Concept Generation & Selection

EML 4551C – Senior Design – Fall 2011 Deliverable

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Introduction

Currently, there are no sensors to quickly and cheaply assess the need for further diagnostics on a GE HSR compressor. Therefore, GE needs a non-intrusive, preliminary diagnostic tool to monitor compressor performance. With the need assessment, project scope, project specification and project plan completed, the next step is the actual design part of the process.

The concept generation and selection phase is the concentration of this deliverable. With an elucidated problem, a search for concepts was conducted externally and internally through research and brainstorming sessions. The concepts were explored systematically and a reflection on the process and the solutions occurred.

The following section will introduce existing technology that is used for performance analysis. These complex systems are not desirable for the purpose of this project, but were taken into consideration. The subsequent section focuses on internally generated design concepts. Delivering a system that will collect, store and display live air flow data from a compressor in P-V/P-T graphs that can be viewed in a mobile application for Android phones involves varies components. Therefore, this complex system was decomposed into smaller subsystems. The subsystems are sensors, data processing unit, wireless communication and a phone application.

Project Statement

To develop a preliminary diagnostic tool that will collect, store and display live air flow data from a compressor in P-V/P-T graphs that can be viewed in a mobile application for Android phones.

Existing Technology

Established in 1968, Dynalco is a division of Crane Co and their main occupations are designing and manufacturing reliable, instrumentation for monitoring, controlling and protecting reciprocating and rotating plant machinery. For the purpose of this project, the instrumentation of interest is the RECIP-TRAP 9260, seen in figure 1. The RECIP-TRAP 9260 system is a machine that gathers and examines technical and financial measure of performance and mechanical condition in order to prevent failure and increase profits. Also sold by Windrock, it includes transducers, cables, accelerometers, ultrasonic sensors, Aqua-Probe, and an IR temperature wand. Some of the information provided by the RTwin 9.2 software suite, the software it utilizes includes: theoretical to actual comparisons of compressor pressure versus time and pressure volume, cycle-to-cycle pressure variations and current-to-baseline comparisons of pressure, vibration, ultrasonic and spectra.[1,2]

Figure 1: RECIP-TRAP. Image Provided by Dynalco

A system that was provided to the group by GE as a model diagnostic tool is Windrock's Model 6320 family of analyzers. This family of analyzers features AMD Geode main processor, Digital Signal Processors (DPS) for four dynamic channel, and the ability to recall historical and baseline data from memory. Some of the information that Model 6320/PA provides to the user includes pressure vs. crank angle, pressure vs. volume and mechanical looseness in pistons and nuts, cross head and pin and bushing. Shown in figure 2, this system is lightweight weighing 5.25 lbs and compact.

Figure 2: Windrock's 6320 analyzer. Image provided Windrock

Concepts

Sensors

In consideration of the given constraints of portability, short installation period, and unobtrusive flow analysis, there are several sensors sufficient for our needs and they are all based on transit time ultrasonic flow measurement technology. The viability of the options listed below are dependent on information such as fluid particulate size, speed of flow, thickness of pipe walls, diameter of inlet/outlet pipe, fluid types, transducer types, and computer interface. There will be a short paragraph describing the pros and cons of each device, and the potential benefits of choosing one flow measurement method over another.

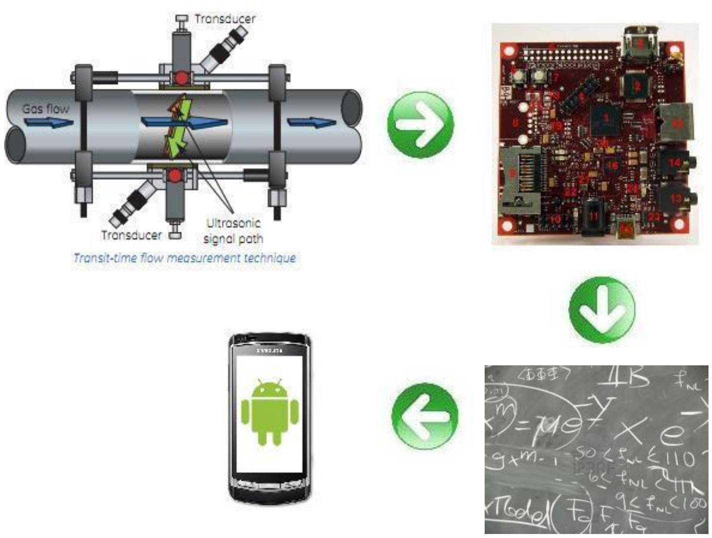
GE TransPort PT878GC - Portable Gas Ultrasonic Flowmeter

