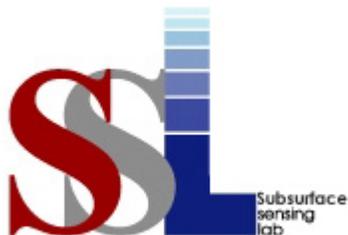


GPR SYSTEM USER GUIDE AND TROUBLESHOOTING GUIDE



Implementation Report 5-4414-01-1

Project Number 5-4414-01



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by

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October 2004

DISCLAIMERS

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.

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1. INTRODUCTION

The GPR technique is based on the measurement of the travel time and the reflection amplitude of a short electromagnetic pulse transmitted through a medium. It can provide continuous and nondestructive measurement compared to some traditional highway detection methods, and is widely applied in thickness measurement, crack detection and pavement moisture-content measurement.

Measurement principle

The GPR system is mainly composed of six parts: a transmitter, a transmitting antenna, a receiver, a receiving antenna, a control/circuit unit (including controlling, sampling, filtering and amplifying functions), and a laptop computer with data acquisition card, used to control the GPR system and process the sampled data. When the control unit receives a command from the computer, it triggers the transmitter to emit a short pulse wave into the space via the transmitting antenna. At the same time, the control unit also sends a command to the sampling unit to get the unit ready for the coming reflected signals. The transmitted wave from the transmitting antenna will propagate in all directions in the space, and part of it will penetrate into the pavement. When the penetrated wave encounters the subsurface interface or rebar, it will be reflected back and be picked up by the receiving antenna. There is also another part of the transmitted wave propagating directly from the transmitting antenna to the receiving antenna or from the transmitting antenna to the pavement ground surface and then bouncing back to the receiving antenna, which is called the direct wave. The received signal is transferred to a laptop by sampling unit and data acquisition card. By processing the received signals, the thickness, dielectric constant and rebar information of the pavement can be obtained.

System block diagram

The block diagram of the radar thickness measurement system is shown in Fig. 1.1.

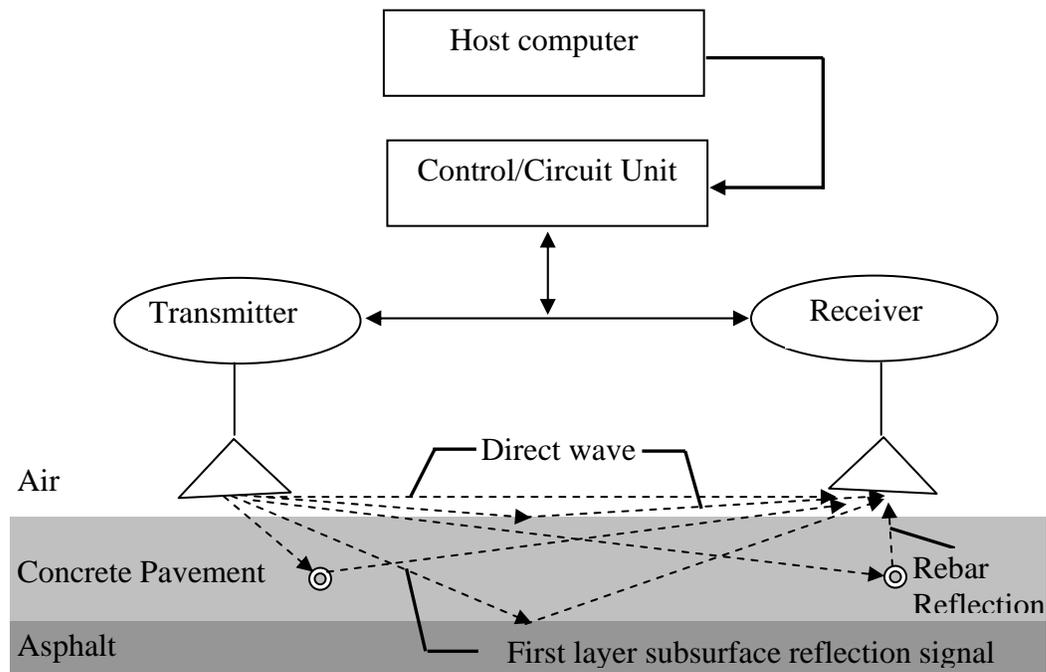


Figure 1.1 Block diagram of the GPR system in pavement thickness measurement

Performance description

The GPR system developed in this project is shown in Figure 1.2. On the cart is installed the encoder, which is used for distance calculation. Inside the black box just above the ground, there are a transmitting antenna and a receiving antenna. The other black box on the cart contains the control/circuit unit, the rechargeable battery and the charger. On the back, there are connection sockets to the encoder, transmitter, and receiver and the power for charging the battery. The output signal is digitized and displayed in a notebook computer.



Fig 1.2 GPR system in measurement configuration

The system performance is as follows:

(1) Maximum Penetration Depth: 30 inches in soil

The radar has been verified to detect pipes buried 30 inches deep in the soil; however, it is not the penetration limit of the radar system.

(2) Transmit Pulse Amplitude: 250 - 530 Vp-p

Usually the higher the transmit pulse amplitude is, the deeper the radar wave can penetrate. However, the higher transmit pulse amplitude strength increases the amplitude of the direct wave, and hinders the recognition of the reflected signals.

The above listed amplitudes are compromised based on experimental results.

(3) Transmit Pulse Width: 5 ns (250 V_{p-p}) – 10 ns (530 V_{p-p})

The transmit pulse width is chosen based on its corresponding comprised frequencies, detection resolution and penetration depth. The higher frequency waves have a higher detection resolution, but decay faster during propagation. The lower frequency waves can propagate at a greater depth, but have a lower resolution.

(4) System Bandwidth: 1.3 GHz

The transmitting waves and the receiving waves are operated in the frequency range from 0 to 1.3 GHz.

(5) Receiver Window: 20 – 60 ns adjustable

The receiver window means a time interval within which the signals received by the receiving antenna are recorded in the computer. The signals out of this time interval are discarded. The receiver window is determined according to the depth to be measured.

(6) System Clock: 100 kHz

(7) Digitization Resolution: 12 bits

(8) Antenna Type: Bowtie antenna

The Bowtie antenna is chosen for the GPR system because it has a wide bandwidth and is easy to construct.

(9) Power Consumption:

0.5 A at 12 V (250 V_{p-p} transmitter), 1.5 A (530 V_{p-p} transmitter)

This is the total power consumed by the GPR system. A car battery provides enough energy for the system to last for a few hours.



(10) Distance encoder resolution: 0.033 inch/pulse

(11) Maximum recorded trace number: 10240

(12) Maximum trace number in one page for multi-trace display: 512, total maximum 20 pages=10240/512.

(13) Each thickness value is calculated using a series of signal traces that are recorded when GPR scans a distance of 4-4.5 feet along the pavement.

(14) The algorithms for the thickness calculation include the consideration of the rebar effect. Together with the hardware, they are quite suitable for the continuous highway measurement.

(15) With the software, you can either start a new measurement, save the results, or open saved files. The friendly interface provides multi-trace map display, single trace display, thickness results and statistical results. From the multi-trace map, the colorful underground information is displayed, and detailed trace information can be obtained from a single trace display. Also, convenient buttons and menus are easily operated. You can also obtain the thickness profiles from the saved results.



2. HARDWARE INSTALLATION

Parts list

Delivered parts include those in Fig 2.1.

