Thermoplastic Pavement Marking Material Thickness Measurement System User Guide

by

Richard Liu, Yuanhang Chen, Aditya Ekbote, Wei Sun,
Xuemin Chen, Jing Li, and Pankaj Chopra

Product 0-5882-P2

Project Number 0-5882
Project Title: Development of Vehicle Mounted Measuring Device Utilizing a Non-Contact Method to Determine the Thickness and Uniformity of Application of Thermoplastic Pavement Marking Material

Performed in Cooperation with the
Texas Department of Transportation and
the Federal Highway Administration

by the

Subsurface Sensing Laboratory
Department of Electrical and Computer Engineering
University of Houston

March 2006

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

University of Houston
4800 Calhoun Road
Houston, TX 77204

ACKNOWLEDGMENTS

We greatly appreciate the financial support from the Texas Department of Transportation that made this project possible. The support of the project director, Danny Magee, and program coordinator, Wade Odell, is also very much appreciated. We also thank the project advisors, John Bassett, Larry Colclasure, and Brian Michalk.

TABLE OF CONTENTS

THERMOPLASTIC PAVEMENT MARKING MATERIAL THICKNESS MEASUREMENT SYSTEM

USER GUIDE

Part 1

Point Laser Device User Manual and Troubleshooting

TABLE OF CONTENTS

LIST OF FIGURES

SECTION 1 INTRODUCTION

1.1 General Description

The developed thermoplastic pavement marking material (TPMM) thickness detector is a vehicle-mounted device that measures the thickness of marking materials on the pavement surface by using point lasers. The device consists of two parts: a hardware system to measure the pavement marking by using the laser triangulation technique and a software package to analyze and process the measured data. Three independent laser devices are installed on a van. One laser device projects a laser beam onto the pavement with marking materials, and the other two lasers project a beam onto the pavement without marking materials. The marking thickness is obtained by processing the three laser devices' output signals. Figure 1 shows the developed device.

Figure 1 Designed vehicle-mounted device.

1.2 System Block Diagram

The vehicle-mounted device consists of a hardware system and a software package. The software will be illustrated in section 3. To describe the architecture of the device, a simple hardware design block diagram is illustrated in Figure 2.

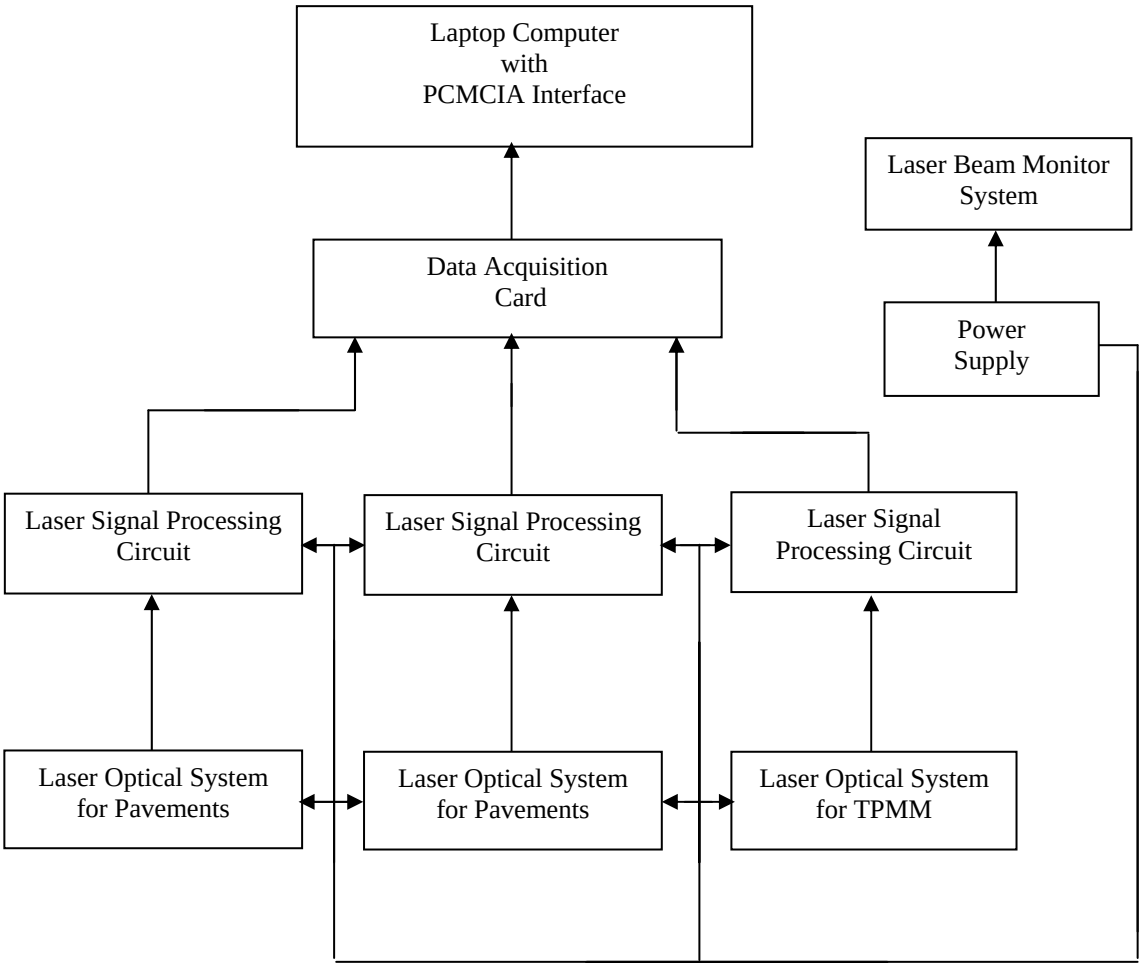
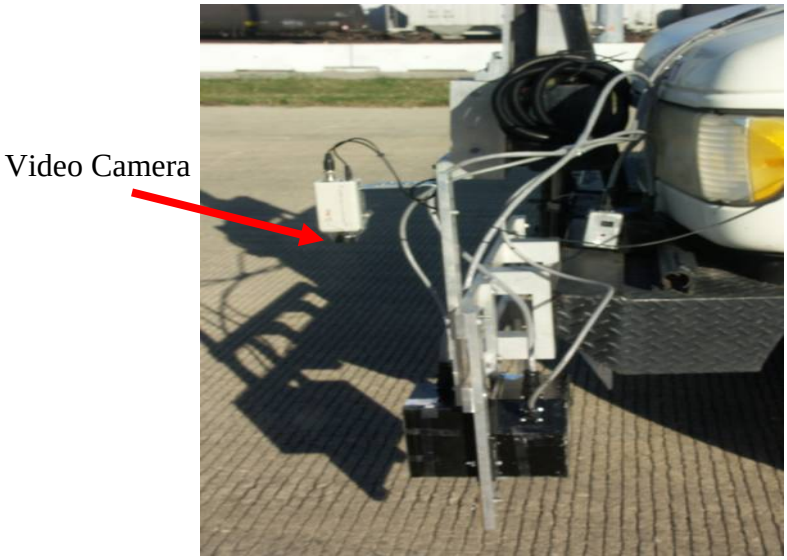


Figure 2 Block diagram of the vehicle-mounted device.

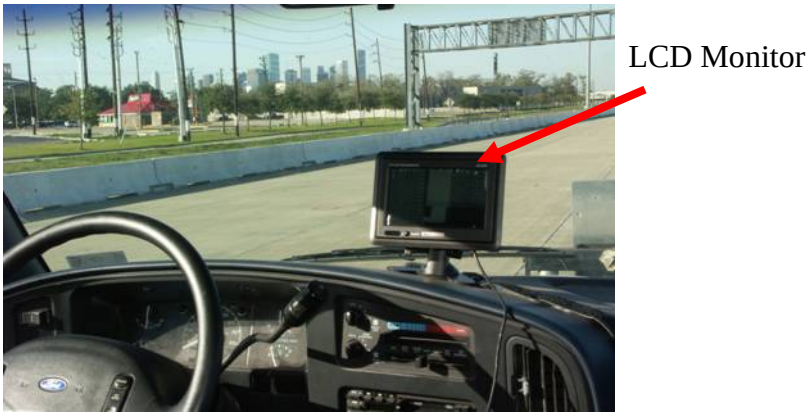
A 12V automobile battery is used as the power source. A laser beam monitor system helps the driver to manage the driving direction. Through the power supply, 12V is converted into different voltages required by the measurement device. Three separated laser optical systems simultaneously detect the position of the TPMM and the pavement. Three laser signal processing units process the detected laser signals and transfer the position signals to the different input channels of the data acquisition card. By subtracting and averaging the three position signals, the software package displays and stores the TPMM thickness imaging.