The GE TransPort PT878GC is an all-in-one portable gas ultrasonic flowmeter geared towards short term flow measurement. It is completely solid state making for a low maintenance, durable sensor. It has a relatively high temperature tolerance and field upgradable memory for extended analysis. The PT878GC also uses a new line of clamp on gas transducers that produce signals 5-10 times stronger than that of traditional ultrasonic transducers. It outputs data via an infrared port, which can be read by our micro-controller and sent through Wifi to our google mobile phone. The portability comes at a price of around $5,300 with required sensors and mounting hardware purchased separately. If the cost is independent of GE branding this would be prohibitively expensive, far surpassing our budget. It also has an approximate 15 minute installation time, which is longer than desired.

	Reflector Size	Pipe Thickness (mm)	Max Velocity (m/s)	Pipe Dia. (mm)	Fluid Types	Transducer	Output
			33.5	50			
			30.5	200			
			25.9	250			
			21.3	300		Advanced	
PT878GC	Any	1.8-25.4	16.5	400	Gas	Clamp-on	Infrared

Custom Transit Time Flow Meter

Expensive flow meters are convenient for complete on-site problem diagnosis, but may prove to be unnecessary. It may be worthwhile to invest time into the design of a custom transit time flow meter system. The components would be the same as required by off the shelf analyzers, such as the advanced clamp-on transducers manufactured by GE. These components will interface with an analog to digital converter, and this raw data can be sent via micro-controller to an off-site location for analysis. This data can be sent live to a google mobile phone on-site. Benefits of this design would be drastically reduced unit price and simplified operation, but the reduced per-unit price may be offset by the cost and time required for development. Where the PT878GC is a complete unit ready for analysis, a custom flow meter would have to go through the design process and prototyping stages.



Flow chart of custom TTFS method (Fig.3)

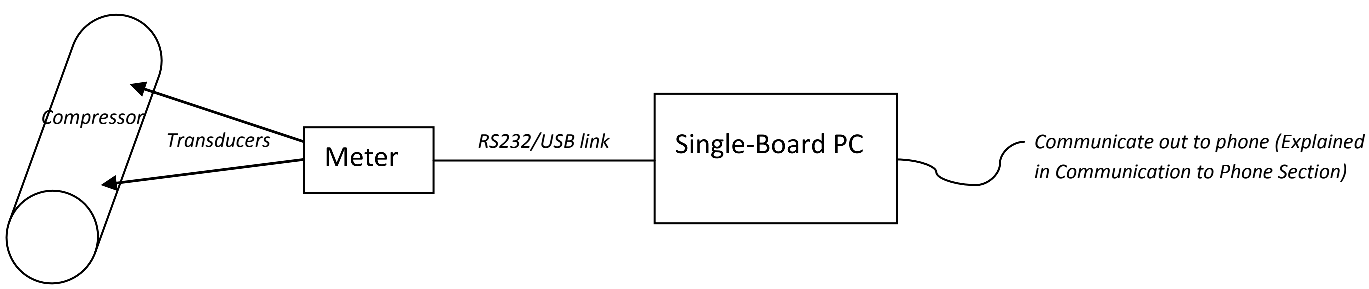
Flow chart of PT878GC method. (Fig. 4)

Data Processing Unit Selection

The selection of our data processing unit will be dependent upon what type of signal will be coming from the sensor/meter selected.

Single-Board PC

If the sensor selected already has a meter that can communicate with a PC via RS-232 serial or USB, a single-board PC would be preferable. The single-board PC can have an operating system such as Windows installed and easily communicate with the sensor/meter in order to receive data and send out to the phone.

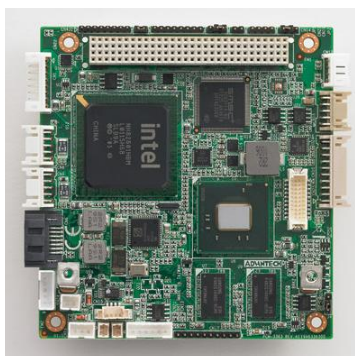


<u>Pros</u>

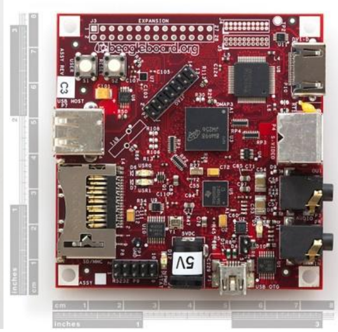
- Software is already provided to take in the data
- Setting up a connection with the phone will be made easier since an operating system is in use
- Has a lot of I/O ports, allows for more features to be added down the road
- Powerful system, capable of doing anything most cheap laptops do