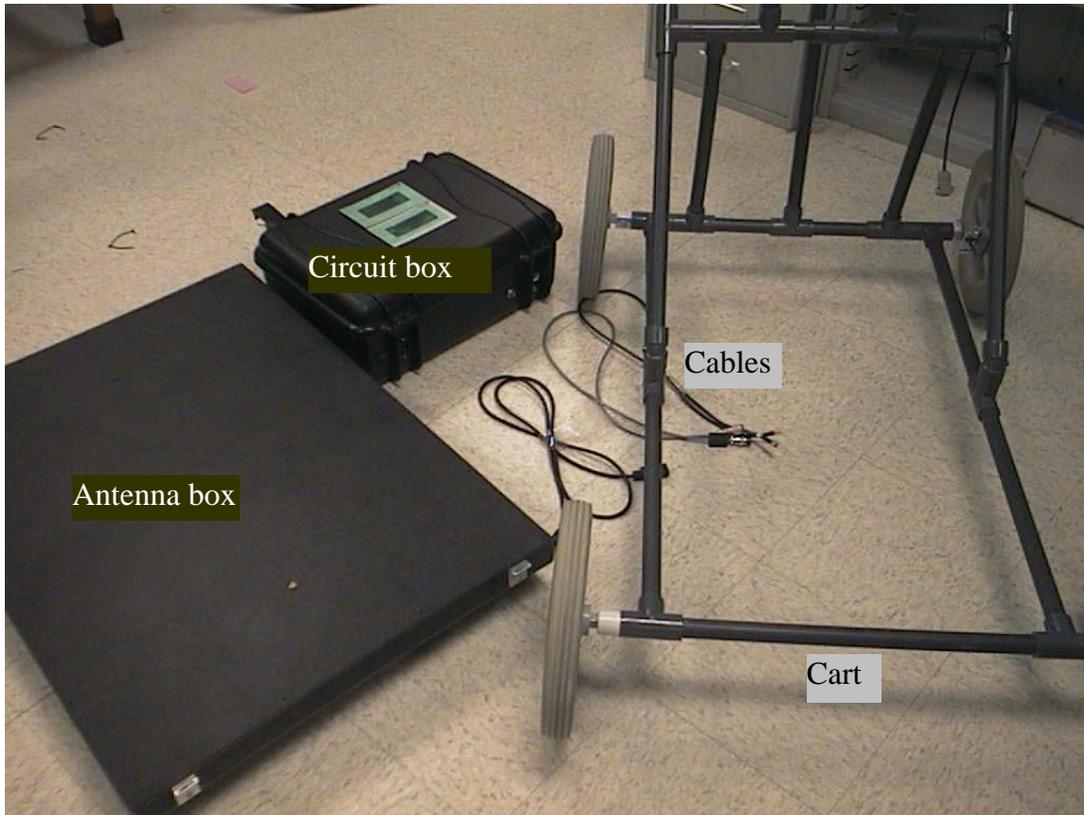


Fig 2.1 System part list

- Cart: with encoder and encoder cable installed
- Antenna box: transmitting antenna and receiving antenna
- Circuit box: a sampling unit, a filtering and amplifying unit, a control unit and a rechargeable battery
- Cables: transmitter cable, receiver cable, and charger power cable

System hardware setup procedure

Follow the steps below (and details in the following sections) to install and configure the hardware.

- Charge battery
- Attach the antenna box and circuit box to the cart
- Connect all cables
- Power on system

Before we go through the details, let us first get familiar with the cables and sockets for connection.

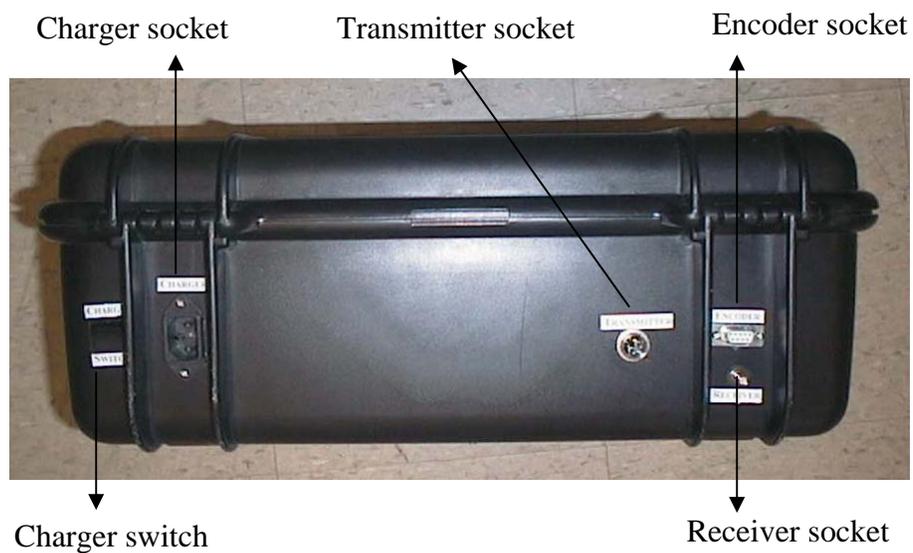
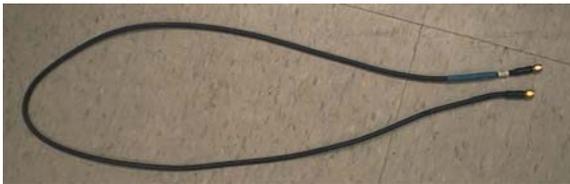


Fig 2.2 Back view of the circuit box

The encoder cable has one end fixed on the encoder on the cart, and the other end (like a serial port), is connected on the back of the circuit box. The other cables look like the following:



5-ft. long 120 Volt charger power cable
3-prong female end: circuit box
3-prong male end: power socket



4-ft. long receiver cable, male ends
1-pin at antenna box end
1-pin at circuit box end



4-ft. long transmitter cable, female ends
4-pin at circuit box end
5-pin at antenna box end

Fig 2.3 Cable notation



Charge battery

Using a charger power cable (Fig 2.3), connect the charger socket (Fig 2.2), to AC power. On average, three hours charge time is appropriate.



Attach the antenna box and circuit box to the cart



Fig 2.4 Attach the antenna box and circuit box to the cart with cable ties

Note: When fixed on the cart, the antenna box should be placed at the height, which is as low as possible, and at the same time makes the movement of the antenna box with the cart smooth for the signal consideration.

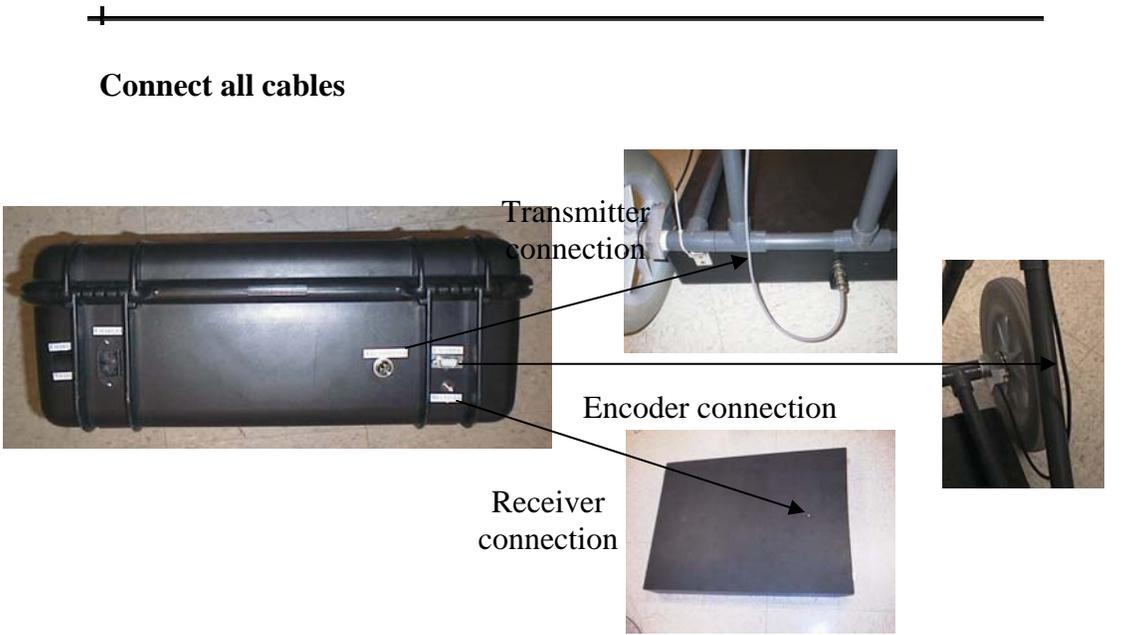


Fig 2.5 Cable connection



Fig 2.6 System after connection

Note:

The encoder is pre-calibrated, so any change or movement is not recommended.

