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The design of a low-cost portable Sensor Configuration Unit (SCU) for engineering measurements with various sensors

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ABSTRACT: In this article, the author describes a low-cost, portable and flexible Sensor Configuration Unit (SCU) design for use in engineering measurements with various sensors. The unit consists of a sturdy ring stand, a plate with holes to hold various sensors, and a bracket fastened to the plate to hold the signal conditioning unit of the sensors and provide the input output connections. This puts the sensor to be used and its signal conditioning unit into a single central unit. The output from the sensor is connected to the measurements hardware and, more preferably, the computer data acquisition hardware, through the BNC connectors on the bracket. The set-up is very portable and has a minimal footprint on the experiment workbench. It eliminates the problems of many wires scattered around the workbench during experiments. The exchange of different sensors in the unit is easily carried out and enables purchasing standalone sensors for different engineering measurements applications for existing measurement hardware, instead of buying much more expensive all-in-one measurement units. This set-up is especially useful to an undergraduate measurement and instrumentation class in small size engineering programmes with limited budgets.

INTRODUCTION

In an engineering undergraduate measurement and instrumentation course, it is imperative to introduce the latest technology in sensors or transducers and their instrumentation to students. This introduction is best achieved by letting students perform experiments using these sensors. The more sensors that students use, the more experienced and better prepared students are for later and more specific laboratory courses, as well as their work after graduation.

However, many experiments performed in such a laboratory course face the following two problems:

- The redundancy of the number of instruments involved in the experiments with different sensors;
- The considerably big footprint of all the devices needed for the experiments, including sensors, sensor positioning set-ups, signal conditioning units, sensor instrumentations plus all the wirings connecting these components.

The first problem comes from the fact that leading engineering measurement equipment vendors usually provide combined sensor and instrumentation units, such as a thermocouple probe and the corresponding thermocouple temperature reader. These units are generally quite expensive and each sensor will have its own instrumentation, which makes the equipment list for experiments using multiple sensors very long.

To solve this problem, a more efficient and cost effective approach is to use a general computer data acquisition system, such as those from National Instruments, as the instrumentation for all the sensors. As a result, the sensors can be acquired without the corresponding instruments. Most sensor units provide voltage as the output that can be directly connected to the computer data acquisition hardware to be measured and then processed using software.

Computer data acquisition vendors also provide signal conditioning units to power other sensors, such as the modules for accelerometers and strain gauges from National Instruments [1]. Using the computer data acquisition software, such as *LabVIEW* from National Instruments, a virtual instrument can be developed to take readings from all the sensors. This approach eliminates the different instruments required for each sensor.

As for the second problem, during the experiment, the sensor probes usually require a positioning set-up to hold them to measure different properties. Many sensors also have a signal conditioning unit. Generally, the sensor positioning set-up, the signal conditioning set-up and the instrumentation (individual ones or computer data acquisition hardware) are scattered around on the experiment workbench, creating a big footprint that requires a larger table for students to work on. In order to solve this problem, a new set-up is desired to accommodate the sensor, its signal conditioning unit, and the interface for input and output into a central unit that would have a small footprint on the workbench.

In this article, the author presents the design, manufacture and application of a portable and versatile unit for engineering measurements with various sensors. This unit is termed the Sensor Configuration Unit (SCU). It is easily exchangeable between different sensors and is very cost effective. The design also takes into consideration the possible use of computer data acquisition by providing standard input-output connectors, with the input defaulted to banana connectors and the output defaulted to BNC connectors.

DESIGN OF THE SENSOR CONFIGURATION UNIT (SCU)

The functions or requirements of such a Sensor Configuration Unit (SCU) and its application in an experimental set-up is illustrated in Figure 1.