<u>Cons</u>

- Costly in comparison to a normal Micro-Controller Unit (Including price of OS if Windows is used)



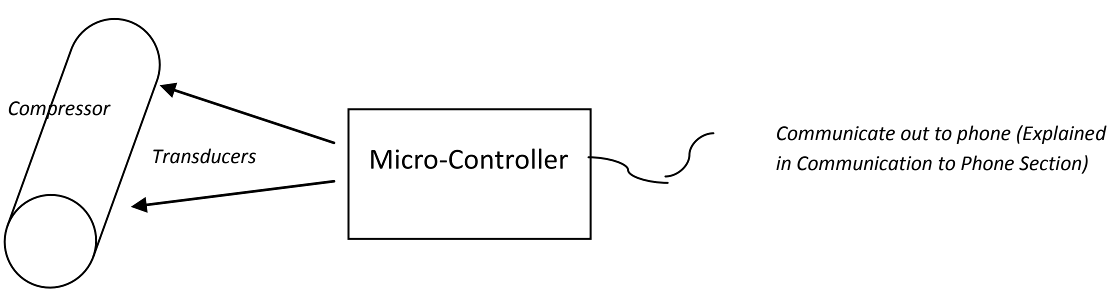
Advantech PCM-3363



TI BeagleBoard

Micro-Controller Unit

If the sensor selected outputs an analog signal that needs to be processed, a MCU (Micro-Controller Unit) is preferable. Most MCU's have built in analog to digital converters that can take in the analog signal, convert it to a digital signal then that digital signal can be sent to the phone.

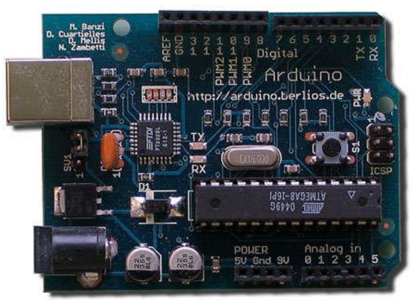


Pros

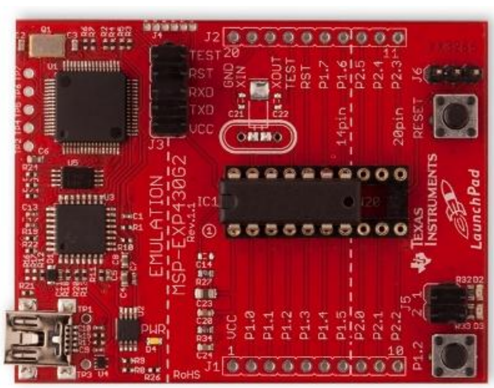
- Cheap in comparison to Single-Board PC.
- Uses little power.

Cons

- Conversion from analog signal to measurable metric may be very complicated for Ultra-sonic measurements.
- Harder to communicate to phone since there is no operating system already handling that.



Arduino Uno



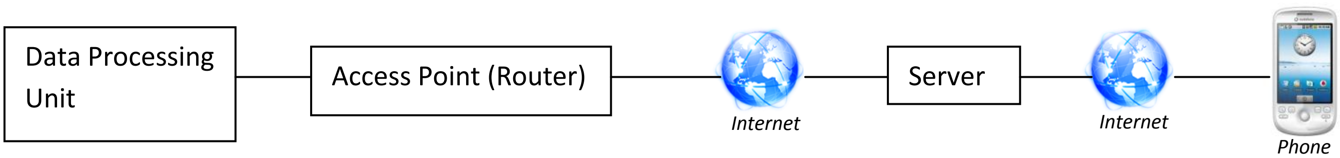
Texas Instruments MSP430

Communication to Phone

Once the data processing unit converts the data to a readable metric, it will need to be sent out to the phone. This can be done a number of ways depending on the environment and what features are desired.

Communicate Through a Server

If a router and internet is available, this is a viable option. This option will have the data processing unit upload the data to a server located on the internet. The phone application will then retrieve data from the server.