Screw the connection tightly. For the transmitter connection socket on the antenna box (Fig 2.5, upper right picture), push the connection cable head until a click is heard.

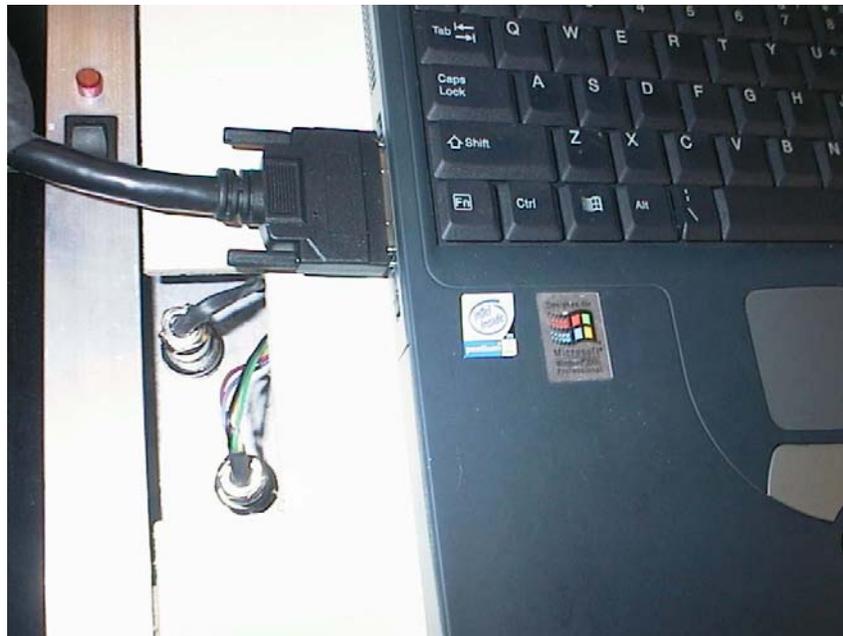
**Connect the PCMCIA card; then turn on the system's power**

Fig 2.7 Inside the circuit box

Connect the PCMCIA cable (which is already inside the circuit box) to the socket in the computer, power on the system, and the small light will turn red. Then start the software for measurement. See next section for detailed software operation.

3. SOFTWARE OPERATION AND DATA INTERPRETATION

Interface description

Fig 3.1 shows the interface of the GPRView software on the laptop computer for the measurement.

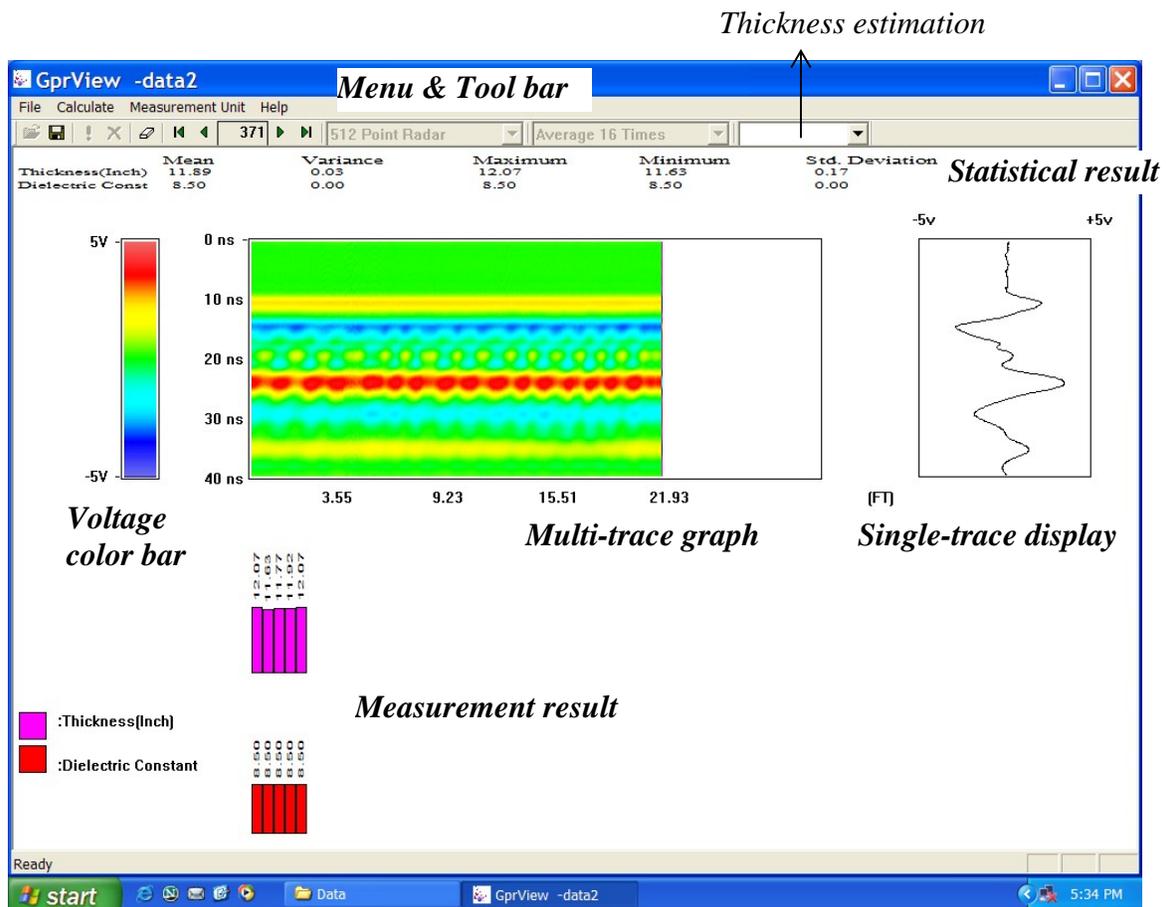


Fig 3.1 The interface for the GPRView software

There are several parts in the interface. From the top are,

Menu and tool bar: function menu and icons. The **toolbar buttons** are, from left to right:

 **Open**, open a saved file, Multi-trace graph, Single-trace display. Measurement result and Statistical result will be updated respectively, and then you can press **Previous page trace**, **Previous trace**, **Next trace**, and **Next page trace** to see trace detail, 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**, **Previous trace**, **Next trace**, and **Next page trace** to see trace detail, 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 corresponding trace on the previous page, if the current trace is on the first page, it will change to the first trace

 **Previous trace**, change the current trace to the trace just before it
Current trace index (display only)

 **Next trace**, change the current trace to the trace just after it

 **Next page trace**, change the current trace to the correspondent trace on next page, if the current trace is on the last page, it will change to the last trace

Radar type (display only)

Stacking number (display only)

Thickness estimation drop box, it includes the ranges of 6"-8", 8"-10", 10"-12", 12"-14", 14"-16", 16"-18", 18"-20". The estimated thickness will be around the selected range, possibly beyond the selected range a little bit. It is recommended that you select the estimated thickness range before measurement; the default is 10-12 inches if there is no selection.

