C

DATA ACQUISITION HARDWARE

This Appendix describes the PC-based instrumentation used by the Irish team for acquiring data in the different experiments described in Chapter 8. This instrumentation is based on the SCXI product line from National Instruments[13]. The SCXI system is used as a front-end signal conditioning system cabled to a PCMCIA DAQ card as depicted in Figure C.1, and it includes: analog input signal-conditioning modules, chassis, terminal blocks and cabling assemblies. Analog signals from the modules are multiplexed back to the DAQ card, which acts as a system controller and digitizes the conditioned signals directly into PC memory.

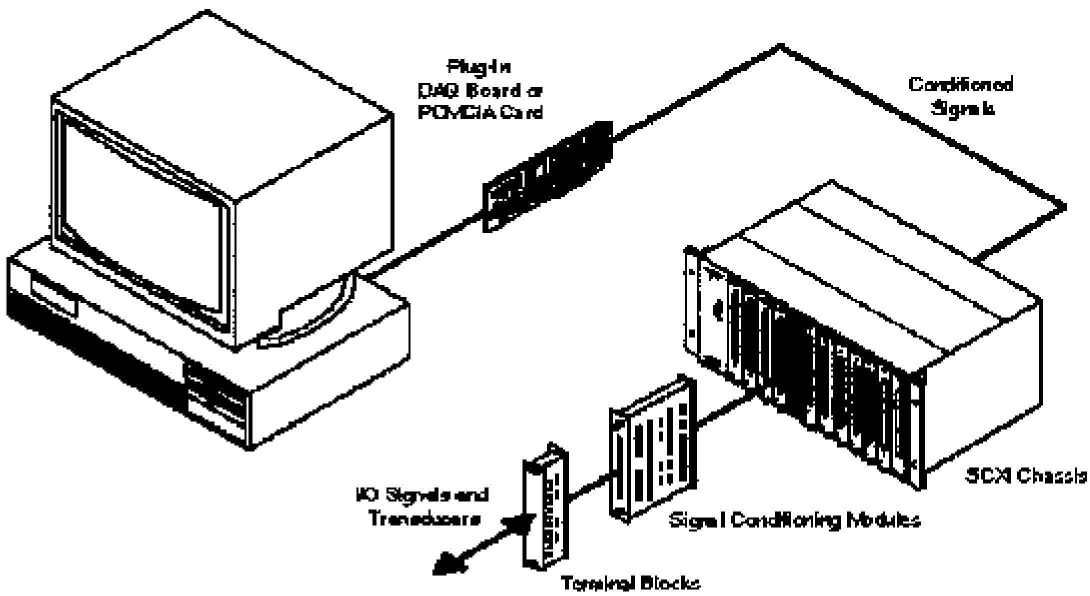


Figure C.1 – SCXI Signal Conditioning Front-End System for Plug-In DAQ Boards[13]

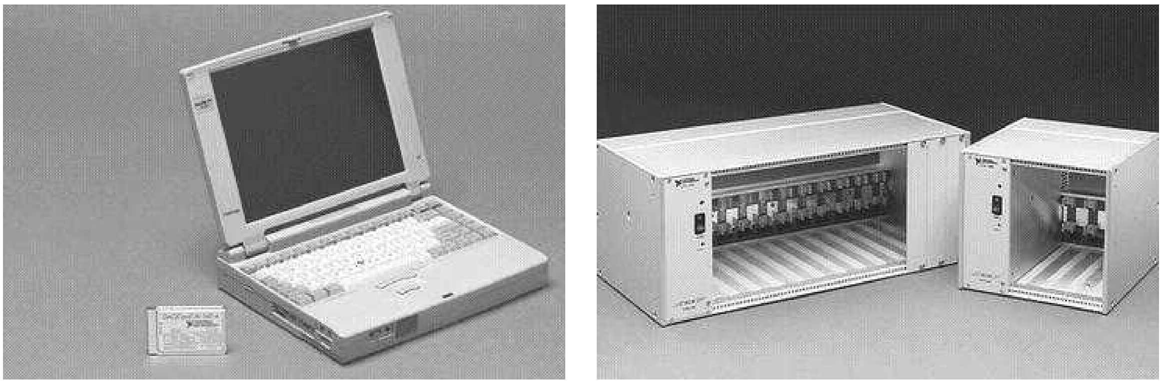
Personal Computer

The personal computer incorporates a PCMCIA port for data acquisition (Figure C.2(a)). The data transfer capabilities of the computer can drastically limit the maximum speed of data acquisition. DAQ cards and computers capable of making DMA (**D**irect **M**emory **A**ccess) transfers are recommended. DMA uses dedicated hardware to transfer data directly into the system memory, and the processor is released for the accomplishment of other tasks.

