

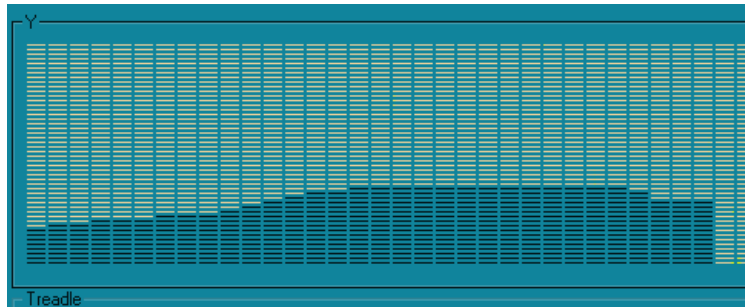
Technical Description

For

Model 230 Automatic Vehicle Classification System

Including

**Doppler Radar, Laser Scanner, and AVC
Processor**



TRANSPORT DATA SYSTEMS



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Table of Contents

1.0	SUMMARY	3
2.0	PERFORMANCE	3
3.0	SYSTEM DESIGN.....	3
3.1	Features	5
3.2	Operational Philosophy	5
4.0	SENSORS.....	7
4.1	Doppler Radar	7
4.2	Laser Profiler	7
4.3	AVC PROCESSOR	9
4.3.1.	AVC Diagnostics.....	9
4.3.2.	AVC Diagnostics.....	9
5.0	INSTALLATION.....	10
5.1	Laser Scanner Installation	10
5.1.1.	Scanner Installation	10
5.1.2.	Scanner Power Supply Installation.....	10
5.1.3.	Scanner Cabling Installation	10
5.2	Radar Installation	11
5.2.1.	Radar Installation.....	11
5.2.2.	Radar Signal Cabling Installation.....	11
5.2.3.	Power Supply Installation	11
5.2.4.	Radar Cabling Installation.....	11
5.3	AVC Processor Installation.....	11

1.0 SUMMARY

The Model 230 AVC system provides automatic vehicle classification using a laser overhead scanner, a Doppler radar and an AVC processor system.

2.0 PERFORMANCE

The AVC will automatically separate and track all vehicles passing through a lane. It will provide vehicle separation and maintain the position of the vehicle as it enters and exits the lane. It will indicate to the customer lane controller when a valid vehicle enters the vehicle separator, as opposed to a non-vehicle (person, bird, et cetera). It will indicate when the vehicle exits the vehicle separator and when the vehicle actually exits the lane.

3.0 SYSTEM DESIGN

The AVC system will consist of the following components:

- Doppler radar
- Overhead laser profiler
- AVC processor

The block diagram of the AVC system is shown in **Exhibit 3.1-1; AVC Block Diagram**.