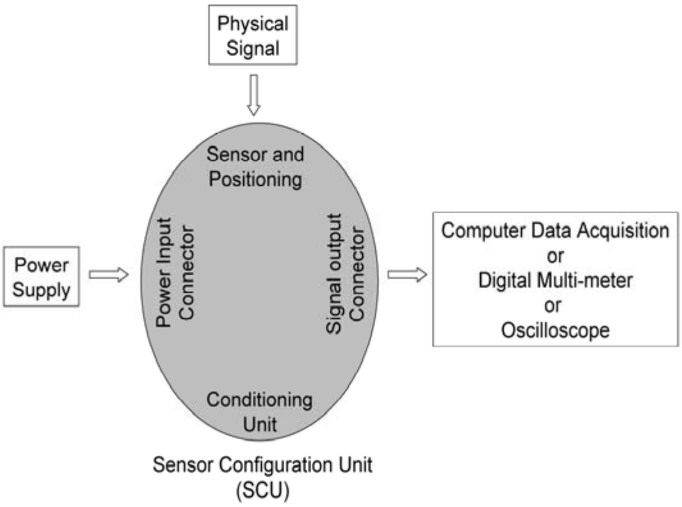

Figure 1: Schematic of the experimental set-up with the Sensor Configuration Unit (SCU).

The unit should provide an interface to get a power supply from an external source and provide the sensed signal to the computer data acquisition hardware, or simply a digital multi-meter or oscilloscope.

The sensor should be properly positioned in the SCU to take measurements of the external physical signal and the sensor's signal conditioning unit should also be attached to the unit to provide a compact layout.

To achieve these functions, a set-up is designed as shown in Figure 2 with a Linear Variable Differential Transformer (LVDT) sensor used as an example. This solid modelling illustration serves both as a visual representation of the desired set-up and as the blueprint for manufacturing.

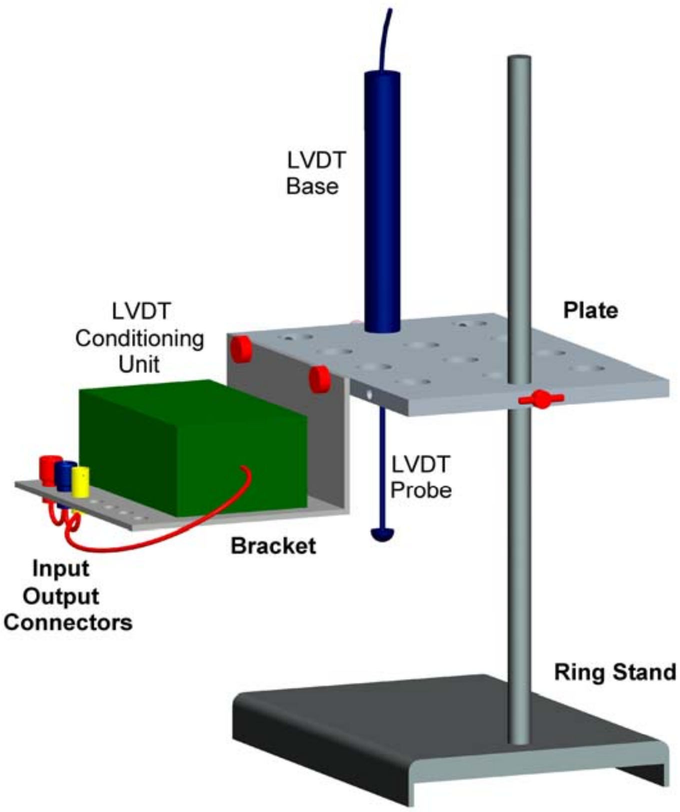

Figure 2: Layout of the components for the SCU with an LVDT sensor.

The Sensor Configuration Unit consists of three parts, namely:

- Ring stand;
- Rectangular plate;
- L bracket.

The whole set-up is based on a ring stand with a heavy solid base to provide the sturdiness of the unit. The rectangular plate is designed to attach to the ring stand through a hole close to the side. More holes (three by four) are in the plate to reduce the weight of the plate and, more importantly, provide the means to hold the sensors to the plate. A row of threaded holes are designed along the vertical sides of the plate.

The plate is then fastened to the ring stand using a wind screw and can be easily positioned up and down to achieve the correct positioning of the sensor relative to the physical signal source. The sensors can also be fastened to the plate using wind screws through the threaded side holes, as this is the case for the LVDT shown in Figure 2.

