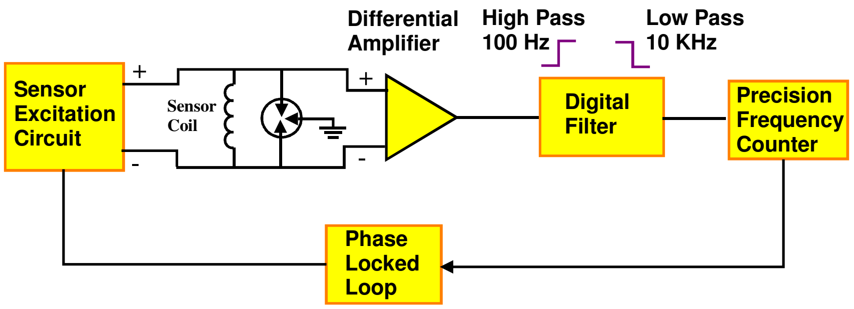
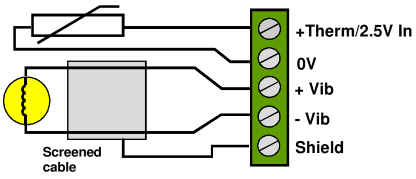
Vibrating Wire Instrumentation

Design, Operations & Lines Test Results

System Diagram - Fig 1





Differential Vibrating Wire Sensor Connection (Fig 2)

Introduction

The following diagram details the operations of the differential input version of the VibWire-108. Figure 1 shows the component parts used to make up VibWire-108. An analogue data acquisition interface built into the instrument is used to read the temperature/analogue input signals. A a singled ended input system is available and works in exactly the same however there is no differential input amplifier

Sensor Excitation

The VibWire-108 initialises any vibrating wire sensor by first sending an excitation pulse of around 200 micro-seconds at 8V amplitude to the sensor coil and forces it to vibrate. The coil is excited and is forced to oscillate at its natural frequency and so produces an echo pulse that is transmitted back to the instrument. The natural frequency of the sensor is determined by the physical properties of the coil and so the physical properties of the sensor used to make an investigation..

The initial start oscillations of the sensor coil is ignored and the echo signal then measured repeatedly over 100 oscillations for a period of 2 seconds and the average value reported. Ensemble averaging the results over a number of measurement cycles reduces false peaks and noise that may contribute errors to the true sensor signal.

The phased locked loop is used to lock the phase and frequency of the sensor excitation signal to that of the echo signal received from the sensor. Each subsequent ping to the sensor are in phase the the previous echo and as such always act to add to the amplitude of the signal, See Fig 3. In this way the VibWire-108 only uses a minimum amount of energy to excite the sensor. The sensor coil oscillates at it's natural frequency and this depend upon the physical conditions into which it is exherted.

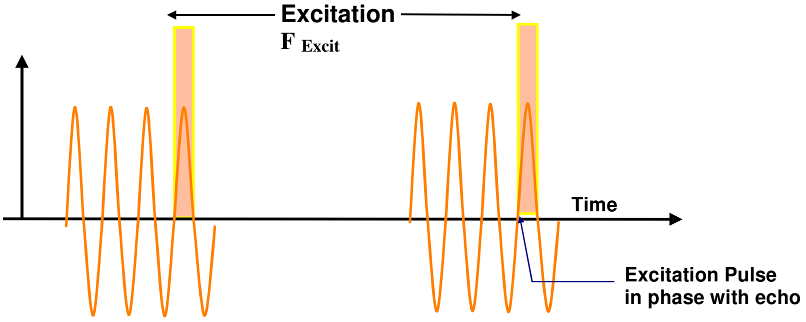


Fig 3

There are little unwanted harmonics in the echo signal and these fade quickly after the first few oscillations. The echo signal settles to a sinusoidal signal that is measured by the frequency counter.

As the excitation signal follows the natural frequency there is little added noise from unwanted harmonics that can in worst case distort frequency measurement. Signals in the order of a few millivolts are all that are needed to make a measurement.

Common Mode Rejection

The VibWire-108 uses a high quality differential amplifier to connect the vibrating wire sensor to the precision frequency counter. The differential amplifier removes common mode signals such as 50/60 Hz mains pickup etc.

A digital filter used in collaboration with a low and high pass filter is used to condition the sensor signal before it is measured by the frequency counter. The analogue filters are set at 100 Hz and 10KHz respectively and remove the out of band signals.

Differential Input Sensor Connection

Figure 3 shows how a vibrating wire sensor is connected to the differential input of the VibWire-108. The shield supplied within some cable is used when noise pickup is a problem and is terminated at the connector shown. The shield can also be terminated at any Gnd point within the instrument and the effect will be the same. The vibrating wire sensors are connected to the +Vib and -Vib inputs respectively.

