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Low-Cost, High Accuracy Multifunction Process Calibrator Cum Smart, Android Based Temperature Transmitter

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ABSTRACT: A multipurpose calibrator is an industrial instrument used to calibrate various control valves, control loop parameters and other instrumentation equipment in the process plant. This calibrator is based on the HART communication protocol. A temperature transmitter is a process plant equipment used to send 4-20mA signals for a pre-set range of temperature. The sensors for the temperature transmitters can be thermocouples, RTDs (resistance temperature detectors) and /or thermistors, depending on the sensor used in the control loop. In this paper, we propose a low cost, compact design for a multipurpose calibrator and a temperature transmitter. This paper will intend to solve the problems faced by small, medium scale industries in developing countries related to their purchase of these costly process plant diagnostics instruments. Moreover these two different instruments will be combined into a single device for the better debugging of the plant during the calibration cycles. We propose to cut down the cost of these devices to the third.

KEYWORDS: universal process calibrator , android, xtr 101, temperature transmitter

I. INTRODUCTION

The cost-effectiveness and the ease of operation are the two pillars on which this product stands. This gives a hand on experience to under-graduate students as well as small and medium scale industries in developing countries. A process calibrator is an imperative part of an automation based / industrial plant. It has an important role of maintaining the accuracy of the process equipments as well as calculating the errors generated in the plant. This is a typical process calibrator which works on the principle of HART protocol. This protocol is one of the most eminent process communication protocol .The HART Communications Protocol (*Highway Addressable Remote Transducer Protocol*) is a digital industrial automation protocol. Its most notable advantage is that it can communicate over legacy 4-20 mA analogue instrumentation wiring, sharing the pair of wires used by the older system[1]. This protocol is profound in industries in the developing countries. Hence the cost effectiveness of this project will revolutionize the small and medium scale industries. Also the use of temperature transmitter with the calibrator, has made this device a promising, universalprocess plant device. Moreover this device has a Bluetooth module which sends and displays the data onto an android smart phone. Also this data will get logged onto the cell phone for future references. .This technology will revolutionize the process industry.

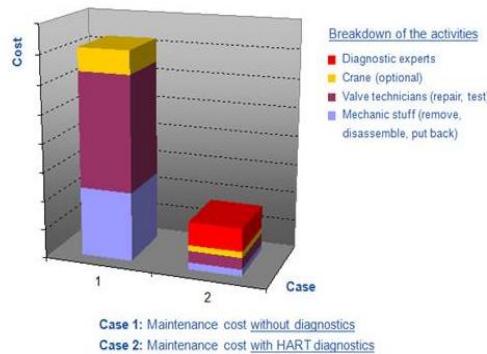
II. HART PROTOCOL

The HART Communications Protocol is the global standard for smart process instrumentation. Seventy percent of all smart process measurement and control instruments installed worldwide each year use HART Communication. The global installed base of HART-enabled devices is the largest of all communication protocols at more than 15 million. Key features of this unique open standard communication technology are 4-20mA compatibility, ease of use, low risk, and cost-efficient implementation for both users and suppliers [2].

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III. PROCESS CALIBRATORS

A process calibrator is a process plant device used to detect and eliminate the errors from the process equipment such as transmitters, process controllers, I-to-P converter etc. The range of process calibrators include: Documenting Process Calibrators, Multifunction Process Calibrators, single function and multifunction temperature calibrators and a variety of mA loop calibrators. A multifunction (or generally known as a UNIVERSAL) calibrator is a combination of all the other calibrators. That is to say that a multifunction calibrator can:-

- Sink and source 4-20mA
- Sink and source 0-200mV(now I'm well aware that voltage cannot be sunk or sourced , it's a difference between the potentials across two points, but in a process plant terminology they call it sinking and sourcing)
- 0-5 V output
- Thermocouple simulator
- Thermocouple temperature detector

These features are available in the process calibrators available in the market today, but are horrifyingly costly (for a student or a small or a medium scale industry). Pointing out some of the costs of the renowned resellers of calibrators:-

(these aren't the universal calibrators , rather they are a particular function based calibrators)

- Fluke 714B Thermocouple Calibrator- \$1,249.99 [4].
- Fluke 709H Precision Loop Calibrator with HART Communications / Diagnostics :- \$809.99 [5].
- Fluke 715 Volt/mA Calibrator :-\$1149.99 [6].