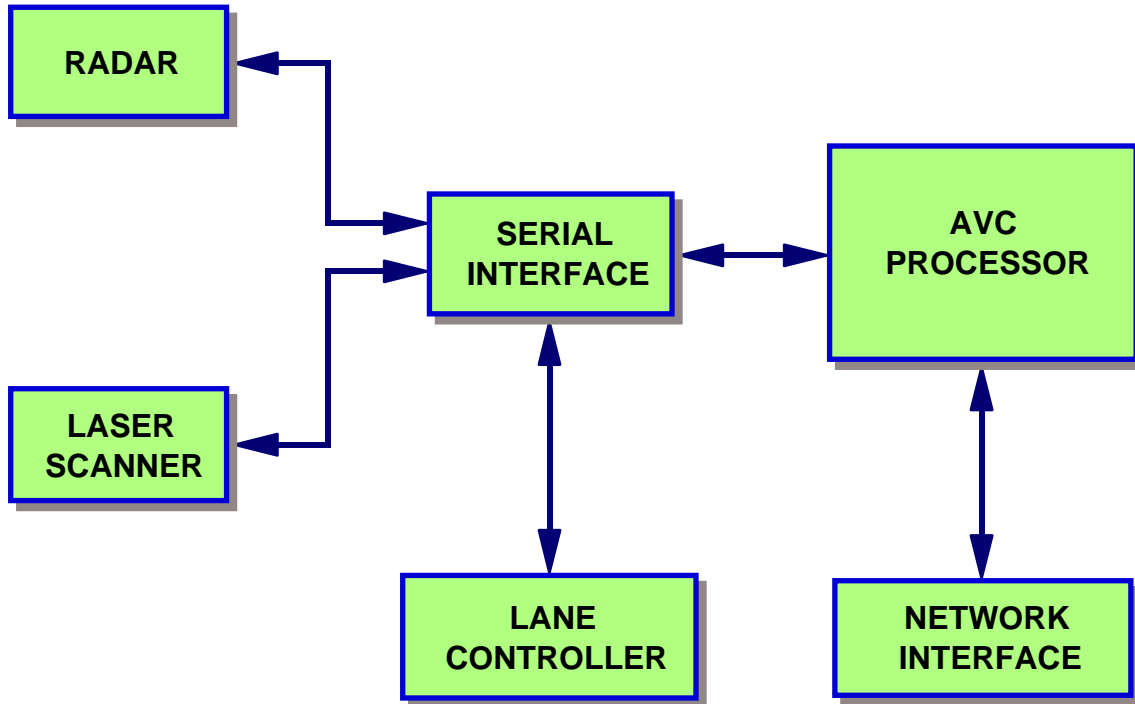


Exhibit 3.0-1; AVC Block Diagram

The lane layout for the AVC lane is shown in **Exhibit 3.0-2; AVC Lane Geometry**.

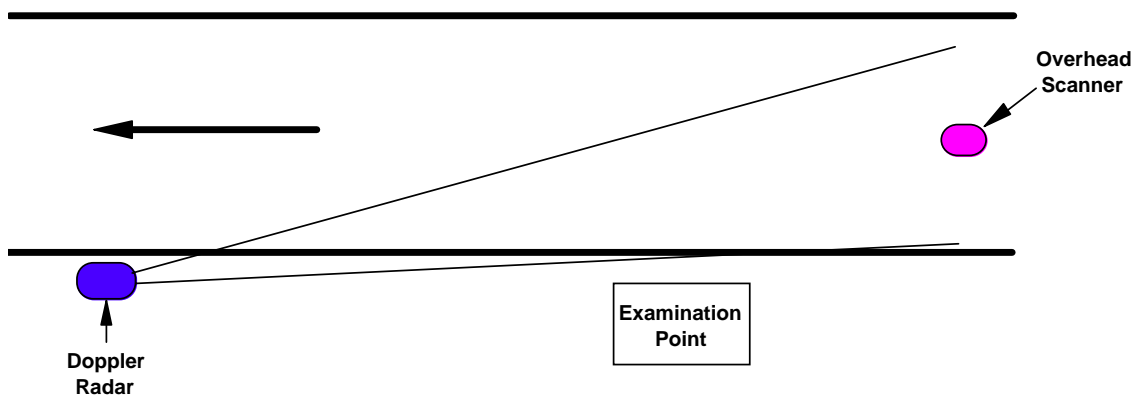


Exhibit 3.0-2: AVC Lane Geometry

3.1 Features

The TDS Automatic Vehicle Classifier (AVC):

- Provides the length of the vehicle.
- Provides the width and height profiles of the vehicle.
- 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 lane controller. This information is used by the lane controller to augment the lane logic and trigger the image capture system.
- Is composed of off-the-shelf technology from major suppliers.
- Has a system MTBF in excess of 30,000 hours.

The system block diagram is shown in **Figure 1; System Block Diagram**. The basic building blocks of the system include a laser scanner, a high frequency CW Doppler radar, and a processing system for processing of the sensor data. The laser scanner provides a method for determining a detailed cross-section of the vehicle looking from the top as the vehicle passes through the scanner. The Doppler radar provides velocity data to allow for linear generation of the samples taken by the scanner elements. These various sensor inputs are fed to a processing system that is able to discriminate between various vehicle types including detecting the existence/position of a hitch.

3.2 Operational Philosophy

The system described herein is a pattern recognition system that creates a vehicle profile as it passes through the profiling zone. A picture of an actual profile of an automobile is shown in **Exhibit 3.2-1; Vehicle Profile**.