The vehicle-mounted system is divided into three subsystems: the laser beam monitor subsystem, laser range finder subsystem, and power supply subsystem.

The laser beam monitor system consists of a video camera and liquid crystal display (LCD). In Figure 3(a), the video camera is installed on the laser device to detect the laser beam, and in Figure 3(b), the LCD display is installed in the van to assist the driver manage the driving.



(a)



(b)

Figure 3 Laser beam monitor system.

The laser range finder subsystem is divided into an optical block and a signal processing block. Figure 4 illustrates the laser-based triangulation optical system, and Figure 5 shows the block diagram of the signal processing circuit.

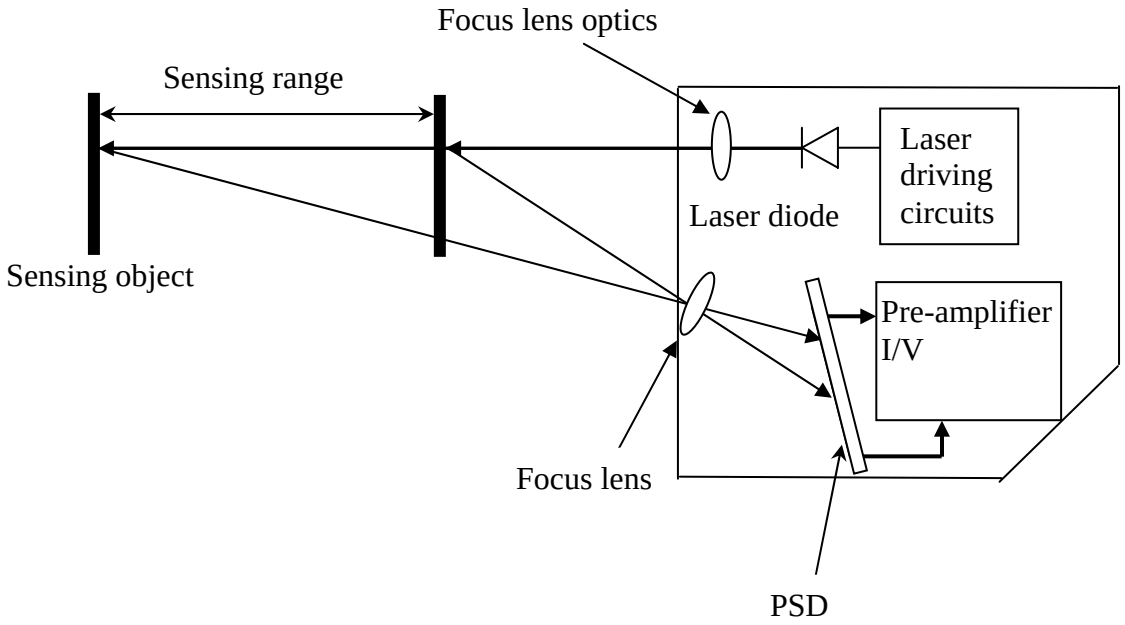


Figure 4 The laser-based triangulation optical system.

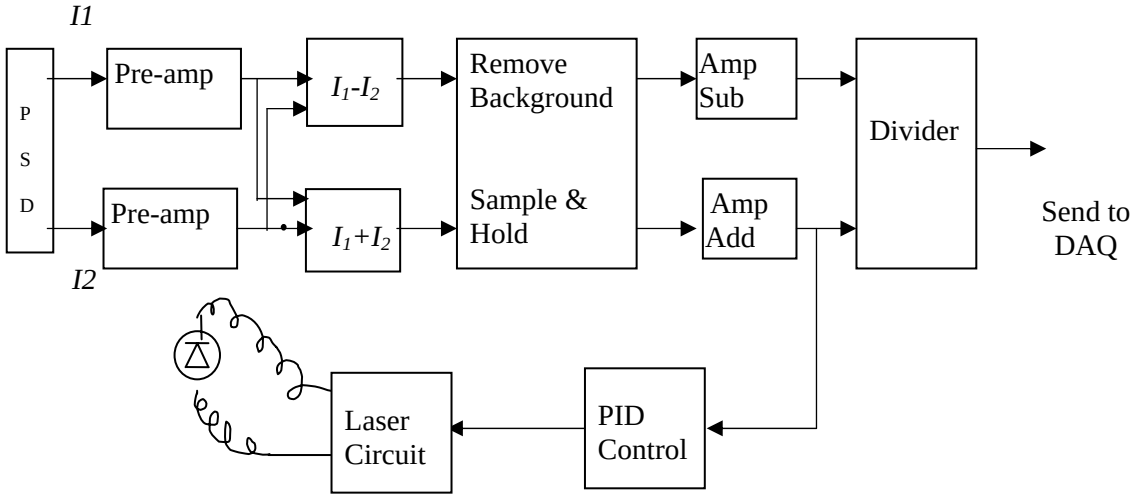


Figure 5 Block diagram of signal processing circuit.

The optical block includes a laser source, position sensitive detector (PSD), laser beam focusing lens, and optical filtering components. The laser signal processing block removes influence from background color, reflectivity changes, and other noises.

The power supply subsystem is to provide power for devices in the field without using AC power input. Only one 12V battery is needed in the device. By using DC-DC voltage converters and voltage regulators, the 12V voltage is converted to ±15V and ±5V.

1.3 Performance Description

Figure 6 shows the vehicle-mounted device in use in the field. The measurement system projects a laser over marking materials and pavement, and the sensor system receives the reflected laser beam. The signal processing circuit sends distance information to the host computer, and the host computer processes and displays the thickness of TPMM in real time.

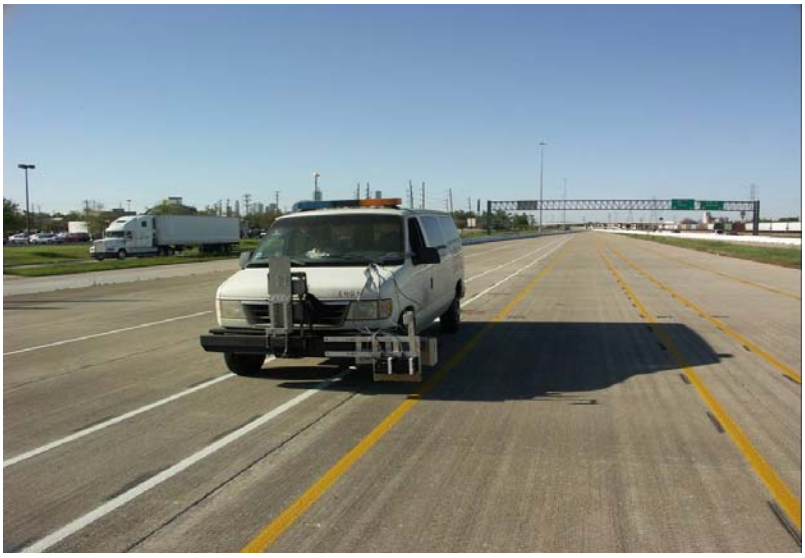


Figure 6 The vehicle-mounted device in measurement.

The system specifications are as follows:

(1) Standoff distance: 12 inches

The standoff distance means the distance between the laser source and object.

(2) Sample rate: 150 KHz

The laser source is operated in the frequency range of 150 KHz.

(3) Maximum range of measured thickness: 6 inches

This detector has been verified to detect a thickness change of 6 inches.

(4) System clock: 1.544 MHz

(5) Digitization resolution: 12 bits

(6) Average power consumption: 2 A at 12 V

An automobile battery is used to provide power for the system to work for a few hours.

(7) Maximum measurement resolution: 5 mils

(8) By using the software, you can either start a new measurement, save the results, or open saved files. You can also obtain the thickness profiles from the saved results.

SECTION 2 HARDWARE INSTALLATION

2.1 Components of Point Laser System

Figure 7 shows the components of the vehicle-mounted device.