To accommodate the signal conditioning unit for various sensors and provide the input/output connections to the conditioning unit, an L-shaped bracket is designed with holes both on the side surface and the bottom surface. Two thumb screws fasten the bracket to the plate through the side holes and the sensor signal conditioning unit is fastened to the bracket bottom surface using screws that usually come with the purchased sensor unit. It should be noted that because the sensor signal conditioning unit comes with different shape and size, the bracket might also have different sizes to make it compact.

For the convention of input/output connection, the banana connector is defaulted to connect inputs to the sensor as most power supply output posts are banana connectors, while the BNC connector is defaulted to output the signal from the sensor.

MANUFACTURING AND COST OF THE SENSOR CONFIGURATION UNIT

The designed parts are either easily purchasable from a laboratory equipment vendor or very simple to manufacture in a machine shop. The ring stands can be purchased from a laboratory equipment vendor, while BNC and banana connectors can be purchased from an electronics parts supplier. The plates and L brackets are made out of aluminium and most of them were machined by the author in the machine shop within the university. The wires are soldered to the connectors and shrinking tubes are attached to provide good insulation by the author.

The detailed cost for such a unit is listed in Table 1 with a total material cost of around $40.

Table 1: Cost of a typical SCU.

Item	Cost/Unit	Remarks
Ring Stand	~$15	From any laboratory equipment vendor
BNC/Banana Connectors	~$5	From any electronics parts supplier
Aluminium Plate/Bracket	~$20	Material cost, manufactured in house
Total	~$40	

APPLICATIONS OF THE SENSOR CONFIGURATION UNIT

Figure 3 shows the manufactured Sensor Configuration Unit with an LVDT sensor and its signal conditioning unit. It should be noted that there are no banana connectors on the bracket because this LVDT sensor conditioning unit is directly powered by an AC power supply. The output DC signal is directly connected to a National Instrument SC-2345 signal conditioning unit with an AI04 module (±5 V input range). A *LabVIEW* virtual instrument is written to acquire the voltage output signal and display it on the front panel. The LVDT probe can be used to measure the height of an object or the displacement of an object, such as a deflected beam.

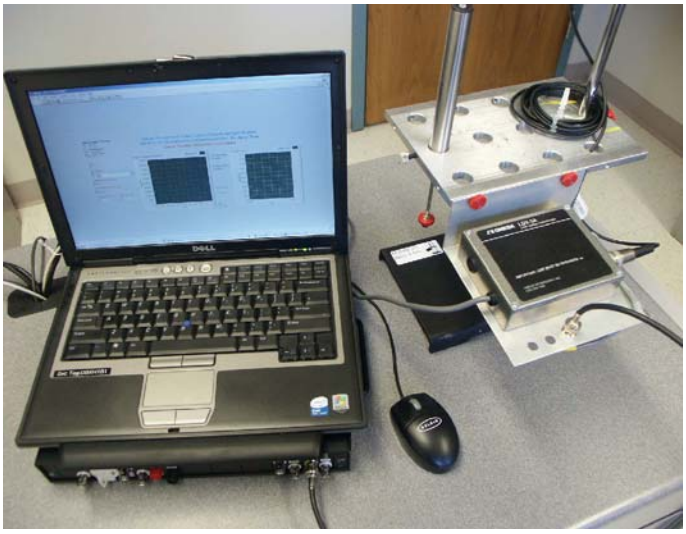

Figure 3: Set-up of the SCU with LVDT sensor and computer data acquisition.

Figure 4 shows the use of the SCU with a laser displacement sensor and computer data acquisition to study the cantilever beam deflection and vibration. A *LabVIEW* virtual instrument has been developed to acquire the voltage output from the laser displacement sensor and give the frequency of the signal. As can be seen from Figure 4, an accelerometer can also be used to measure the acceleration rate of the beam vibration in addition to the displacement output from the laser displacement sensor. Further, the bracket also has four more banana connectors.