For the menus:

File, include the open file menu and save file menu, which provide the same functions as those by clicking the icons  and  respectively

Calculate, un-accessible, for algorithm debug only

Measurement unit: English or Metrics; default English

Statistical result: statistical analysis of the measurement result.

Color bar: relationship between the color and signal value for the Multi-trace bar.

Multi-trace graph: a three-dimensional chart. The x-axis means moving distance. When you move the radar on the ground, the traces and their distances are displayed from left to right. The y-axis actually means the propagation time, the same meaning as y-axis in the single-trace chart. The color means value indicated in the color bar.

Single-trace display: also current trace chart (the trace index is shown on the current trace index display of the toolbar). The x-axis means signal value, the y-axis means propagation time.

Measurement result: the thickness and dielectric constant information. Each bar provides the result of one measurement cycle, not of one trace, because the algorithm needs several traces (one measurement cycle) to locate the rebar location and cancel its effect. Since several traces cover at least one time distance between adjacent rebars, we set it at approximately 4 feet.

Software operation**Note :**

When you want to start the measurements in a different folder, copy GPRview.exe together with wavelet.dat to the new folder.

I. Start a new measurement.

1. Double click the GPRView.exe on desktop
2. Select the estimated thickness range and preferred measurement unit (optional)
3. Click the **Start** to start a new measurement
4. Move the cart slowly; the interface will update as the cart moves forward
5. Click the **Stop** to stop the measurement
6. See the results or click **Previous page trace, Previous trace, Next trace, and Next page trace** for trace detail
7. If useful, **Save** the result
8. **Erase** the result, then go to I.2 for a new measurement or II.2 to open a new file

II. Open a saved file

1. Double click the GPRView.exe on desktop
2. Click **Open** to look for the saved file; the interface will update according to the saved file
3. See the results or click **Previous page trace, Previous trace, Next trace, and Next page trace** for trace detail
4. **Erase** the result, then go to I.2 for a new measurement or II.2 to open a new file

Tip:

Except for I.5 and II.3 to see the trace detail, you can also click the mouse at your interested parts in the multi-trace chart. The current trace will change to the trace, which you click, and at the same time a horizontal line and a vertical line will appear for reference; then you can move around by **UP**, **DOWN**, **LEFT** and **RIGHT** on the keyboard for details. If you press outside the multi-trace chart, the horizontal line and the vertical line disappear and the multi-trace chart is updated.

Note:

When you want to save the results, the file name should not include the dot(.); for example, **FebResult**. Then four files are created to save the results: **FebResult**, **FebResult.dis**, **FebResult.cle**, **FebResultthickness.dat**.

The next time you want to open the file by GPRview.exe, open the one with the exact name such as **FebResult**, with no suffix, no appended characters.

Among the four files, the **FebResultthickness.dat** file provides you with the measurement results like thickness, dielectric constant, start distance and end distance, from which you can get the thickness profile through Excel.

If you want to move the saved file to another folder, move the four files together.

Data interpretation

Multi-trace chart: visual information of measured trace. In Fig 3.1, the periodicity represents the periodical existence of rebar underground. You can also get the approximate horizontal position of rebar with this chart as well as a vertical location by combing with the **Single-trace charts** for the subsurface reflection.

Single-trace chart: detailed information for current trace

Measurement result: the thickness and dielectric constant information of one measurement cycle, which are obtained from several traces covering at least one time distance between adjacent rebar.

Statistical result: statistical analysis of the measurement result.

Later, rebar locations can also be added into the measurement results after the new algorithm is mature.

Thickness profile:

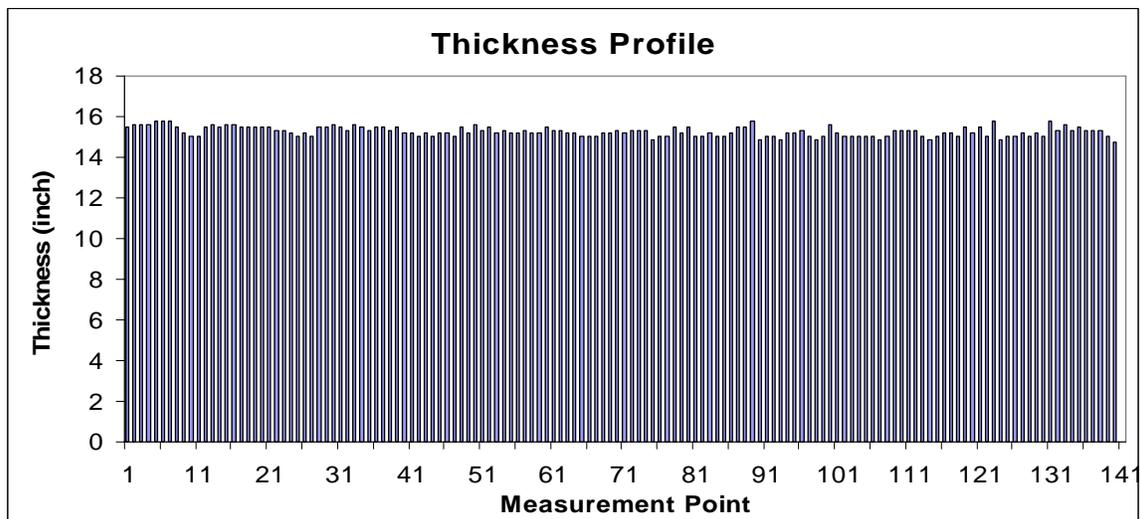


Fig 3.2 GPR thickness over 1000 FT I-45 N. Conroe, Site 1091-1081

4. TROUBLESHOOTING

In the event of a problem, refer to the following for possible solutions:

PROBLEM	PROBLEM CAUSE	SOLUTION
No signal or wrong information when you just start a new measurement	Power off or Connection problem	<ul style="list-style-type: none">• Check if the battery has enough capacity• Check if the power is on• Check the encoder cable, transmitter cable and receiver cable connection• Check if the PCMCIA cable is connected to computer
File open error	Wrong files	Open the exact right file name, no appended characters; if files are moved to a new folder, remember to move four files together
Too less traces after a certain distance	Speed is too fast	Move slowly
No error in old folder, but error appears in new folder when the first calculation is just beginning after certain traces are obtained	Forget the parameter file, wavelet.dat	When you want to start the measurements in a different folder, copy GPRview.exe together with wavelet.dat to the new folder.

