux operating system.

For an external installation, the processor is a hardened PC designed to be installed in tunnels and open air booths. It uses a Celeron processor. It includes 128 megabytes of RAM and a 20 Gb hard drive. It will contain an Ethernet port for LAN connection. The unit will run the Linux operating system. The unit is equipped with a heat exchanger to allow for completely sealed operation.

The WIM unit will be equipped with a two channel RS-422 serial channel board and an analog to digital convertor board for interfacing to the sensors. The WIM unit will include an RS-232 port for interfacing with the host computer. One processor is required for each lane.

In the event the user system design incorporates a lane controller running Linux or Windows XP/2000, the WIM software can be integrated into the lane controller. This does require a development effort by the system integrator.

# 5.0 INSTALLATION

## 5.1 Radar Installation

The radar installation consists of:


- Mounting the radar mount on the island.
- Mounting the radar power supply near the radar antenna. The radar power supply will need to be put into an enclosure for external mounting.
- Installing a single cable between the power supply and the antenna.
- Installing a single cable between the radar and the WIM processor in the plaza.

### 5.1.1. Radar Antenna Installation

TDS has designed and built a small pedestal mount for the Doppler radar. The mount is adjustable in both azimuth and elevation. The mount is attached to the island with four bolts. The mount is adjustable in both azimuth and elevation to allow for beam alignment of the radar.

### 5.1.2. Radar Power Supply Installation

The radar requires a special 7.5 volt DC power supply. TDS will supply this power supply in a separate rugged container for installation near the radar installation. This unit must be installed within 3 meters of the radar.

### 5.1.3. Radar Cabling Installation

A single cable connects the radar antenna/processor to the WIM processor and the radar power supply. The cable will be supplied with the radar connector installed and the power supply/WIM processor connections left un-terminated.

## 5.2 Quartz Sensor Installation

Special sand/epoxy grout secures the sensor strips into the pavement slots. After curing, the hardened grout and the exposed top surfaces of the sensor modules are ground flush with the surrounding pavement using a belt sander. After grinding, the sensors may be immediately exposed to traffic. An overnight post cure is recommended before calibration and acceptance tests are performed.

Installation instructions for the installation of the sensors will be provided by TDS. The potting compound used to install the sensors will be supplied by TDS.

### 5.3 Inductive Loop Sensor Installation

Two inductive loop sensors are installed in the road surface. Loop installation can be done using two methods: asphalt overlay and poured concrete.

### 5.4 WIM Processor Installation

The WIM processor can be located anywhere within 500 feet of the lane.