IV. TEMPERATURE TRANSMITTER

A temperature transmitter (in a process plant terminology) is a device that transmits HART signal after detecting the changes in the temperature (from a temperature sensor). In the device designed, I have been successful in incorporating a RTD temperature transmitter. To explain the role of this transmitter here follows an example: a HART signal ranges from 4-20 mA. Now for example we need to monitor a temperature of a process vessel between 20 degrees Celsius to 80 degree Celsius. This information is further fed into the process controller (ex PID controller) to take the necessary action. To convert an analogue, sensor signal into an HART based signal a process transmitter is used. This transmitter gathers the changes sensed by the sensor (here an RTD) and converts into a 4-20mA signal which is readable by the

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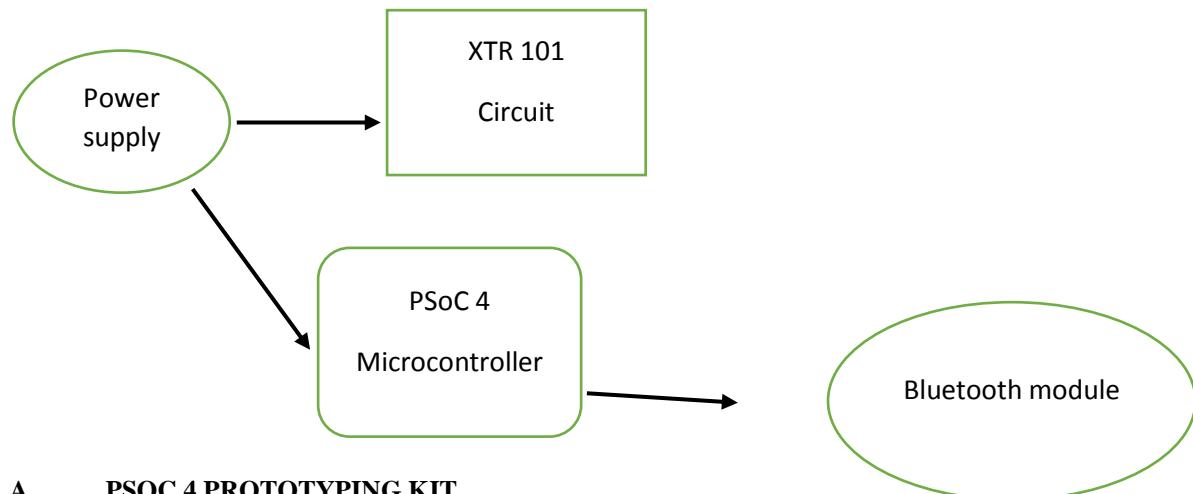
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controller. So for this example when the RTD senses 20 degree Celsius, the transmitter will transmit 4mA and when it senses 80 degree Celsius it will send 20mA to the controller.

V. THE DESIGN

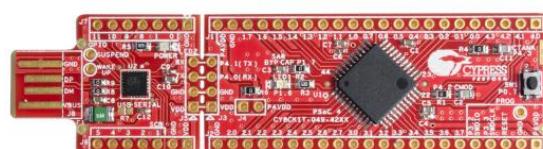
This design consists of the following components:-

- PSoC 4 prototyping kit
- XTR 101
- Potentiometers
- Power supply (AC to 24V DC)
- Bluetooth module
- Android cell phone
- Resistors and capacitors



A. PSoC 4 PROTOTYPING KIT

This is one of the cheapest microcontroller based development board available n the market today. It costs a total of \$4 [7] and is sold by Cypress semiconductors. One of the main reasons for using this microcontroller is the fact that it has two inbuilt SAR –ADCs and it also encompasses one I-DAC(current DAC). Since, the motto of this device is to output 4-20mA , this current DAC makes PSoC 4 prototyping kit the best possible solution. PSoC stands for Programmable System on Chip and is one of the latest boons of the famous VLSI family. This microcontroller supports digital as well as analogue inputs /outputs and works on 5V DC supply. Programming of this kit is done by using the IDE presented by Cypress and is extremely easy to understand and work on. Also one of the benefits of using this microcontroller is its size.