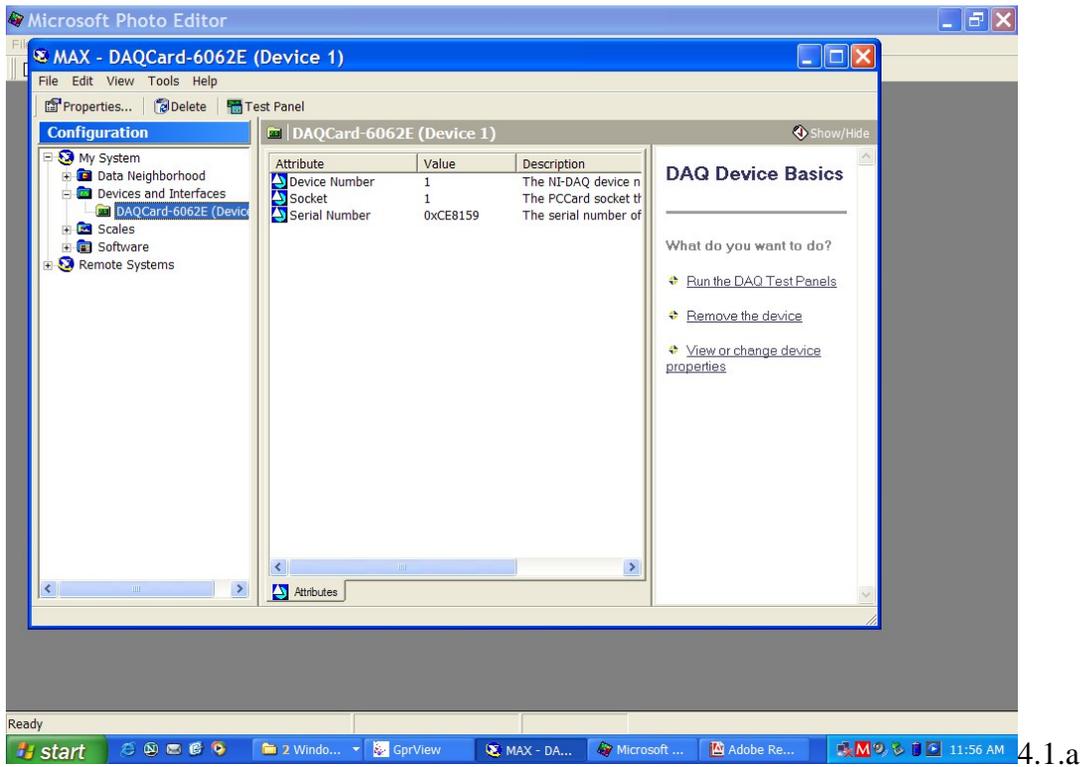
Note:

When you want to disconnect the PCMCIA cable, do it after you shut down the computer in case you disconnect the PCMCIA card unintentionally. And if the PCMCIA card is moved out, reinsert it before you power on the computer. If, when you start a new measurement, there is an error like no signal, follow the next tip.

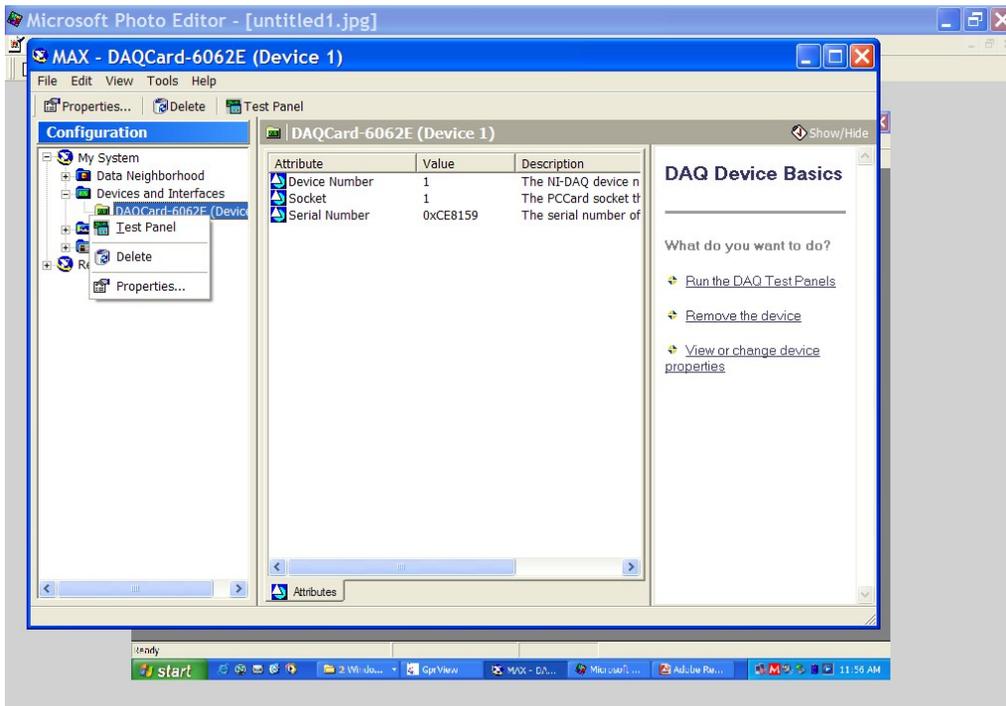
Tip:

Sometimes, when there is no signal, follow the solution table above. And if the problem is not fixed, check to see if the PCMCIA card works correctly. Follow the next procedures.

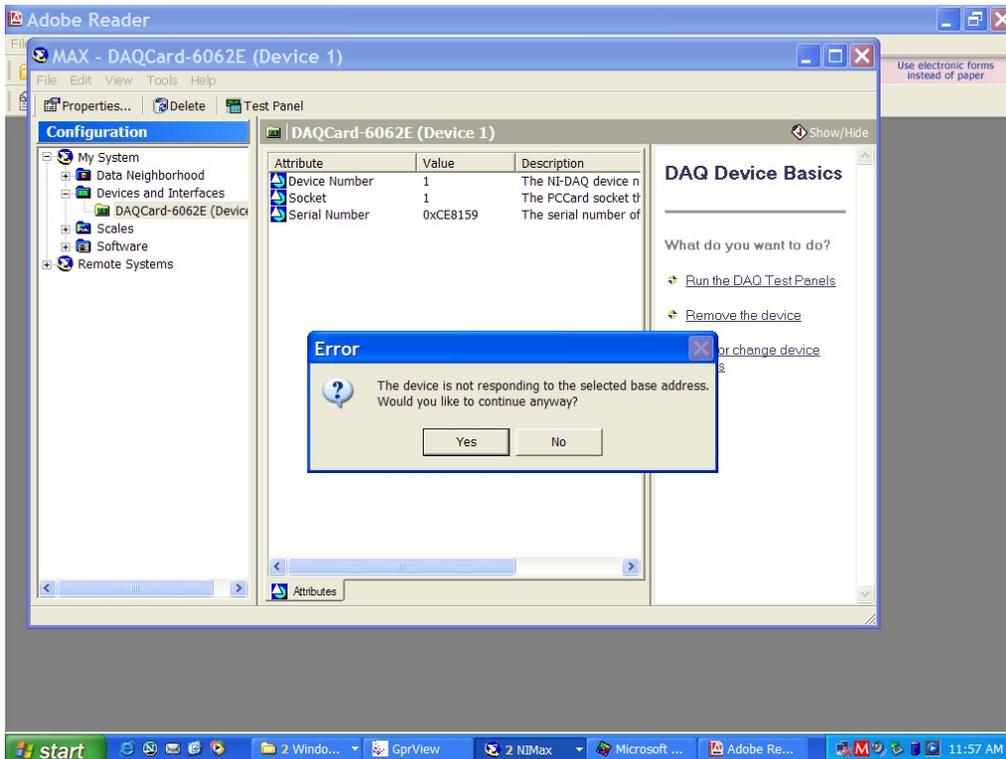
From **Program**, click **Measurement and Automation** and a window like that shown in [Figure 4.1.a](#) will appear. Expand **Devices and Interfaces**; the device of **DAQCard 6062E** should be in the list.



Right click **DAQCard 6062E**, then press the **test panel** menu. If an error message like 4.1.c pops up, click yes to continue, then go to 4.1.d.