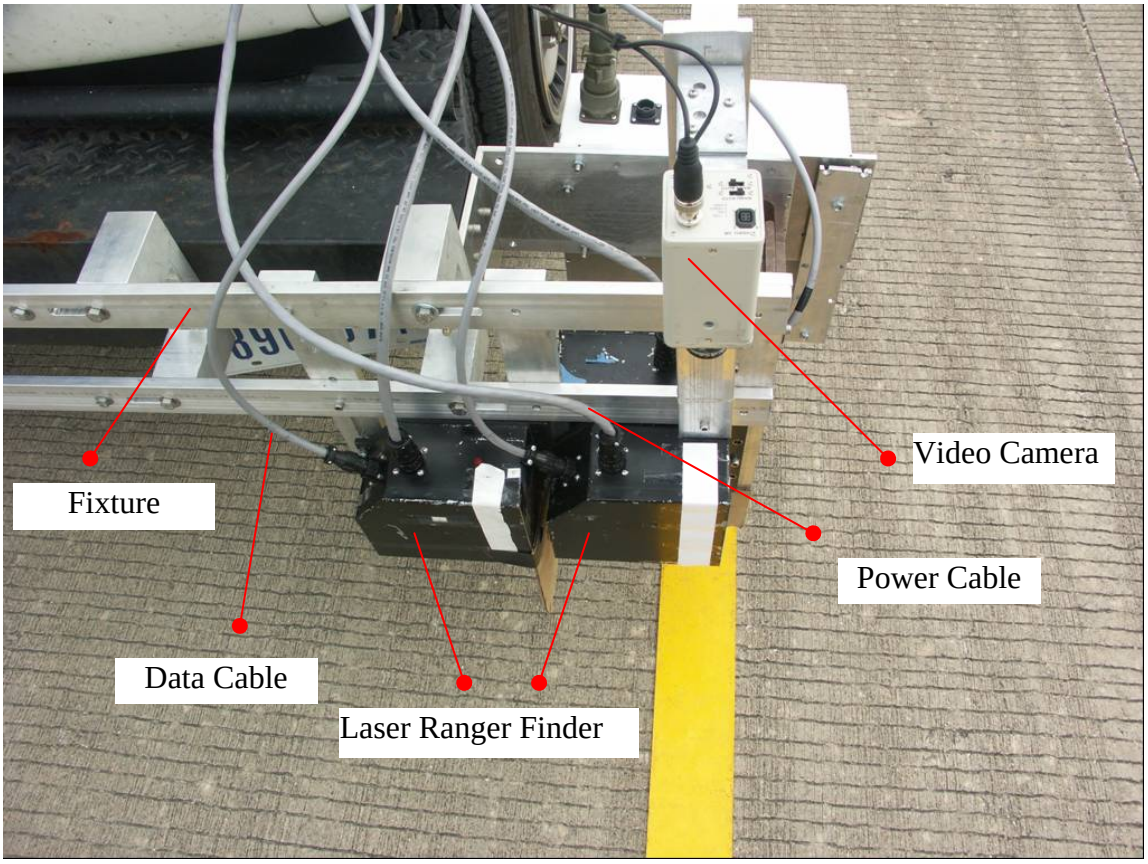


Figure 7 Vehicle-mounted measurement system components.

The vehicle-mounted measurement system components are:

- **Fixture**: the connection between laser devices and vehicles.
- **Laser ranger finder**: transmits laser beam and processing thickness information.
- **Video camera:** monitors the laser beam and pavement marking.
- **Power cable:** connects power supply to laser device.
- **Data cable:** sends distance information to the host computer.
- **Host computer**: contains installed data acquisition card and software; the data acquisition card (NI DAQCard-6062E) is a PCMCIA card installed in the socket of the laptop computer.

Figure 8 shows the connection of the data acquisition cable (which is the output of the laser device) to the socket in the computer.

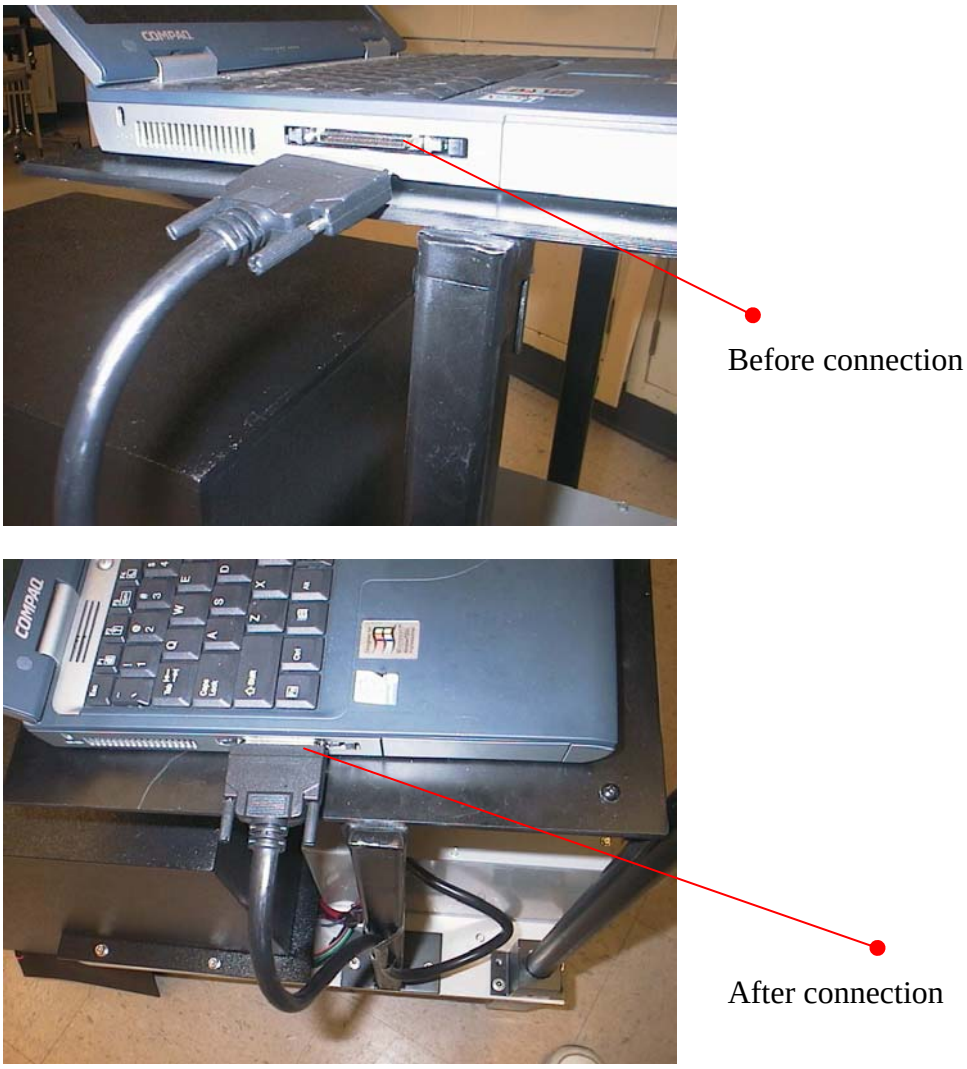


Figure 8 Connection of data acquisition cable to computer.

2.2 System Hardware Operation Procedures

The following steps will aid the operator in the startup and operation process:

- **Step 1**: Turn on the electronics power supply switch, which is located in the vehicle.
- **Step 2**: Load the software for measurement and find the detailed software operation in the next section.
- **Step 3**: When finishing the measurement, always turn off the power supply switches.

SECTION 3 SOFTWARE OPERATIONS AND DATA INTERPRETATION

3.1 Interface Description

Figure 9 shows the interface of the TPMM thickness measurement software on the laptop computer for the measurement.