<u>Pros</u>

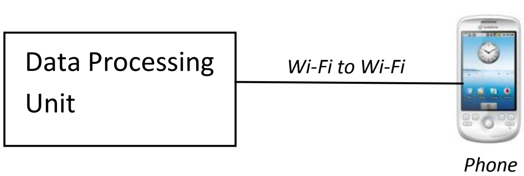
- Phone can access data from anywhere in the world as long as it has internet access
- Large amounts of data can be stored on the server

<u>Cons</u>

- A router and internet will need to be available where compressor is at
- Server adds more cost
- Can have a large latency so the data being viewed on the phone may be a bit delayed

Communicate Direct Wi-Fi to Wi-Fi

This option will have the phone communicate directly to the data processing unit without the need of any access point. This will be done via the Wi-Fi modules on the phone and data processing unit.



<u>Pros</u>

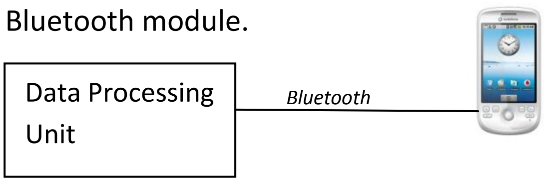
- No need for the internet or an access point
- Reduced latency since distance is small, seeing instantaneous data

<u>Cons</u>

- Data will need to be stored on the phone, limited amount of space available
- Phone will need to be within the range Wi-Fi module (Approximately 100 meters, 10x larger than Bluetooth)

Communicate via Bluetooth

Bluetooth is commonly used in today's world whether it's for phone headsets, gaming consoles or connecting IO devices. This is a viable option since all android phones have a built-in Bluetooth module.



Phone

<u>Pros</u>

- Easily configured
- No need for internet or an access point
- Reduced latency since distance is small, seeing instantaneous data displayed on phone

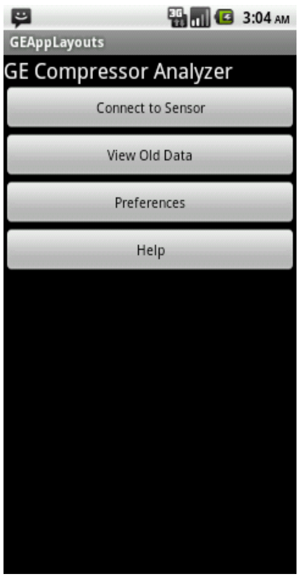
<u>Cons</u>

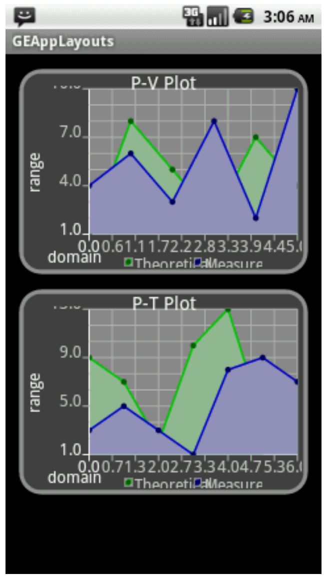
- Data will need to be stored on the phone, limited amount of space available
- Phone will need to be within range of Bluetooth module (Approximately 10 meters, 10x smaller than Wi-Fi)

Phone Application

In designing a mobile application there are numerous options to consider such as look, function, and ease of use to name a few. For this particular application it is desirable to focus on the appearance and ease of use of the application. Because our system will be used as a first diagnostic tool of the compressor it is desirable for the data taken by our system to be displayed in an efficient and logical way so that appropriate decisions can be made based upon the P-V and P-T graphs which will be displayed by the application. Appearance and ease of use shall be given high priority for this reason.

The main functions this application must satisfy in order to meet the system requirements are to store the data and display it as P-V and P-T graphs. Multiple concepts for both will be described in detail below:

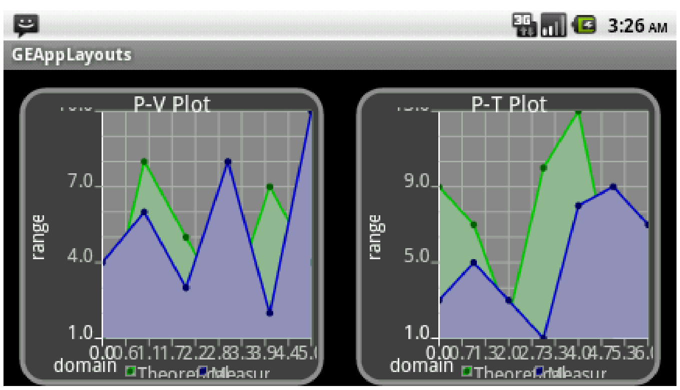




Data Storage

The method of data storage will be dependent on whether a server is used or if the data shall be stored in the application itself via a database. Those options were discussed in greater detail in a previous section. However, the way in which the data is displayed to the user in the application has yet to be discussed.