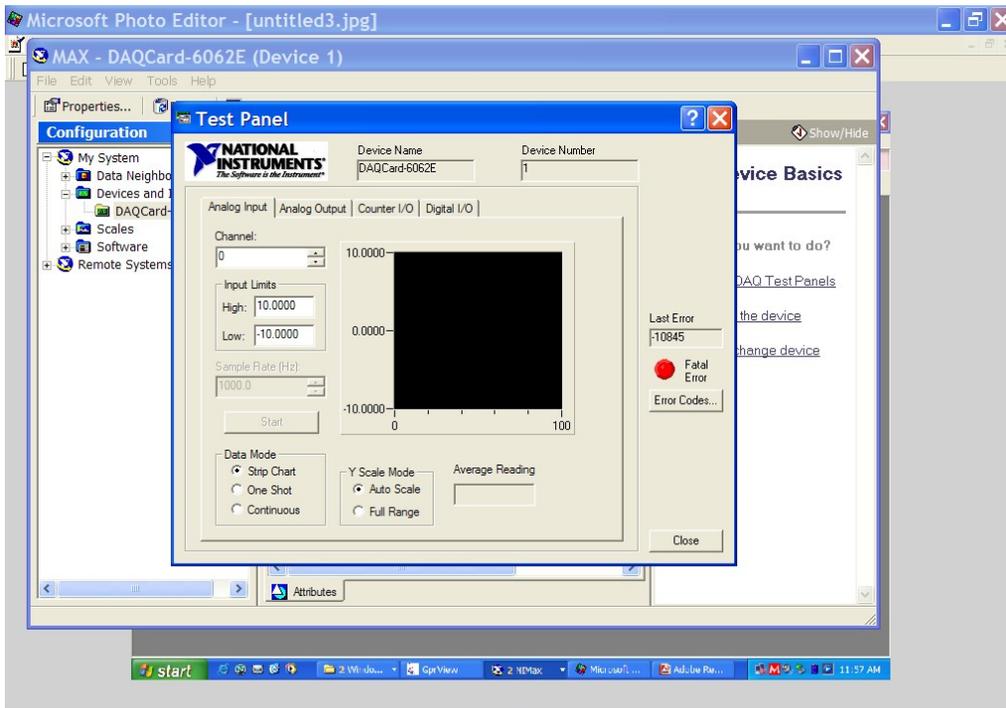


4.1.b

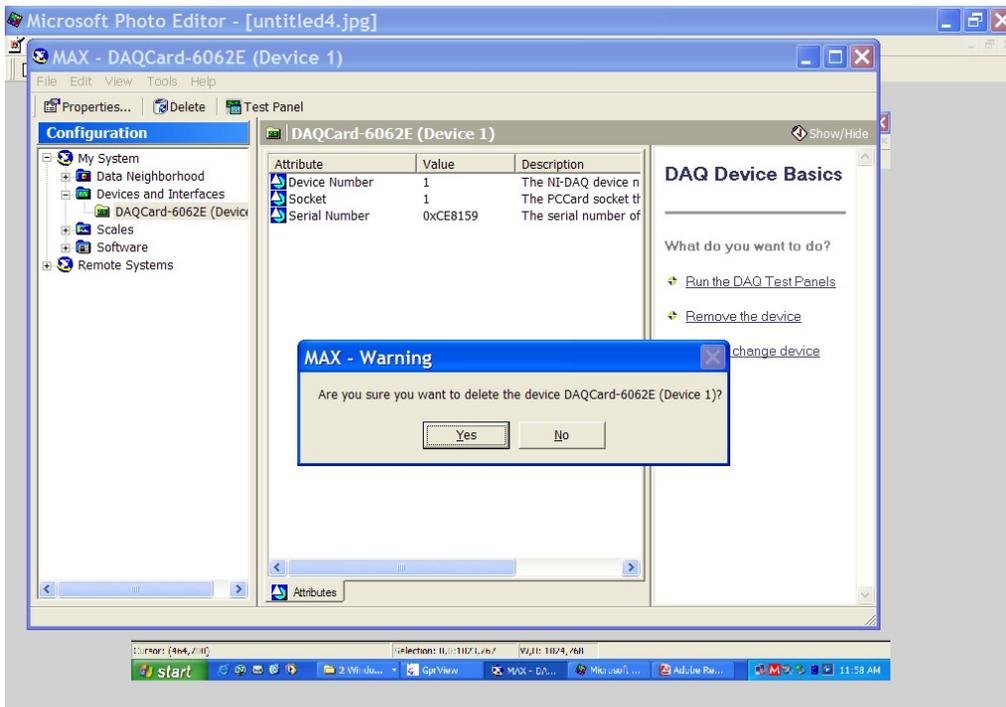


4.1.c

If an icon indicating error is red in Figure 4.1.d, that means the problem is exactly what we expect. If it is not red, it does not matter.



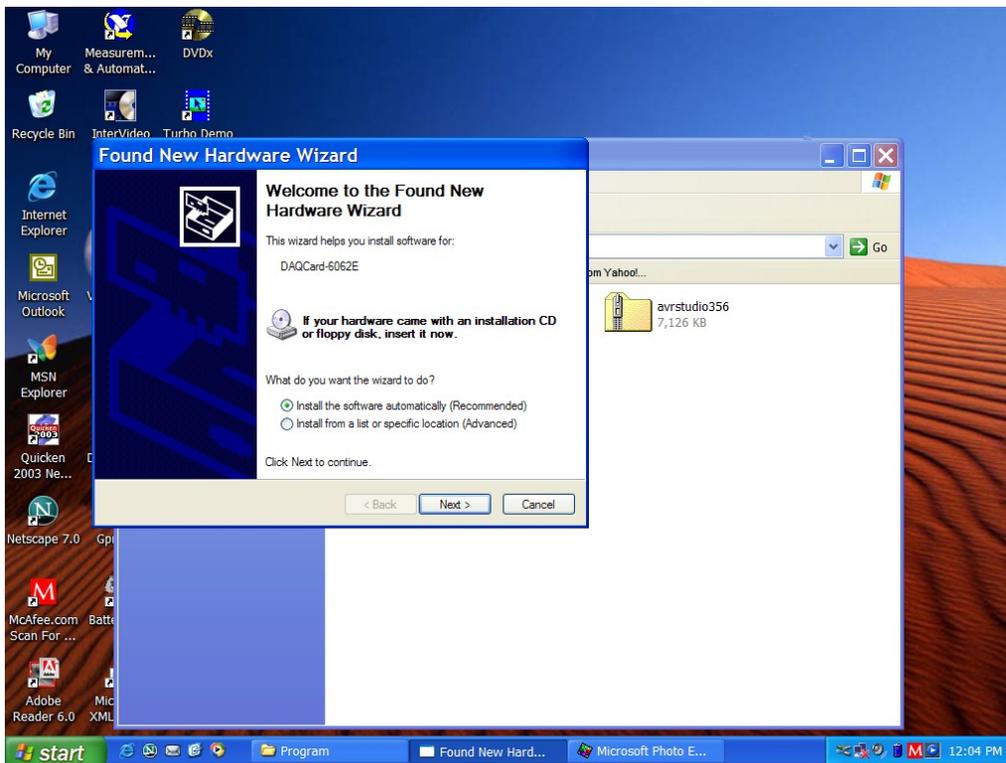
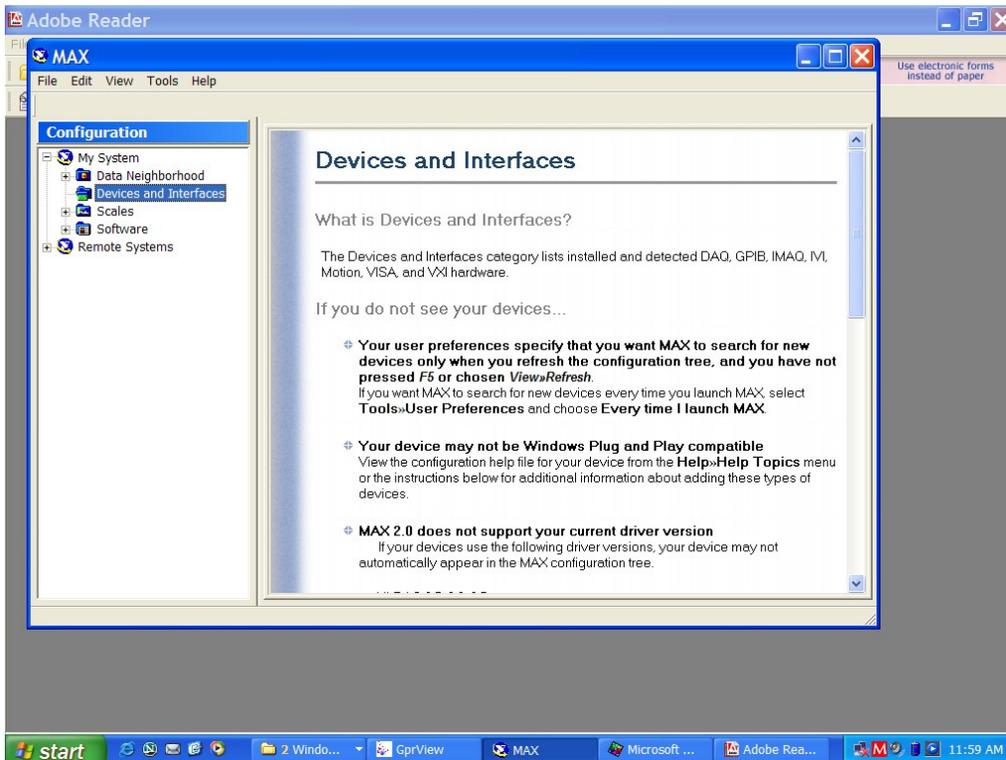
4.1.d