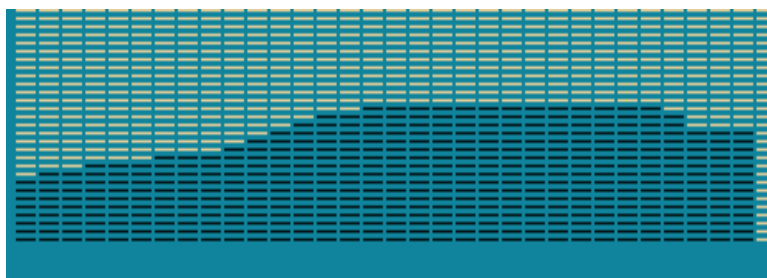


Exhibit 3.2-1; Vehicle Profile

Vehicle detection and profiling are accomplished by processing the sensor data from the radar and the laser scanner. The AVC processor receives frequent sensor messages from the radar and laser scanner. Each radar message reports the distance and velocity of up to seven targets that the radar is currently sensing in its beam. Each laser scanner message provides a report of the distances measured from the laser scanner to any

object in its swept beam in four-degree increments. The vehicle detection process begins when the laser scanner reports sufficient penetration concurrent with a radar report of an object moving in the vicinity of the lane in the path of laser scanner beam. A filter is implemented to eliminate false classifications from being reported due to penetration of the scanner by objects other than vehicles.

While the laser scanner is sufficiently penetrated, 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 laser scanner sample. This process continues until the scanner no longer detects a presence in the laser scan path.

After the vehicle has exited the scanner 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 laser scanner acts as a laser curtain 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 will be transmitted to the lane controller as part of the primary AVC message.

The AVC software will provide for the following functions:

- Receipt of data from the radar
- Receipt of data from the laser scanner
- Vehicle presence detection
- Vehicle position tracking through the collection zone
- Vehicle speed
- Lane entry and exit messages
- AVC system diagnostics (remote or local)
- Error reporting to the lane controller

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

The use of the overhead laser scanner provides excellent vehicle separation and hitch detection. The hitch detection module uses information from several different range

samples to determine the presence of a hitch. This insures that the system accurately detects the presence of a hitch, thereby eliminating the possibility of two classifications being generated for the same vehicle or connecting two closely spaced vehicles into a single vehicle. The combination of the laser scanner and the radar provides sufficient information to effectively filter out non-vehicle traffic through the lane (i.e. inspectors).

The width resolution is also useful in determining if multiple vehicles (motorcycles) are passing through the lane simultaneously.

4.0 SENSORS

4.1 Doppler Radar

The SI-3 was designed to meet a wide variety of demands, including radar message trailers, computers, and conveyer belt controls. A self-contained, stand-alone unit, the SI-3's internal firmware is customizable, allowing changes to range, output format as well as many other options.

4.1.1.1. Features

- K-Band Antenna
- Directional
- RS232 Serial Port
- 5-150 mph (8-241 km/h) Speed Range
- Range: 1,500 ft default; 3,000 ft max.

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

4.2 Laser Profiler

The laser profiler is a model LMS211 produced by Sick, Inc. It is a non-contact measuring system that scans its surroundings two dimensionally. The scanner does not require any reflectors or positional markers to function as a scanning system.



The LMS 211 operates by measuring the time of flight of laser light pulses. The time between emission and reception of a light pulse, after it has been reflected from a surface, is directly proportional to the distance between the light source and the object. The laser can scan a large area by using a pulsed laser beam deflected by a rotating internal mirror. The LMS can produce the contour of an object using a rapid sequence of distance measurements. The serial data itself is sent to the lane controller in real time via the RS-422 link.

The unit operates at a scanning rate of 75 scans per second. The scan angle that is reported is programmable. For this application it will be set to 68 degrees. The beam width of the laser beam is approximately 1 degree. The reported angular scanning resolution is programmable. For this application it will be set to 4 degrees, resulting in 17 segments being reported per scan. The range resolution of this configuration is approximately 50 millimeters.



The unit includes internal heaters for environmental control. A built-in thermostatically controlled heater and a front screen heater enable the LMS to be used at temperatures to minus -30 degrees Centigrade. The heaters are activated at 10 degrees Centigrade to prevent any thawing from occurring within the unit.

The unit is delivered with an optional dust prevention shield. This shield prevents direct exposure of the front screen to precipitation or sources of dirt.

The scanner unit weighs approximately 9 kilograms. The unit is delivered with a separate mounting bracket that provides adjustment of the device in both of the relative axes.