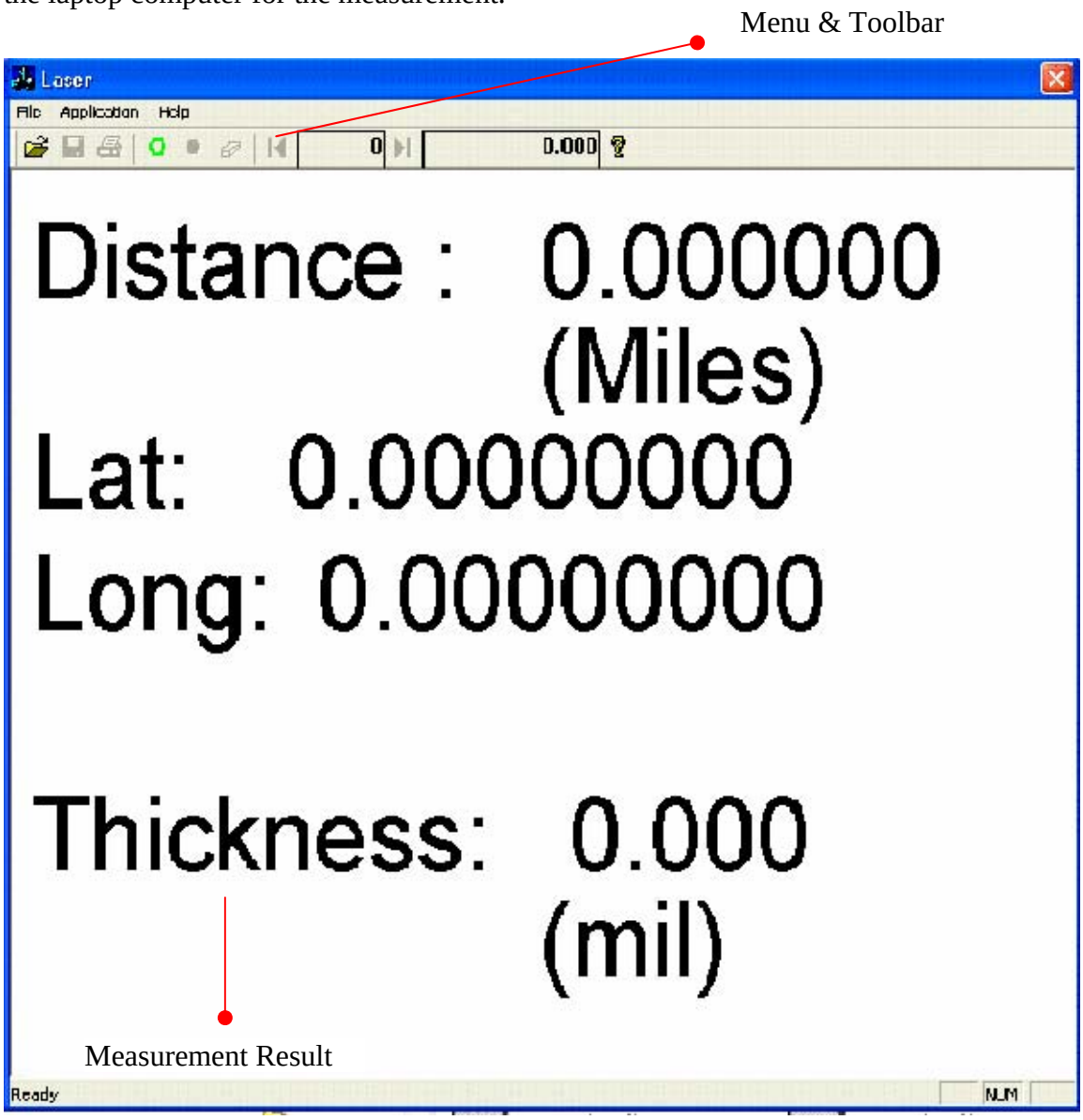


Figure 9 The interface of TPMM measurement software.

There are several parts in the interface. The detailed descriptions of those parts are following:

- **Menu and toolbar**: function menu and icons. The toolbar buttons are, from left to right:
  - **Open:** Open a saved file. The thickness chart and measurement result will be updated respectively, and then you can press **Previous page trace** or **Next page trace** to see trace details, or **Erase.**
  - **Save:** Save current measurement result.
  - **Start:** Start a new measurement.
  - **Stop:** Stop the current measurement. Then you can review the results, or press **Previous page trace** or **Next page trace** to see trace details, or **Save**, or **Erase.**
  - **Erase:** Erase the current result. Then you can press **Start** for a new measurement or **Open** for a saved file.
  - **Previous page trace:** Change the current trace to the correspondent trace on the previous page, but if the current trace is on the first page, it will change to the first trace.
  - **Next page trace:** Change the current trace to the correspondent trace on the next page, but if the current trace is on the last page, it will change to the last trace.
- **Measurement result:** The average thickness of TPMM measured, GPS position, and distance measurement are updated every second.

3.2 Software Operation

3.2.1. Start a new measurement:

1. Double click laser.exe on the desktop.
2. Click the **Start** button to start a new measurement.
3. While moving the cart, the interface will update as the vehicle moves forward.
4. Click the **Stop** button to stop the measurement.
5. See the results or click the **Previous page trace** or **Next page trace** buttons for trace details.

6. If useful, **save** the result.
7. **Erase** the result. Then go to step 2 for a new measurement or step 2 of 3.2.2 to open a new file.

3.2.2. Open a saved file:

1. Double click laser.exe on the desktop.
2. Click the **Open** button to look for the saved file. The interface will update according to the saved file.
3. See the results or click the **Previous page trace** or **Next page trace** buttons for trace details.
4. **Erase** the result. Then go to step 2 of 3.2.1 for a new measurement or step 2 of 3.2.2 to open a new file.

SECTION 4 TROUBLESHOOTING

In the event you encounter a problem, refer to the following for possible solutions.

PROBLEM	PROBLEM CAUSE	SOLUTION
No signal or wrong information when you start a new measurement	Power off or connection problem	• Check if the battery has enough capacity • Check if the power is on • Check if the PCMCIA cable is connected to computer
File open error	Wrong file name	Get the correct file name.

Note:

Disconnect the PCMCIA cable after you shut down the computer. Do not disconnect the PCMCIA card at the same time as the computer is shutting down. Make sure the PCMCIA card is inserted before you turn on the computer so that when you start a new measurement, there will be no error messages.

Tip:

If there is no signal, follow the solution table. If the problem persists, it may be necessary to check if the PCMCIA card works properly. Follow these procedures:

On the desktop, click **Measurement and Automation.**

In the left frame **Configuration**, expand **devices and interfaces** and delete device **DAQ6062E.**

Restart the computer. If a new device is found and a driver is needed, **insert the NI driver CD** and follow the instructions.

Restart the computer and test a new measurement.

THERMOPLASTIC PAVEMENT MARKING MATERIAL THICKNESS MEASUREMENT SYSTEM

USER GUIDE

Part 2

Scanning Laser Device User Manual and Troubleshooting

TABLE OF CONTENTS

LIST OF FIGURES

SECTION 1 INTRODUCTION

1.1 General Description

The developed thermoplastic pavement marking material (TPMM) thickness measurement system is a vehicle-mounted device that measures the thickness of marking materials on the pavement surface by using scanning laser technology. The device consists of two parts: a hardware system to measure the pavement marking by using the laser triangulation technique and the auto-synchronized scanning technique. A software package is used to analyze and process the measured data. Figure 1 shows the designed scanning laser device. The device measures 12 inches wide, 10 inches long, and 5.75 inches high.

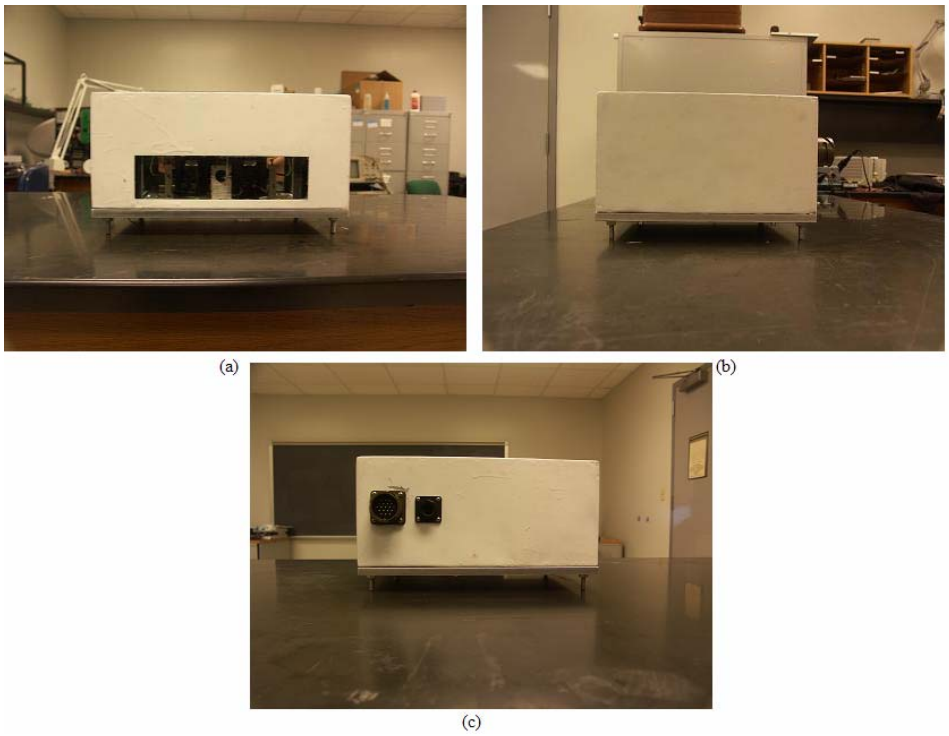


Figure 1 Designed scanning laser device: (a) front view, (b) side view, and (c) back view.