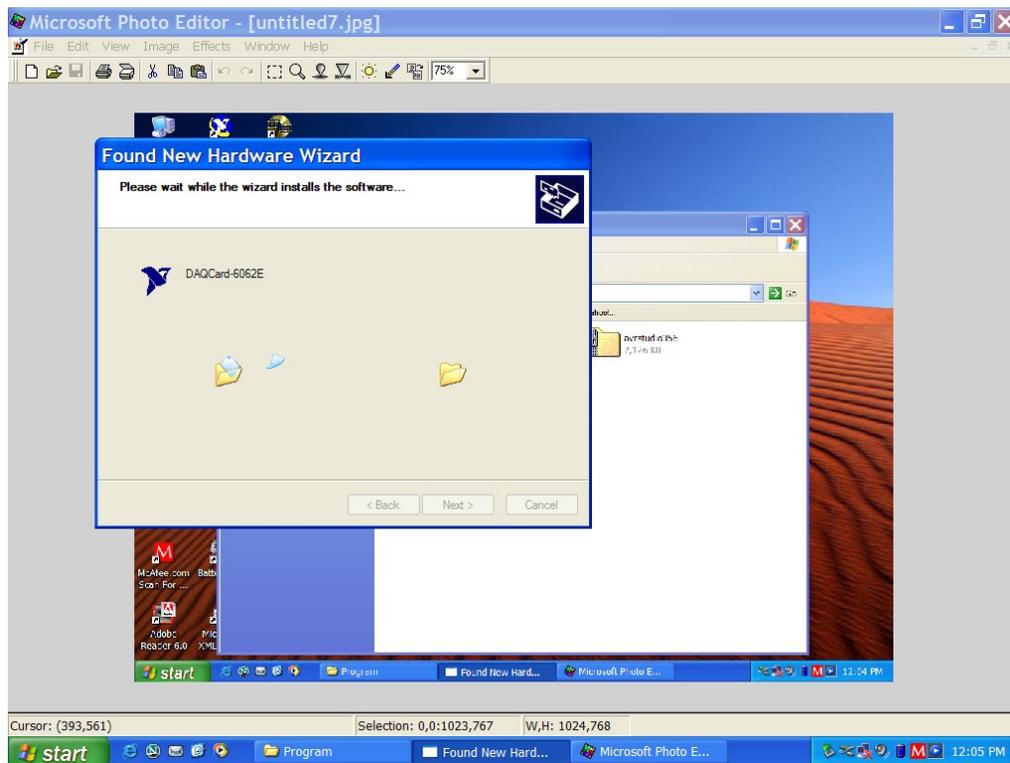
4.1.e



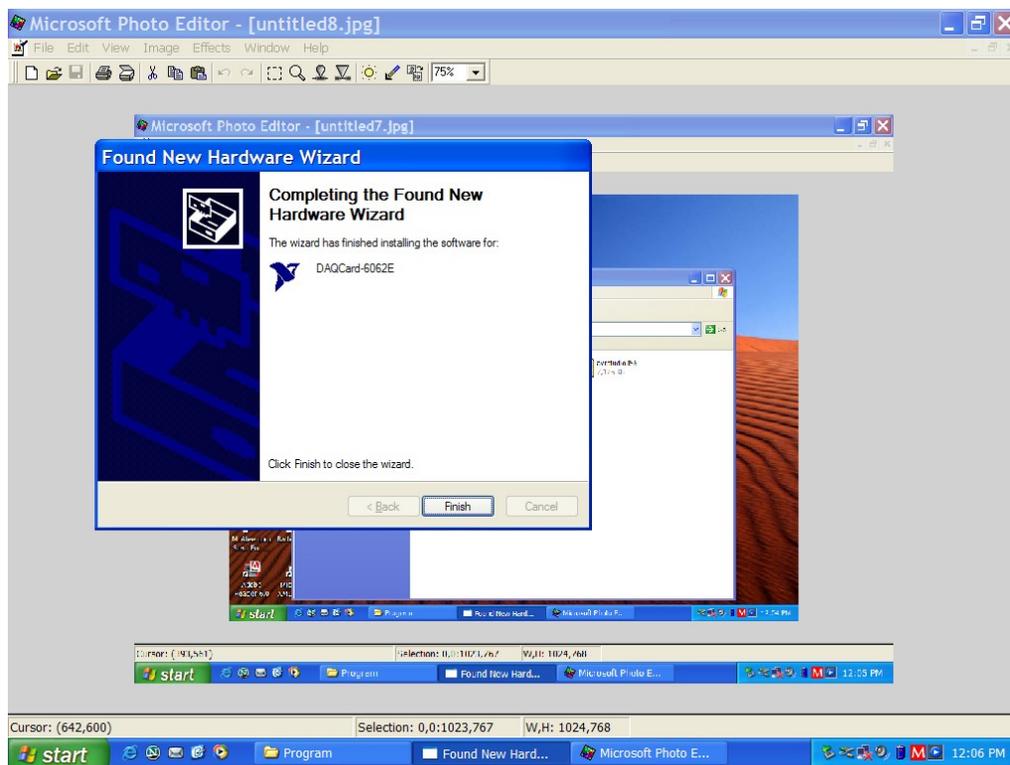
Select **DAQCard 6062E**, press **Delete** on the keyboard, the card will not be in the list as shown in [Figure 4.1.f](#).



Restart the computer. Found new hardware wizard appears as in [Figure 4.1.g](#). Choose the recommended installation, then go to [Figure 4.1.h](#) and [4.1.i](#).