The size of the hard drive limits the amount of data that can be acquired. Apart from the memory size, high-speed and unfragmented drives are recommended when large amounts must be recorded.

Chassis

The SCXI chassis circuitry acts as a conduit for signal routing, transferring data, programming modules and passing time signals. The model SCXI-1001 used in the experiments is represented in Figure C.2(b). This is a 12-slot chassis, that can be chained up to other eight chassis with a single DAQ device and is ideal for high-channel count systems (National Instruments 1996). Signals can be scanned from several modules in several chassis at rates up to 333 kS/s. The cable assembly that will connect the PCMCIA card to the SCXI chassis must be selected according to the card type.



(a) Data Acquisition Card and Labtop (b) Chassis SCXI-1001

Figure C.2 – Data acquisition components[13]

Signal Conditioning

The mission of the modules handling signal conditioning include:

- Amplifying the low strain signals to increase the resolution and reduce noise. Gain is applied to the low-level signals within the SCXI chassis located close to the transducers, sending only high-level signals to the PC, minimising the effects of noise on the readings.

- Isolating strain signals and computer to protect the computer from high-voltage transients and strain readings from differences in ground potentials.
- Multiplexing, this is, a single measuring device samples one channel, switches to the next channel, samples it, switches to the next channel, and so on. Because the same analog-to-digital converter (ADC) is sampling many channels instead of one, the effective sampling rate of each individual channel is inversely proportional to the number of channels sampled.
- Filtering unwanted signals (i.e. noise) before being digitised by the DAQ card.
- Generating external voltage required by strain or road sensors.

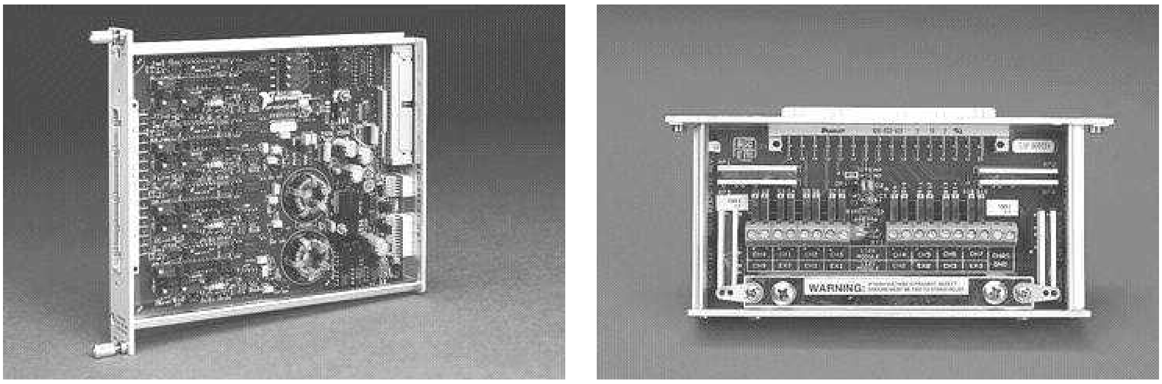
The SCXI-1121 (Figure C.3(a)) is a 4-channel isolation amplifier module with transducer excitation sources (3.333 / 10 V). The SCXI-1121 includes a gain amplifier (1 to 2000) and lowpass noise filter (4 Hz / 10 kHz) with complete channel to channel electrical isolation (250 Vrms). Gain and filtering are independently configurable on each channel via jumpers. The maximum sampling rate is 333 kS/s, though it will depend on the DAQ card and cable assembly. The module also includes half-bridge completion circuitry consisting of two 4.5 kΩ resistors. This circuitry is enabled when using strain gauges in a quarter or half Bridge configuration and disabled when taking measurements from a full Bridge or road sensor.

The channel in the SCXI-1121 is configured for gain 2000 and 3.333 V voltage excitation (e_o) if recording a signal from strain gauges of the type described in Section 4.2. Channels receiving a signal from pneumatic converters are configured for gain 1 and 3.333 V (Section 4.3.1). The gain and voltage are chosen to provide a current that allows the acquisition of strain or rubber tube measurements successfully. When piezos were employed, as their interface requires a higher excitation voltage than the one provided by the SCXI module, an extra 15 V external source was applied.

The SCXI-1321 terminal block (Figure C.3(b)) connects signals from strain transducers or road sensors to the module block. It consists of screw terminals in a fully shielded enclosure with strain-relief clamps that hold signal wires securely in place. In combination with the SCXI-1121 module, this terminal block adds manual offset nulling and programmable shunt calibration for each channel. If the bridge is balanced, e_i*(unstrained)* in Equations 4.2, 4.4 and 4.5 becomes zero. When a quarter bridge is necessary, an extra resistor must be placed between the positive input channel and the negative excitation output.