The electronic part of the sensor is powered directly from a regulated 24 VDC 1 amp power supply. The scanner heater is also powered from 24 VDC at 6 amps. The heater supply does not require regulation. Both the electronics and the heaters can be powered from the same primary power supply if desired.

TDS provides a maintenance screen in the AVC software package that allows a technician to easily align the scanner and configure the height and lane width settings during installation.

4.3 AVC PROCESSOR

The AVC software module will be installed on an AVC Processor. TDS offers a choice of two different AVC processor options. 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 Advantech ARK Series Industrial controller. It uses an Intel Core2Duo™ processor. It includes 2 gigabytes of RAM and a 200 Gb hard drive. It will contain dual Ethernet ports for LAN connections. The unit will run the Linux operating system.

For an external installation, the processor will be mounted in a hardened enclosure designed to be installed in tunnels and open air booths. The enclosure is equipped with a heat exchanger to allow for completely sealed operation.

The AVC unit will be equipped with a four channel RS-422 serial channel board for interfacing to the sensors. The AVC 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/2000/7, the AVC software can be integrated into the lane controller. This does require a development effort by the system integrator.

4.3.1. AVC Diagnostics

The AVC module will monitor the operation of each of the sensors associated with the AVC subsystem. Whenever a failure occurs with any of these sensors, the AVC module will send a warning message to the user lane controller.

The AVC system will include a number of degraded modes to facilitate continued operation when one or more of the AVC sensors are not functioning properly.

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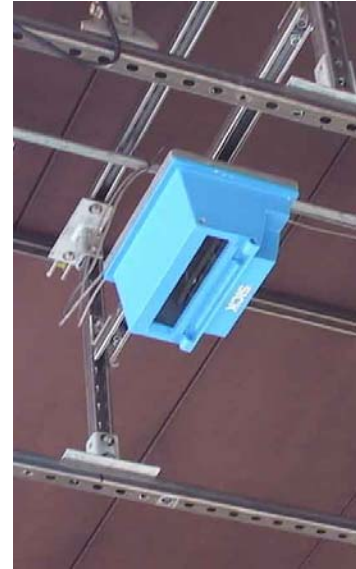
5.0 INSTALLATION

5.1 Laser Scanner Installation

The laser installation consists of:

- Mounting the laser mount on the overhead structure.
- Mounting the laser power supply near the scanner. The laser power supply will need to be put into an enclosure for external mounting.
- Installing a single cable between the power supply and the scanner.
- Installing a single cable between the scanner and the AVC processor.

The laser scanners must be installed overhead at a height of approximately 18 feet from the road surface.



5.1.1. Scanner Installation

The scanner is supplied with a mounting bracket for attachment to the structure. The mount is adjustable to allow for alignment of the scanner.

5.1.2. Scanner Power Supply Installation

The scanner requires a special 24 volt DC power supply. TDS will supply this power supply in a separate rugged container for installation near the scanner installation. The power supply for the scanner must be mounted either on the gantry or at the base of the gantry

5.1.3. Scanner Cabling Installation

The scanner is connected to the AVC processor via an RS-422 link. A single cable connects the scanner to the AVC processor and the scanner power supply. The cable will be supplied with the scanner connector installed and the AVC processor connections left un-terminated. This cable should be run inside of a conduit to the AVC processor location.

5.2 Radar Installation

The radar installation consists of:

- Mounting the radar mount on the island.
- Attaching the radar enclosure to the radar mount.
- Installing a single AC power cable to the radar.
- Installing a single fiber cable between the radar and the AVC processor.

5.2.1. Radar Installation

TDS uses a standard Pelco mount for the Doppler radar. 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.



5.2.2. Radar Signal Cabling Installation

A single fiber cable connects the radar to the AVC processor. Fiber converters are provided within the radar enclosure and at the AVC processor. The fiber cable will be supplied with the fiber connectors installed on both ends. This cable should be run inside of a conduit to the AVC processor location.

5.2.3. 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.

5.2.4. Radar Cabling Installation

A single cable connects the radar to the AVC processor and the radar power supply. The cable will be supplied with the radar connector installed and the power supply/AVC processor connections left un-terminated. This cable should be run inside of a conduit to the AVC processor location.

5.3 AVC Processor Installation

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