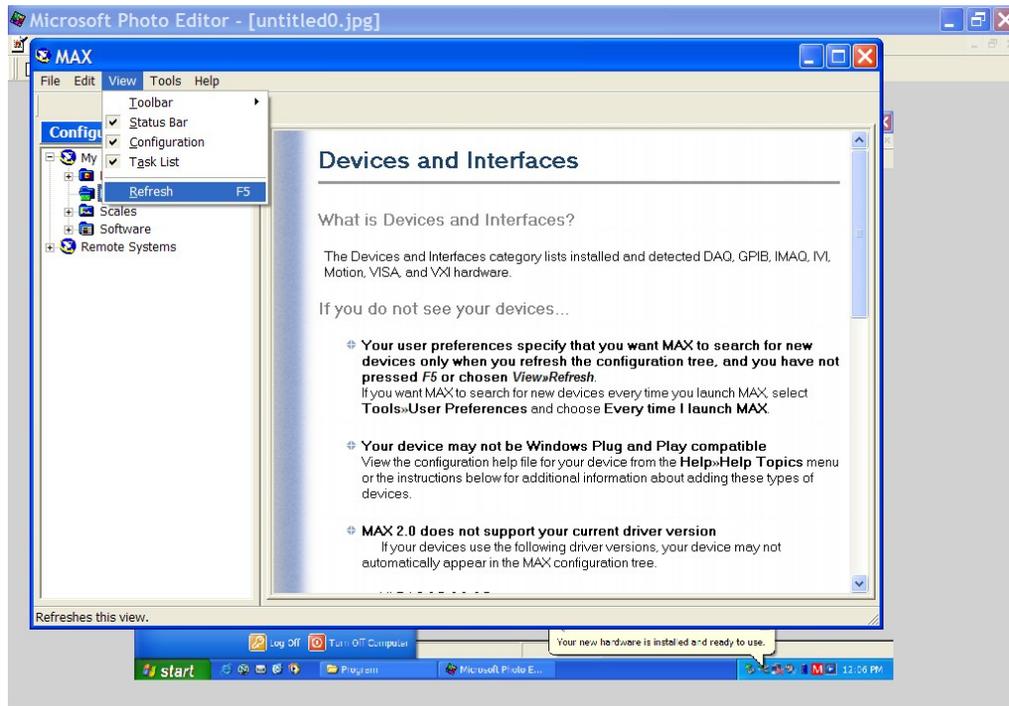


4.1.h

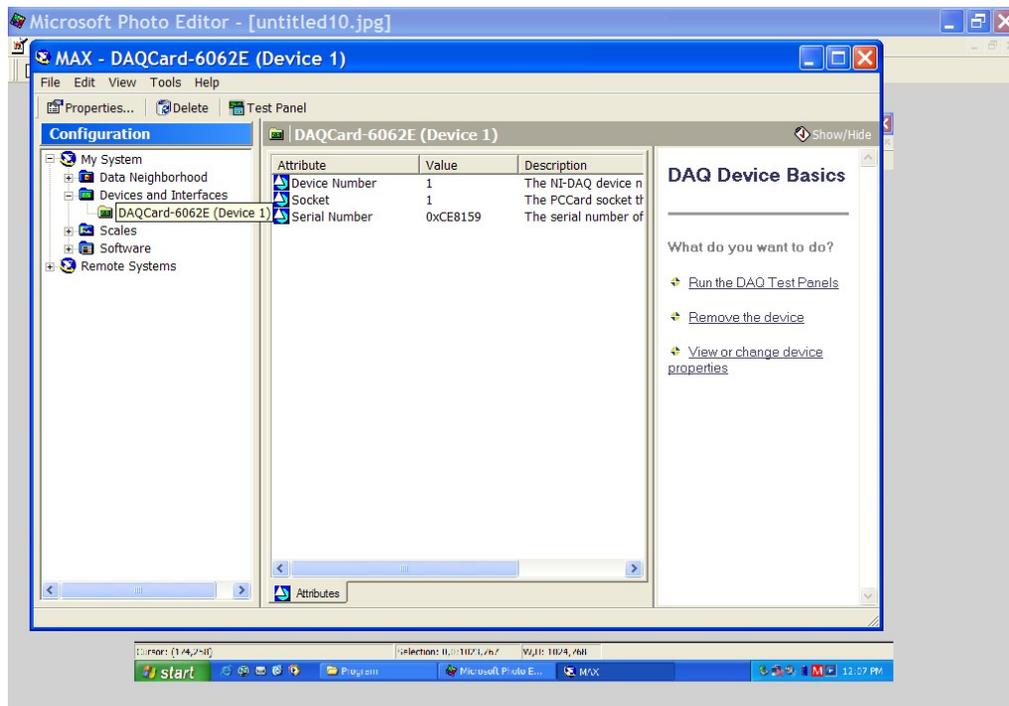


4.1.i

Open **Measurement and Automation**, click menu **View->Refresh**. The device of **DAQCard 6062E** will appear under **Devices and Interfaces** as in **Figure 4.1.k**.



Cursor: (174,258) Selection: 0,0:1023,767 W,H: 1024,768 4.1.j



Cursor: (522,746) Selection: 0,0:1023,767 W,H: 1024,768 4.1.k

Open the **test panel**, the red light turns off as in [Figure 4.1.1](#). Then **start** the GPRView.exe, and it will return to normal. The problem is because of the driver, and it can be solved in this way.

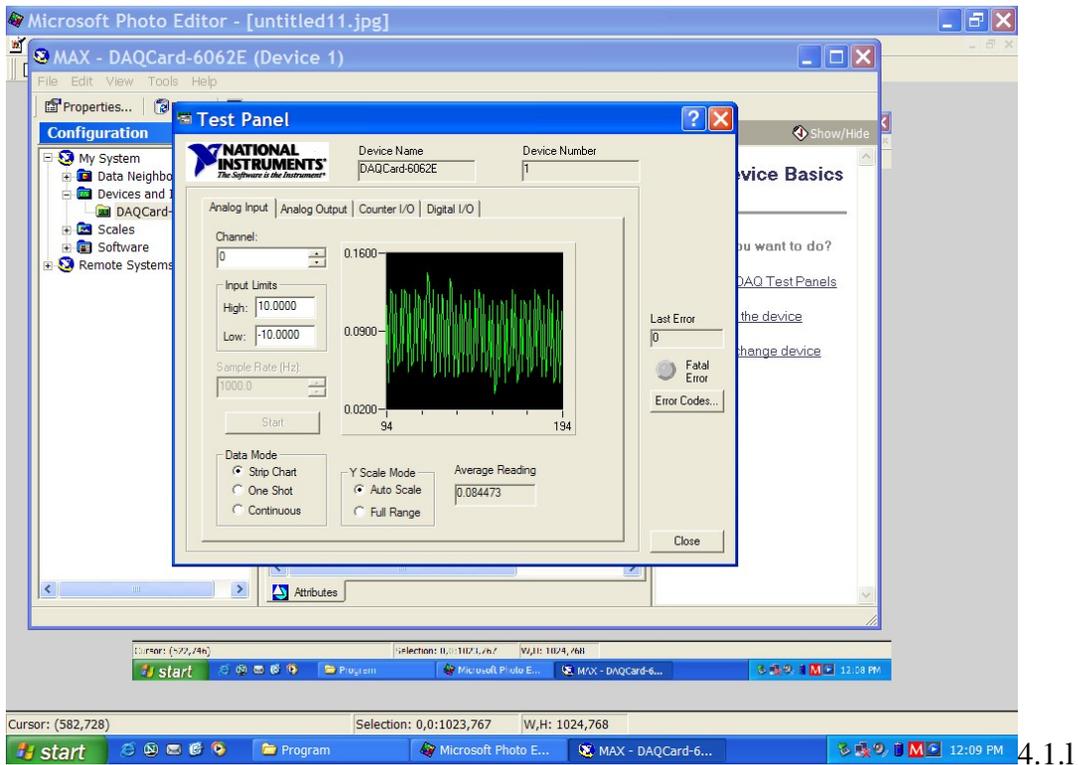


Fig 4.1 NI card problem solving procedures