Measuring Gauge Temperature

Most vibrating wire sensors are susceptible to errors caused by temperature fluctuations and as such are often fitted with an embedded thermistor allowing the gauge temperature to be measured. The VibWire-108 uses an analogue data acquisition system to make the temperature reading. A precision 2.5V volt regulated supply along with a 3.3K Ohm resistor completes the bridge circuit to the sensor, see figure 4. Any resistive temperature sensor can be used with the instrument however conversion to engineering units is undertaken is a feature of the analysis software of a logger or PC and is not part of the embedded software.

The VibWire-108 contains 8 analogue inputs suitable for digitising the temperature sensor signals or configured as analogue inputs. The instrument does not itself undertake any linearisation or display results in engineering units, it simply makes an analogue measurement and transmits the information for later processing to a logger or computer. Any conversion of the temperature measurement into engineering units is a function of the logger unit or analysis software on the computer system.

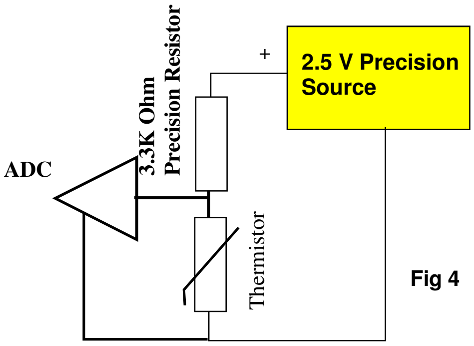


Fig 4

Range Tests

It is impractical to to test the VibWire-108 in place with physical amounts of cable due to the physical problems involved in obtaining and manipulating such large objects. To get around this problem Keynes assembled an in-line simulator that combines all the same electrical properties of cable in a small easy to use circuit. The in-line simulator was used to determine the maximum cable length that can be deployed in order that a vibrating wire sensor can reliably return signals back to the instrument.

Cable Type Model

Keynes chose Category 5 cable for the line simulator model as this cable type is available as standard product internationally and is of a lower specification than standard instrumentation cable. Any practical deployment using good quality signal cable will offer superior results to the to those obtained

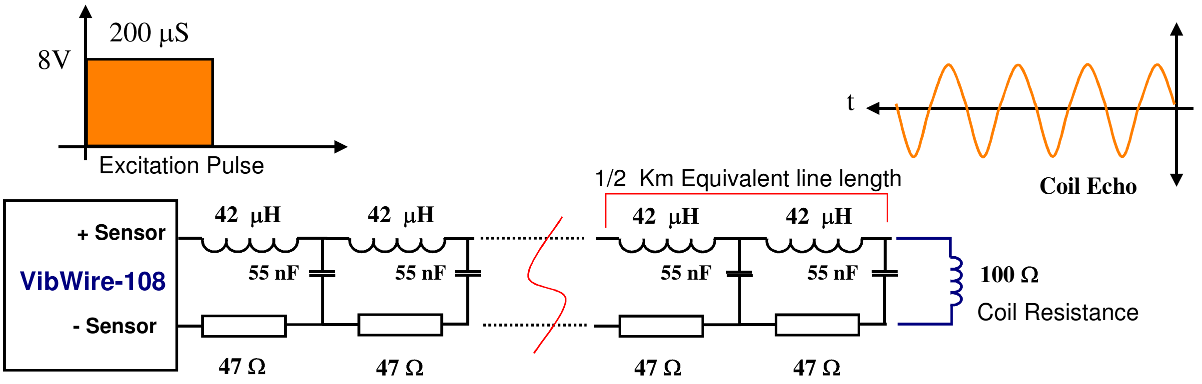


Fig 5

Figure 5 shows the circuit for the line simulator. To aid testing, the simulator was assembled using circuit blocks representing 1/2 km cable lengths.

Figure 6 shows the excitation signal at the start and end of the line simulator. The yellow trace is the signal at the start of the simulation and the green trace at the end. Clearly shown is the distortion in the excitation signal that can occur in long cable lengths.