1.2 System Block Diagram

The TPMM detector consists of a hardware system and a software package. The software is illustrated in section 3. To describe the architecture of the device, a simple hardware design block diagram is illustrated in Figure 2.

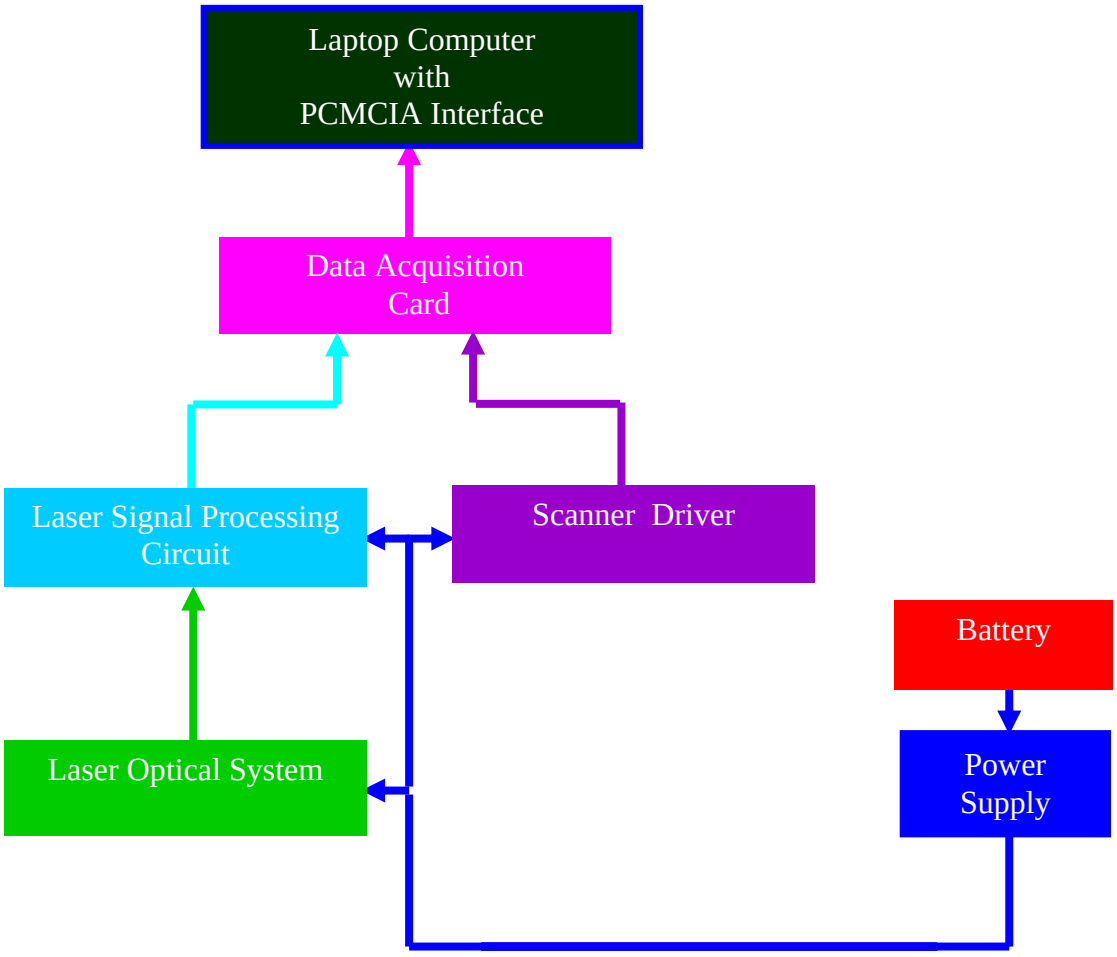


Figure 2 Hardware design block diagram.

The prototype hardware of the pavement marking thickness measurement system is divided into three subsystems: the scanning laser range finder subsystem, signal processing subsystem, and power supply subsystem.

The scanning laser range finder subsystem is divided into an optical block and a signal processing block. Figure 3 is the laser-based auto-synchronized triangulation optical system, and Figure 4 is a block diagram of the signal processing circuit.

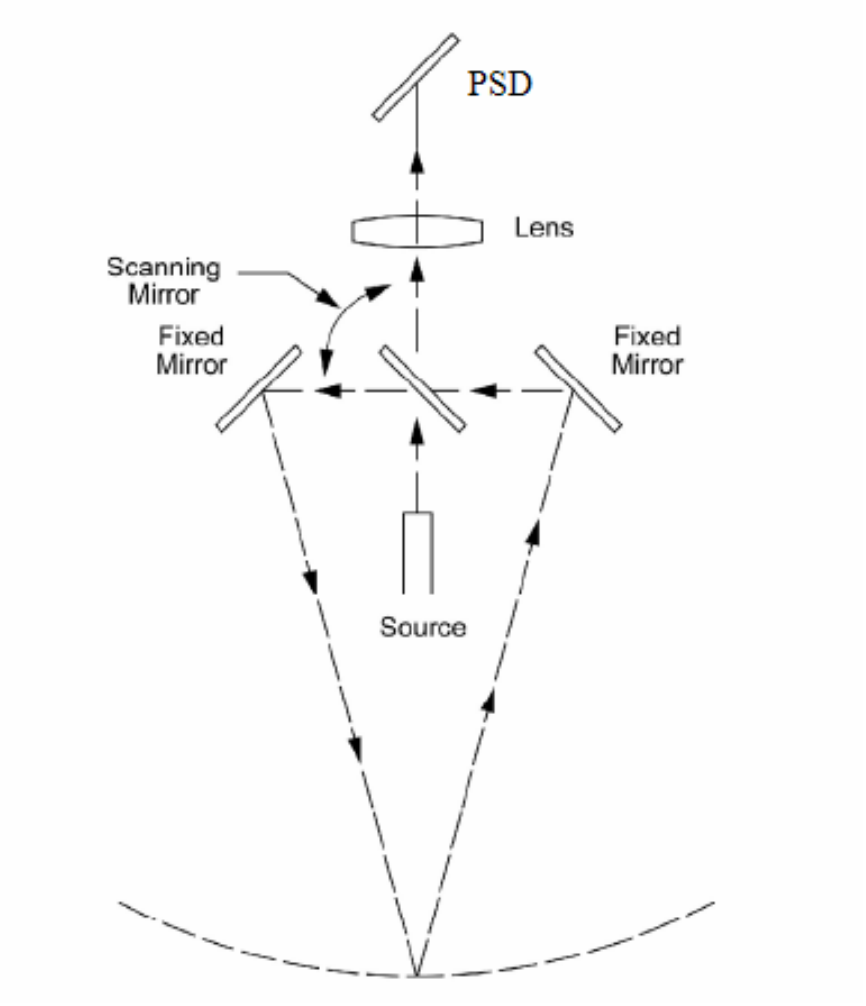


Figure 3 Auto-synchronized triangulation optical system.