When the application is opened and connected to a sensor the user will be able to create a new storage element or choose the option of adding the data about to be measured to an existing compressor file. The user may have access to a list of all data taken previously by the application. The data can be sorted by name or date the data was taken. Many other options for sorting the data may be considered based on customer feedback. The option to select and upload data to a server or send data via other means may be considered as well.



Data Display

There are many options and functions which can be added to make the visualization of the data more useful. GE expressed a desire to be able to compare theoretical data with the data being plotted live. This will most likely be done by making the theoretical plot a background to the graph. An option can be to allow the user to pick what background data will be used for comparison. By default it may be the ideal P-V and P-T plots but perhaps the user may want to set the background to a more expected values graph or maybe even past data for the specific compressor to compare performance over time.

During live plotting of the data there may be options to pause and resume plotting as well as the option to take a screen shot of the plots. Also, because there will be two graphs to display, it may be easier to see the graphs if only one was displayed at a time. However using landscape view (turning the phone on its side) more options can be given to the user. Now the user may have the option of viewing both graphs at the same time because the of added screen space, or they may continue to view both separately but have them displayed bigger.

Design Selection

One of the largest factors in deciding between different design concepts is often the cost. Unfortunately, we have yet to find definitive pricing on the sensors that we need to use. GE produces ultrasonic flow sensors that we may be able to borrow, rent or purchase at a discounted rate, but we have not yet nailed down any of these possibilities. Many other brands of ultrasonic flow sensors are available as well, ranging from about $1300 to well beyond our budget of $2000. The less expensive transit time ultrasonic flow meters will probably require some kind of modification for our purposes, but this may be our only feasible option to stay within our budget. However, the sensor selection is but one level to consider in our concept selection; there are many options to consider for the process in which data will be received by the sensors and ultimately sent to the phone, and they mostly depend on the communication protocol that the sensors use. Thus far there are two main options that should cover our uses: a single-board PC and a microcontroller. Since each have their associated components, the cost of the necessary hardware is grouped together as separate concepts. Beyond that, we need to decide which route to transfer data to the phone (via bluetooth, wireless network, etc) – which will be somewhat dependent on which type of processing unit we decide to use. The breakdown of prices of each option is shown in Table 1 in the Cost Analysis.

Outlined below is a projected series of decisions to be made for the overall design selection process:

1. Source a viable set of ultrasonic flow sensors based on price and availability, since this seems to be the most difficult requirement to meet

2. Based on the communication protocol of these sensors, determine whether a single-board PC or MCU will be the most efficient

3. Simultaneously considering the abilities and/or inhibitions of each of the above, determine which method of data transfer should be used to communicate with the phone, given other in-field constraints (e.g. lack of internet access in a remote geographic location)

4. If necessary, develop solutions for further issues that may present themselves (e.g. phone memory capacity)

Cost Analysis

Table 1 shows rough estimates of the costs of each associated bundle of hardware options

Sensors	**Low**	**High**			
Cheaper ultrasonic flow meters	$1,300	$1,600			
GE PT878GC		$5,300			
Single-Board PC			**Microcontroller**		
Single-Board PC	$150	$400			
WiFi interface	$30	$60	MCU	$25	$125
Battery pack	$20	$90	WiFi Shield	$90	$90
Windows XP		$87	Battery pack	$20	$50
Subtotal	**$200**	**$637**	**Subtotal**	**$135**	**$265**
	Low	**High**			
Total	**$1,435**	**$2,237**			

Table 1 - Estimated Costs

Bibliography

http://www.omega.com/ppt/pptsc.asp?ref=FDT-30_Series&Nav=gree03
http://www.dynasonics.com/products/tfx-ultra.php
http://www.grainger.com/Grainger/DWYER-Ultrasonic-Flow-Detector-3PCL4?cm_mmc=GoogleBase-_-Test%20Instruments-_-Process%20Monitoring-_-3PCL4&ci_src=17588969&ci_sku=3PCL4
dmt instruments david thomson 3525648004

http://www.dynalco.com/product/pdf/product_ngbrochure_rt9260.pdf

http://www.dynalco.com/

http://www.windrock.com/portable-files/6320upgrade.html

https://campus.fsu.edu/@@/87603AF60C089401EE5D2B92EDEFA975/courses/1/EML4550-01.sp11/content/_4295070_1/06_Design%20Process_3_02022011.pdf