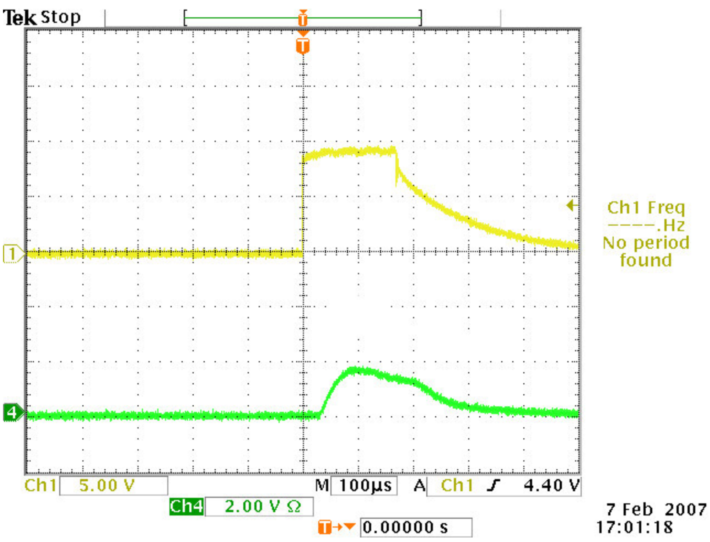


Fig 6 - Sensor Excitation Signal

Cable Deterioration

The VibWire-108 supports sensor excitation into high impedance loads. The basic sensor coil impedance is 100 ohms as standard and can be excited even when the load reaches a level of 2K ohms ie an increase of a factor 20 in the circuit resistance.

Cable type

BS 6360, class 1, 2 or 5, Instrumentation cable Low voltage

Construction

Plain annealed copper wire conductors to BS 6360, class 1,2 or class 5, PE insulation, cores twisted into pairs or triples, each pair/triple foil screened with a drain wire, overall foil screen and drain wire, LSHF sheath – Black or blue.

Conductor Plain annealed copper to BS6360 class 1, 2 or class 5

Mutual Capacitance

Collective screened cables except 1 & 2 pair

0.5mm^2	**0.75mm^2**	**1.0mm^2**	**1.5mm^2**
75pF/m	75pF/m	75pF/m	85pF/m

1 & 2 pair collective screened and all individual screened cables

0.5mm^2	**0.75mm^2**	**1.0mm^2**	**1.5mm^2**
115pF/m	115pF/m	115pF/m	120pF/m

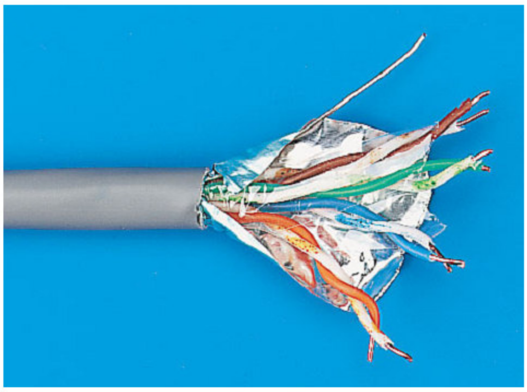
Resistance Ohms/Km

36	24.5	18.1	12.1

Deterioration before signal failure **0.036 mm^2**

Category 5 Cable

Low quality cable as used in the line simulator



Mechanical Data

Inner Conductor	0.52	mm^2 plain copper
Deterioration before signal failure	**0.09**	**mm^2**

Electrical Data
Capacitance(s) : 55nF/Km.
Inner Conductor(s) : 94 ohms/km.
Velocity Ratio : 76%.

Results

For example a BS6360 type instrumentation cable of length 4 km and cross sectional area 0.5 mm^2 will have to reduce 0.036 mm^2[i] ie to 7.2% over its original diameter before there is a failure. When shorter sensor cable lengths are involved a cable diameter smaller than 0.036 mm^2 will still maintain instrument readings.

Sensor Life

Vibrating wire sensors only have a finite life and the lower the strain put onto the sensor coil the longer it will operate before failure. The Keynes control sensor excitation provides a very good compromise between sensor wear and signal strength echo response. Using a lower excitation signal but with the energy concentrated at resonance frequency ensure that the VibWire-108 produces results with the same accuracy as much more expensive brute force excitation systems.