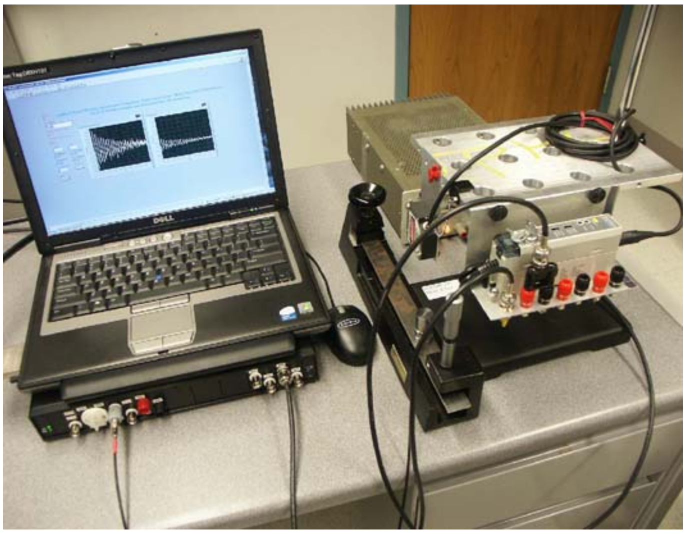

Figure 4: Set-up of the SCU with a laser displacement sensor and computer data acquisition.

Strain gauges can be installed on the beam and connected to these connectors and then to the computer data acquisition hardware or other strain measurement device.

The measurements of beam vibration using multiple sensors on the designed Sensor Configuration Unit provide students with a more extended experience with vibration measurements. It also fully demonstrates the compact design and versatility of the SCU.

To further demonstrate that multiple sensors can be easily used together with the Sensor Configuration Unit, Figure 5 shows the use of the SCU with a thermocouple and a thermistor to measure water temperature during the heating process. The thermocouple voltage is connected to the computer data acquisition hardware and the temperature measurement is displayed in the front panel of the *LabVIEW* virtual instrument. It should be mentioned that the thermistor is connected to a voltage divider circuit and the voltage drop across the thermistor is measured using a DMM in the set-up shown in the figure.

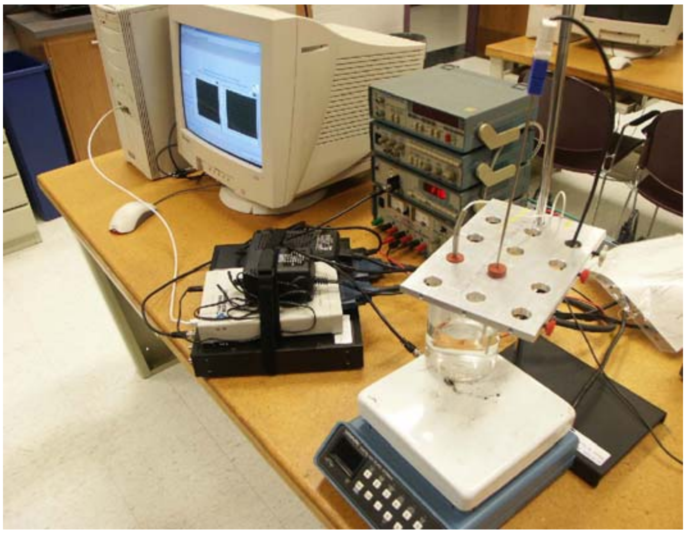

Figure 5: Set-up of the SCU with thermocouple and thermistor and computer data acquisition.

CONCLUSIONS

A Sensor Configuration Unit (SCU) has been designed, manufactured and used by the author. The SCU has a very low cost of around $40 for the materials. The SCU has a rather small footprint on the experiment workbench, packing the sensor, its positioning and its signal conditioning unit into a single unit. It is also very portable and can be easily assembled and disassembled using wind screws and thumb screws. The SCU also has great versatility, can easily switch among various sensors and can accommodate multiple sensors at the same time. Three examples of using this Sensor Configuration Unit are described, specifically LVDT, laser displacement sensor, and thermometers. These examples demonstrate the versatility and benefits of the SCU.

With this unit, introducing students to more sensor technology only requires purchasing standing alone sensors for different engineering measurements applications to use with existing measurement hardware. This eliminates the need to buy much more expensive all-in-one measurement units with combined sensor and instrumentation. Multiple sensors can also be used together with a small footprint to study the same engineering problem to demonstrate different ways for engineering measurements. This unit is very useful for undergraduate measurement and instrumentation classes, as well as other laboratory classes, especially in small size schools with limited budgets.

REFERENCE

1. National Instruments, Signal Conditioning (2006), http://www.ni.com/signalconditioning/