Field Wiring

The integrity of the acquired data depends upon the entire analog signal path. Interference noise can be minimised by proper cabling and shielding. The Irish team uses a 4-core signal cable. Each core consists of a 7/0·2 mm-tinned copper-stranded conductor, insulated with PVC.



(a) Module block SCXI-1121 (b) Terminal block SCXI-1321

Figure C.3 – Electronic components[13]

Sampling Rate, Resolution, Range and Gain

According to Nyquist's Theorem, an analog signal containing components up to some maximum frequency f_1 Hz may be completely represented by regularly spaced samples, provided the sampling rate is at least $2f_1$ samples per second. This corresponds to two samples per period of the highest frequency present and it is a minimum sampling rate which avoids aliasing. In practise, a higher sampling rate is chosen to leave a margin between adjacent spectral repetitions. Generally, the highest frequency component with a significant contribution to the bridge response would be well below the frequency of main power supply (50/60 Hz), a source of unwanted noise. However, a minimum scanning frequency of 200 Hz is recommended for an accurate synchronisation between strain readings and axle detectors or for FAD purposes (Section 4.3.2).

Two different types of resolution have been used: a 12 bit card (model DAQCard-AI-16E-4[13]) and a 16 bit DAQ card (model DAQCard-AI-16XE-50[13]). The 16-bit converter divides the analog range into 2^{16} divisions. The disadvantage of this better resolution card is the inferior sampling rate (20 KS/s for multiple-channel sampling), but it is more than sufficient for WIM purposes. The range, resolution and gain available on a DAQ board determine the smallest detectable change in voltage. If the resolution were 12 bits, range 3.333 V and gain 2000, the theoretical resolution of one bit would be:

$$\frac{3.333}{2000 * 2^{12}} = 40.86 mV \tag{C.1}$$

In the same conditions of range and gain, a 16-bit card can measure a minimum voltage 16 times smaller than the one given in Equation C.1. Section 3.7.4 describes how B-WIM achieved an accuracy class B(10) in the final experiment in Luleå, thanks among other factors to the use of a 16-bit card instead of the previous 12-bit card.

C.2 INSTALLATION

The computer containing the DAQ card must be disconnected from the SCXI chassis and the SCXI chassis turned off. After having made any necessary changes and having verified the jumper settings (National Instruments 1994), the SCXI-1121 modules are inserted into the board guides of the chassis. Its front mounting panel is screwed to the SCXI chassis. The next step is connecting the SCXI-1121 to the terminal block SCXI-1321 by:

- Connecting the SCXI-1121 front connector to its mating connector on the terminal block.
- Making sure that the SCXI-1121 top and bottom thumbscrews do not obstruct the rear panel of the terminal block.
- Tightening the top and bottom screws on the back of the terminal block to hold it securely in place.

Finally, the installation is checked, the SCXI chassis is turned on, and the computer is turned on and reconnected to the chassis.

Connection between Signal and Terminal block

In order to connect the terminal block to the signal wires, the following steps are carried out:

- The grounding screw of the top cover of the terminal block SCXI-1321 is removed.
- The top cover of the shield is snapped out by placing a screwdriver in the groove at the bottom of the terminal block.
- Then, the signal wires are slid one at a time, through the front panel strain-relief opening.
- The wires are connected to the screw terminals as explained further on.
- The larger strain-relief screws are tightened.
- The top cover back is snapped in place.
- The grounding screw is reinserted to ensure proper shielding.

Signal wires are fixed in the input channel of the terminal block in different ways depending on the signal source. Figure C.4 shows the diagram of the SCXI-1321 terminal block[13].