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B. XTR 101

This is an IC manufactured by Texas Instruments and forms the heart of this device. The XTR101 is a microcircuit, 4-20mA, two-wire transmitter containing a high accuracy instrumentation amplifier (IA), a voltage-controlled output current source, and dual-matched precision current reference [8]. Here, the two wire transmitter is an important term. This allows signal and power to be supplied on a single wire pair by modulating the power-supply current with the input signal source. This IC is perfect for commercial use as it is immune to voltage drops from long runs and noise from motors, relays and other devices in the plant. Again this IC plays a major role in the production of noiseless 4-20mA signal.

The output equation of the IC is :-

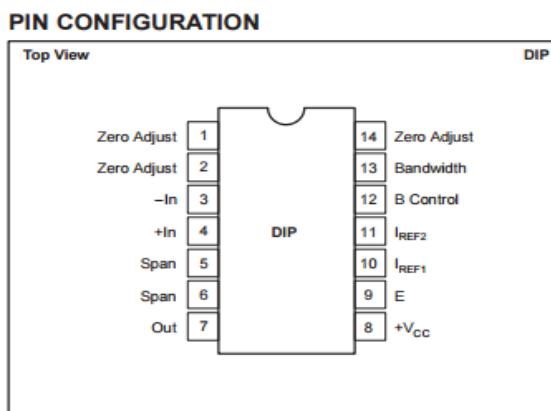
$$I_o = 4 \text{mA} + (0.016 \frac{\text{amps}}{\text{volts}} + \frac{R_s}{40})$$

Here,

I_o = output current

R_s = impedance matching resistance

The minimum voltage required by this IC for its functioning is 11.6 V.



This IC works on varying voltages, depending upon the impedance of the process equipment. The formula relating the impedance and the power supply requirement is:

$$R_s = [40 / (\frac{\Delta I_o}{\Delta e_{in}}) - 0.016 \frac{\text{amps}}{\text{volts}}]$$

This equation has been derived from the output equation of the IC.

Now, as the role of XTR 101 producing 4-20mA is clear. Let's throw some light on the fact that this CI is also helpful in the designing of the RTD transmitter. This IC has the capability of sensing the resistance change produced by the RTD and converting it into the 4-20mA signal.

Hence this IC forms the basis of this device.

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C. POWER SUPPLY

Power supply here plays an important role as the noise immunity of this device needs to be high. Hence use of elegant power electronics principles were used in making this power supply unit.

The input is 220V AC and is converted into a 24 V DC needed for running the XTR101. Also this power supply unit has a provision for 5V DC for running the microcontroller.

D. BLUETOOTH MODULE

The Bluetooth module used in this design is HC-06. This module is used to send the data inputted or outputted to an android cell phone. This technique eradicates the tedious practices of holding this device and can be simply mounted on various sectors of the plant. Hence once the operator enters the plant area all he needs to do is switch on the Bluetooth of his android cell and the application. The data from the device will be transferred to the screen of the cell phone. This data will also get logged onto the memory of the cell in a text format. This app was designed using MIT app creator. Hence this module revolutionizes the use of the whole device.

VI. FUTURE SCOPE

This device was planned based on the fact that, during long and arduous calibrating cycles going on in a plant, the plant operator has to hold this device in his hand throughout. Hence this device should in future achieve a database management through the various Bluetooth modules connected throughout the plant, with only one master Bluetooth module (which will be responsible for sending the data to the android device). Hence making it a child's play for the process operator to detect the errors in the plant. A mesh of Bluetooth modules will be attached at each and every corner of the process plant with their respective universal calibrator next to them. They all shall communicate with a master Bluetooth module which will prioritize between the various signals it receives from the slave modules and send it to the cell phone. This shall make the whole calibration cycle process cheap and less cumbersome.

VII. CONCLUSION

The main purpose of this device is to make the universal calibrators easily and more importantly cheaply available to the small and medium scale industries. Also setting up a whole network of these calibrators shall automate the whole calibration cycles to new and promising standards.

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