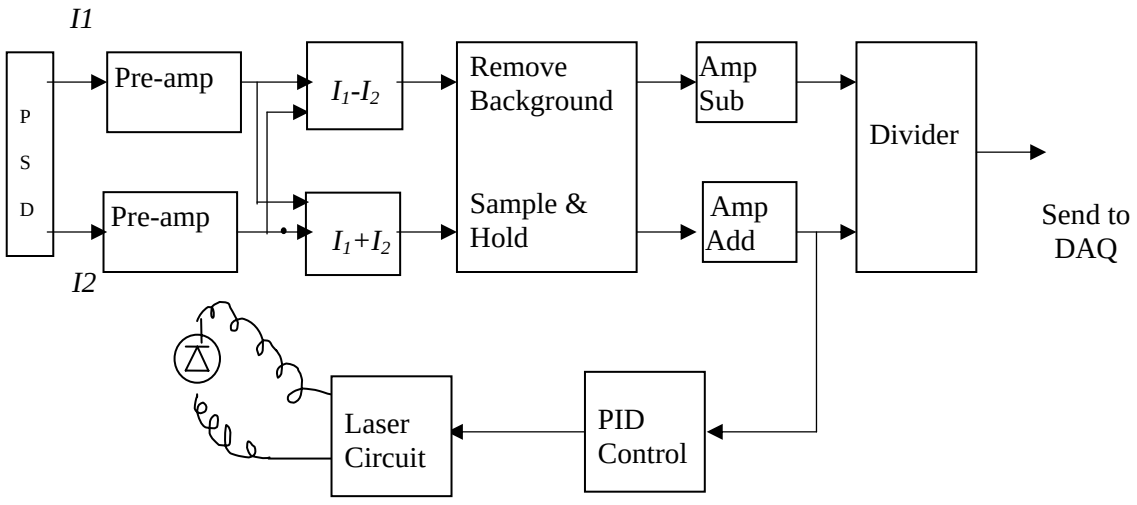


Figure 4 Block diagram of signal processing circuit.

The optical block includes a laser source, position sensitive detector (PSD), laser beam focusing lens, single side coating projection mirror, single side coating recollection mirror, double side coating scanning mirror, and optical filtering component. The laser signal processing block removes the influence from background color, reflectivity changes, and other noises.

The power supply subsystem provides power for the device in the field without using AC power input. Only one 12V battery is needed in the device. By using DC-DC voltage converters and voltage regulators, the 12V voltage is converted to 24V, ±15V, and ±5 V. The converted voltages supply the power for the electronic double side scanner and electronic circuits. Figure 5 shows the block diagram of the power supply system.

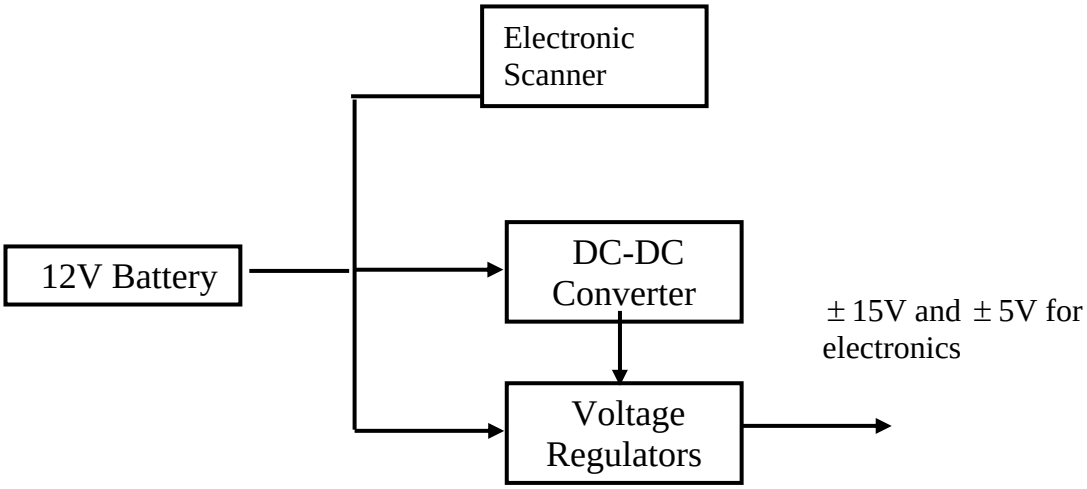


Figure 5 Block diagram of power supply system.

1.3 Performance Description

Figure 6 shows the scanning laser TPMM thickness measurement device mounted on the vehicle used in the field. The device scans the laser beam over the marking material, and a PSD sensor receives the reflected laser beam. The PSD sensor then converts the optical signal to the electronic signal and feeds it to the signal processing circuit. The signal processing circuit sends distance information to the host computer, and the host computer processes and displays the thickness of TPMM in real time.

Figure 6 Scanning laser device in measurement.

The system specifications are as follows:

(1) Standoff distance: 12 inches

The standoff distance means the distance between the laser source and object.

(2) Sample rate: 60 KHz

The laser source is operated in the frequency range of 30 KHz.

(3) Maximum range of measured thickness: 4 inches

This detector has been verified to detect a thickness change of 6 inches.

(4) Scan rate: 100 lines per second

(5) Scan width: 12 inches

(6) Digitization resolution: 12 bits

(7) Average power consumption: 1.5 A at 12V

(8) Maximum measurement resolution: 5 mils

(9) By using the software, you can start a new measurement, and display and save the results.

SECTION 2 HARDWARE INSTALLATION

The scanning laser TPMM thickness measurement system can be installed either on the left side or the right side of the vehicle depending on the requirement. Figure 7 shows the device installed on the left side of the vehicle, and Figure 8 shows the device installed on the right side of the vehicle.

Figure 7 Measurement device mounted on the left side of the vehicle.

Figure 8 Measurement device mounted on the right side of the vehicle.

2.1 Configuration of the Scanning Laser System

Figure 9 shows the configuration of the vehicle-mounted TPMM thickness measurement system. The system consists of the scanning laser measurement device, point laser measurement device, and a driving guide system. The user guide of the point laser TPMM thickness measurement device is in Part 1 of this user manual.

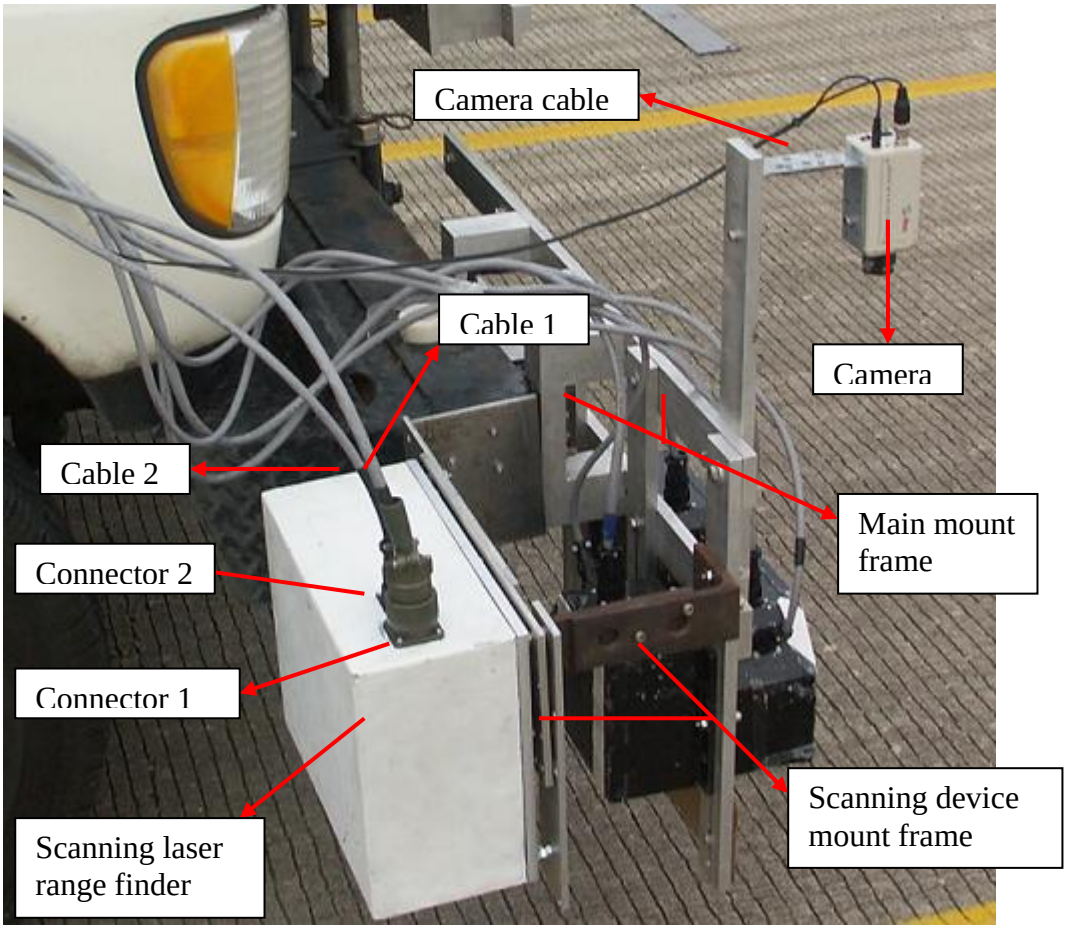


Figure 9 Configuration of vehicle-mounted TPMM measurement system.