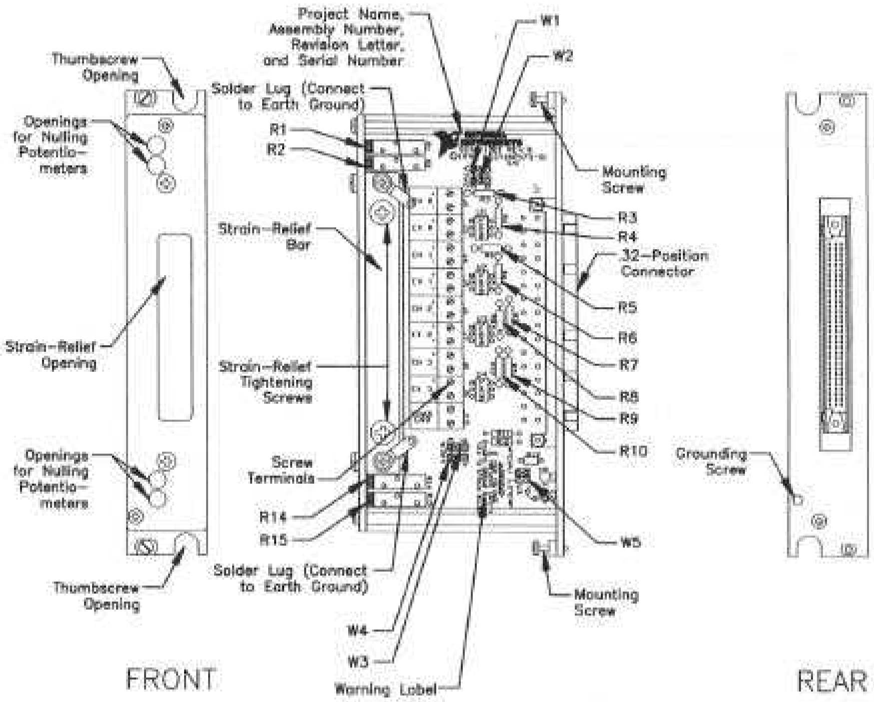
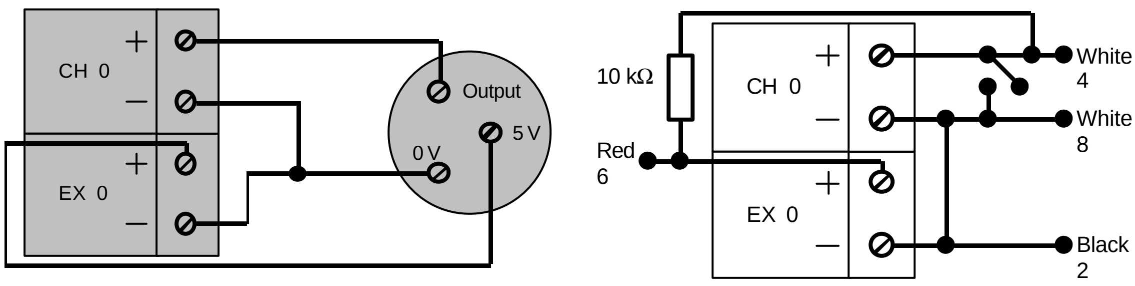


Figure C.4 – SCXI Parts Locator Diagram (after National Instruments 1993)

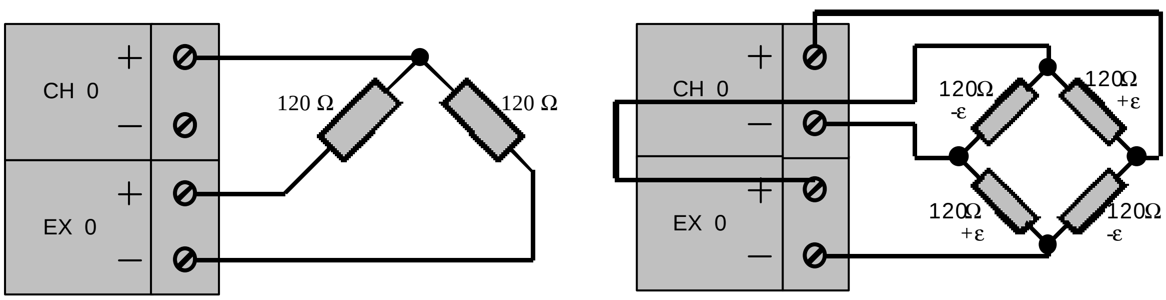
Figure C.5 shows the configuration of one channel in the terminal block for two types of axle detector: rubber tubes and piezos respectively. The signal from rubber tubes and piezos come from different interfaces described in Section 4.3.1. In the case of Figure C.5(b), the Traffic 2000 interface opens the circuit while there are no vehicles on the sensors. CH+ is wired to the supply via a 10 kΩ resistor so the input reads the supply voltage.



(a) Rubber Tubes (pressure sensor) (b) Piezos

Figure C.5 – Signal wiring in the case of axle detectors

Figure C.6 illustrates the connections that take place when using strain gauges in different Wheatstone Bridge arrangements. In Figure C.6(a), the meaning of the resistors depends on the configuration that is chosen. Resistors will be active and dummy or in tension and compression, if using a quarter or half Wheatstone bridge respectively.



(a) Quarter/Half Bridge (b) Full Bridge

Figure C.6 – Signal wiring in the case of strain gauges