The vehicle-mounted TPMM measurement system components are:

- **Scanning laser ranger finder**: transmitting laser beam and processing thickness information.
- **Connector 1**: green color, 19 pin connector on the back of the laser range finder for cable 1 connection.
- **Connector 2**: black color, nine pin (the system only uses four of them) connector on the back of the laser range finder for cable 2 connection.
- **Cable 1**: six twisted-pairs inside, a female green 19 pin connector at one end for connecting to connector 1 on the laser range finder device. The other end is connected to a data acquisition cable. Cable 1 transfers the power supply to the device and transfers the output signal of the device to the DAQ card.

- **Cable 2:** three twisted-pairs inside, a female black nine pin connector at one end for connecting to connector 2 on the laser range finder device. The other end is connected to a data acquisition cable. Cable 2 transfers the sample trigger signal from the laser device to the DAQ card for synchronizing the laser signal and sample procedure.
- **Host computer**: installed data acquisition card and software; the data acquisition card (NI DAQCard-6062E) is a PCMCIA card installed in the socket of a laptop computer. The computer is set up inside the vehicle and connected to the scanning laser range finder by cable 1, cable 2, and the data acquisition cable. Figure 10 shows the connection of the data acquisition cable to the socket in the computer.

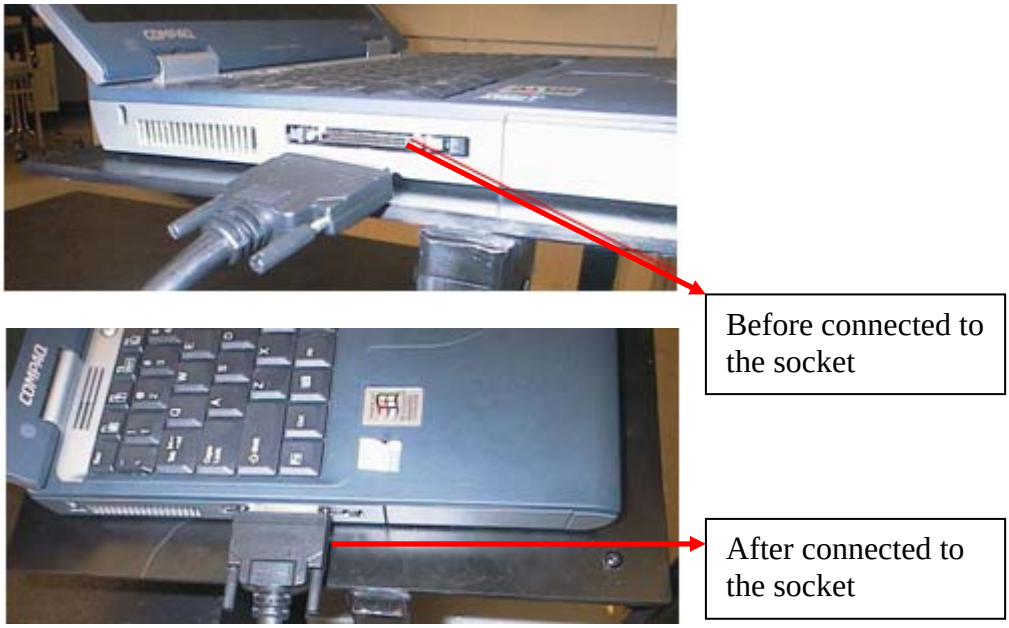


Figure 10 Connection of the data acquisition cable to the socket.

- **Camera:** monitors the driving direction to help the driver direct the vehicle advancing along the pavement marking tape. There is a monitor installed inside the vehicle for displaying the driving situation. Figure 11 shows the monitor inside the vehicle.

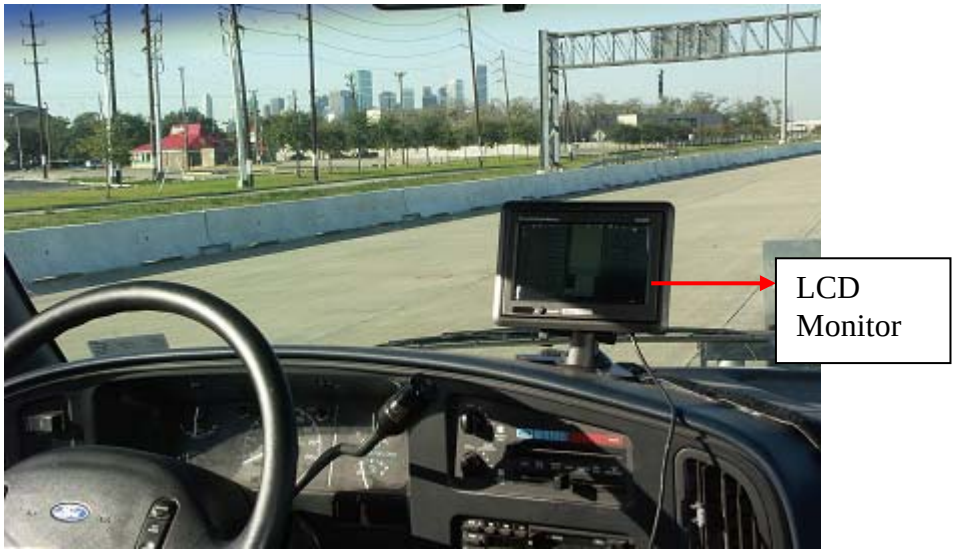


Figure 11 Monitor inside the vehicle.

- **Camera cable:** connects the power supply to the camera and transfers the video signal from the camera to the monitor for displaying. The cable is black with two connectors at each end. One is for power connection, and the other is for video signal connection.
- **Main mount frame:** for mounting the whole system (scanning laser device, point laser device, driving guide system) on the vehicle.
- **Scanning device mount frame:** for mounting the scanning laser device to the main mount frame.

2.2 System Hardware Operation Procedures

The following steps will aid the operator in the startup and operation process:

- **Step 1**: Install the main mount frame on the vehicle. Then install the scanning device mount frame on to the main mount frame. Screw the scanning device onto the scanning device mount frame.
- **Step 2**: Connect cable 1 to connector 1 of the scanning laser device, connect cable 2 to connector 2 of the scanning laser device, and connect the camera cable to the camera.
- **Step 3**: Turn on the 12V power supply, which is installed inside the vehicle. Wait for 30 seconds for the system warm up.

- **Step 4**: Load the software for measurement. The detailed software operation is in the next section.
- **Step 5**: When finishing the measurement, turn off the power supply.

SECTION 3 SOFTWARE OPERATIONS AND DATA INTERPRETATION

3.1 Interface Description

Figure 12 shows the interface of the TPMM thickness measurement software on the laptop computer for the measurement.

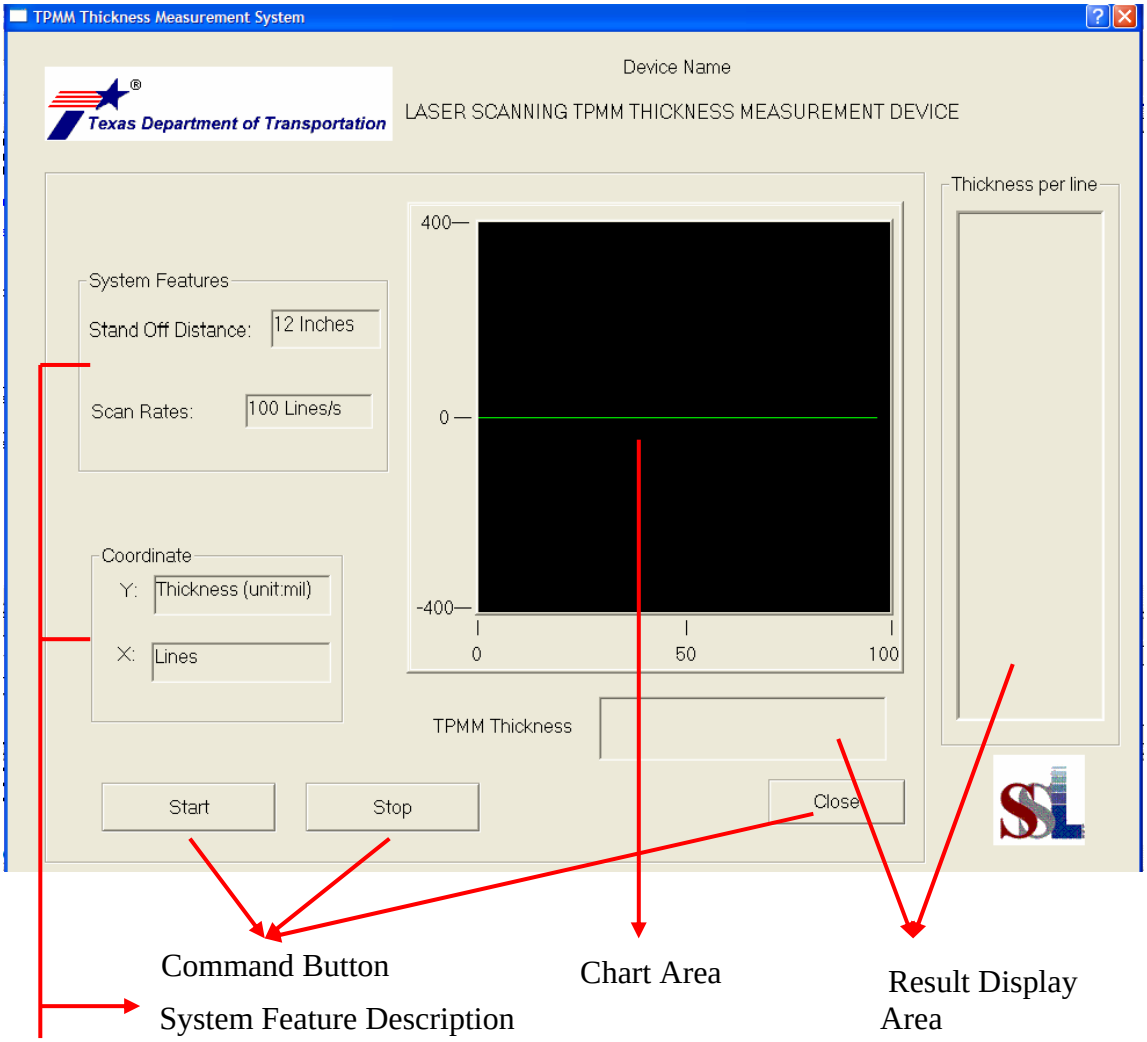


Figure 12 The interface of TPMM measurement software.

There are several parts in the interface. The detailed descriptions of those parts are following:

- **Command buttons**: The command buttons are, from left to right:

Start: start a new measurement.

Stop: stop the current measurement.

Close: close the window and exit the application software.

- **Measurement result:** the TPMM thickness information (unit: mil). Each result of the average thickness of TPMM measured at every scan is shown in the "Thickness per line" area. The result of the average thickness of TPMM measured per second is shown in the "TPMM thickness" area. Figure 13 shows the thickness information on those two result display areas.
- **Chart area:** The chart area shows the average thickness per scan. The chart area can display 100 lines of average thickness information.

  Figure 13 shows the thickness information on the chart area.

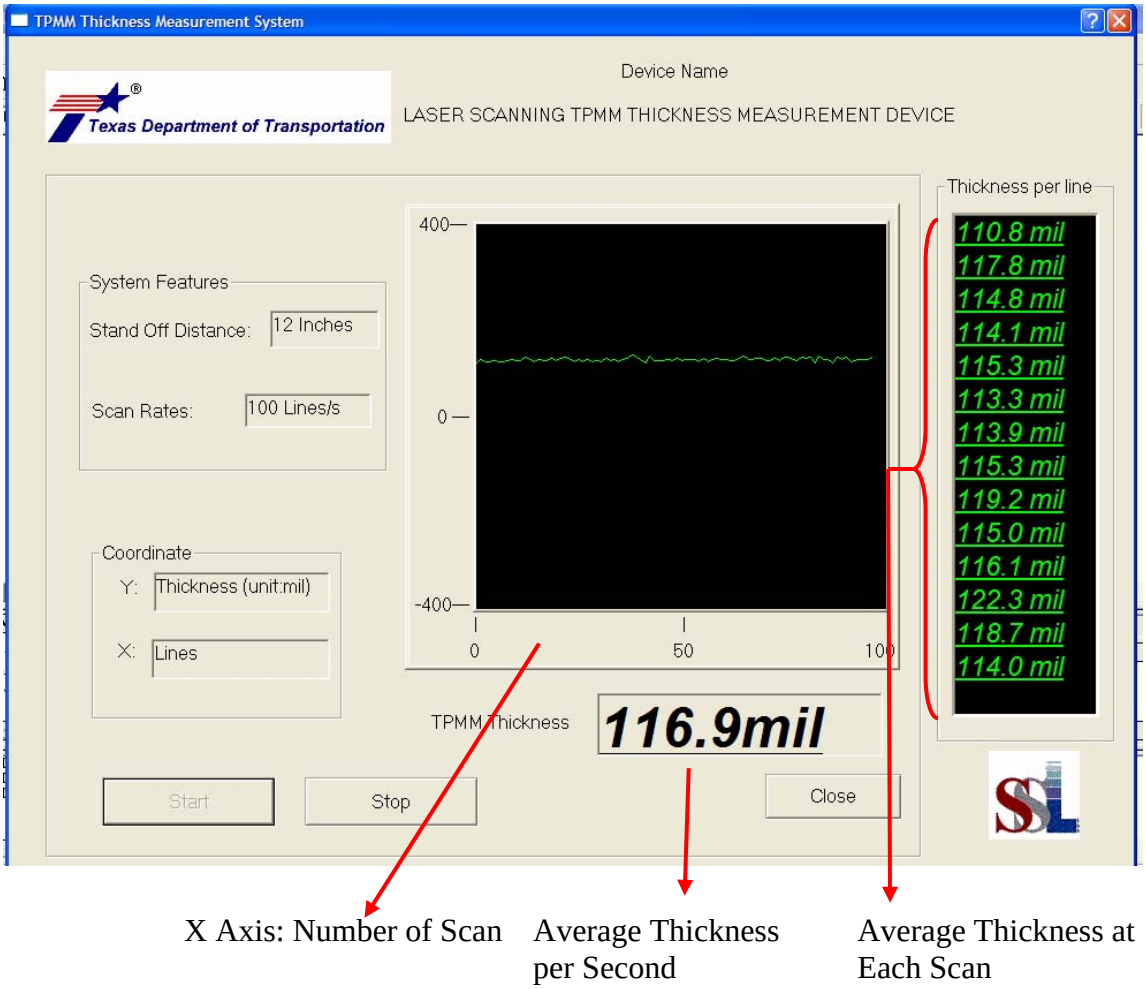


Figure 13 Thickness information display.

3.2 Software Operation

The following are the steps for software operation:

1. Double click Scanning Laser.exe on the desktop.
2. Click the **Start** button to start a new measurement. The **Start** button will turn gray after clicked, which means this button is disabled.
3. Click the **Stop** button to stop the measurement. The **Start** button goes back to normal, which means it is enabled and the system is ready for another new measurement.
4. Click the **Close** button to close the interface window and exit from the software.

Tip:

After you click the **Start** button, a file named "average thickness.dat" is created by the software automatically to store the average thickness of the TPMM measured every second. Every time you click the **Stop** button or the **Close** button, the file is saved in the same directory as the software.

SECTION 4 TROUBLESHOOTING

In the event you encounter a problem, refer to the following for possible solutions.

PROBLEM	PROBLEM CAUSE	SOLUTION
No signal when you just start a new measurement	Power off or connection problem	• Check if the power is on. • Check if cable 1 and cable 2 are connected well. • Check if the PCMCIA cable is connected to computer.
Curve not correct when you start a new measurement	Scanning unstable	Wait for 30 seconds after you turn the power on for scanner warm up. Then start a measurement.

Note:

Disconnect the PCMCIA cable after you shut down the computer. Do not disconnect the PCMCIA card at the same time as the computer is shutting down. Make sure the PCMCIA card is inserted before you turn on the computer so that when you start a new measurement, there will be no error messages.

Tip:

If there is no signal, follow the solution table. If the problem persists, it may be necessary to check if the PCMCIA card works properly. Follow these procedures:

On the desktop, click **Measurement and Automation.**

In the left frame **Configuration**, expand **Devices and interfaces.** Delete device **DAQ6062E.**

Restart the computer. If a new device is found and a driver is needed, **insert the NI driver CD** and follow the instructions.

Restart the computer and test a new measurement.