50m line test

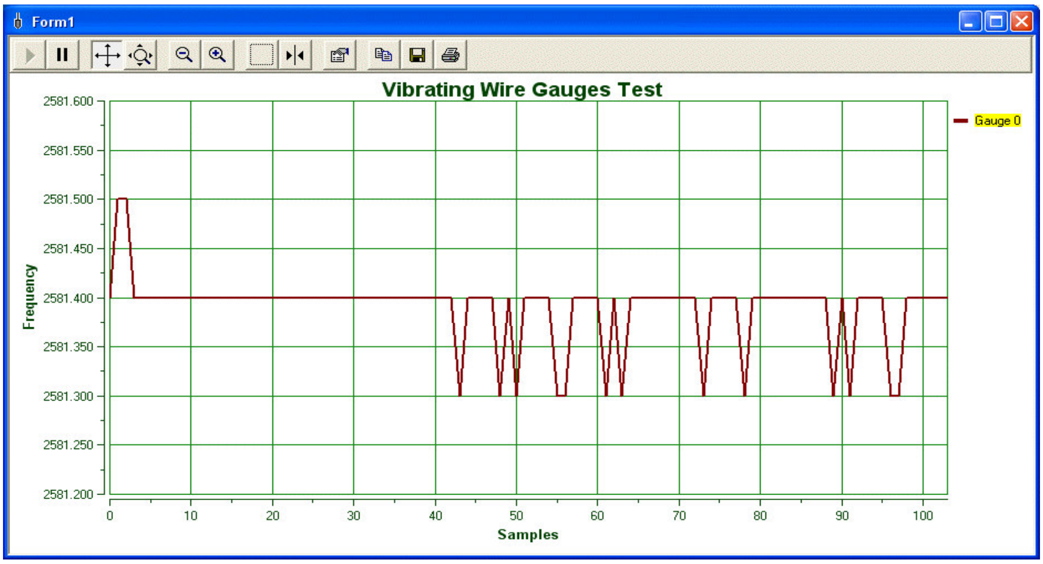


Figure 7 shows a sample of results taken using a sensor cable length of only 50m. Clearly shown are the 0.1 Hz steps that is the maximum resolution for which the instrument can resolve.

The measurements are very stable and suitable for any application.

Fig 7

4 Km Line simulation with 500 Ohm Load

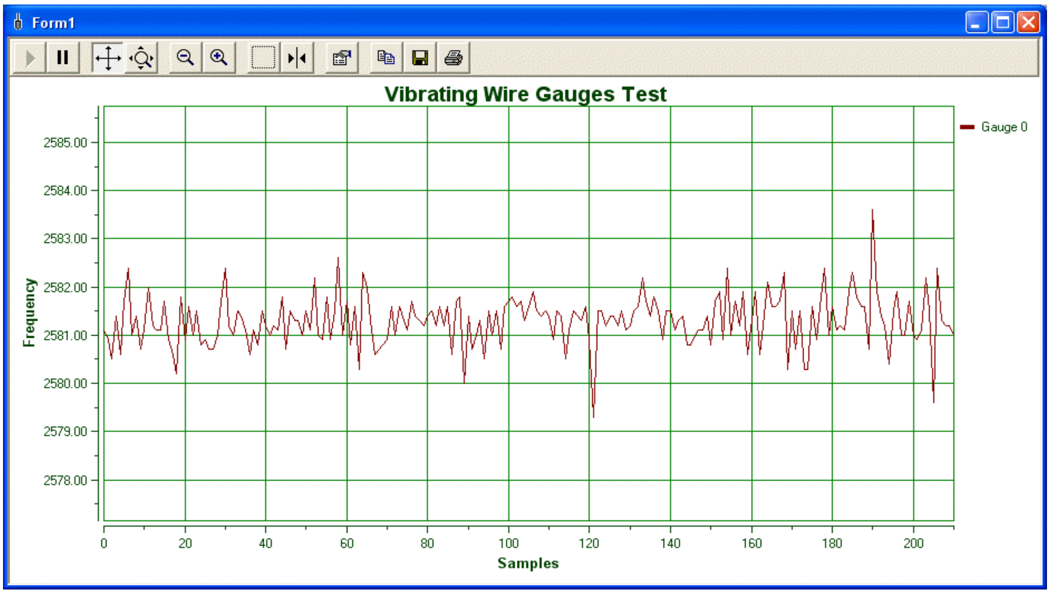


Figure 8 shows a series of measurements taken from the line simulator when the cable resistance has been increased to 500 Ohms.

The results are satisfactory and the increased variation of the data being caused in part by the thermal effects on the various components of the circuit.

Fig 8

4 Km line test with 2K Ohm Load

Figure 9 shows a series of measurements when the line simulator resistance is increased to to 2 K Ohm ie 20 times that of a normal 4 Km circuit using category 5 cable.

The results show that the VibWire-108 maintains its reading even when a sensor cable deteriorates considerably as occurs in most systems over time.

Fig 9

Advantages

No Vibrating Wire Sensor Configuration Parameters
Any Manufacturers Sensor
High Operating Frequency
Minimised Sensor Wear
High Signal / Noise Ratio
Ensemble Averaged Results over multiple measurement cycles
No false peaks
Automatic frequency tracking for excitation signal
Temperature Compensation/ analogue 0-2.5V DC support.
High impedance circuit support
High Reliability for sensor cable deterioration

The only user configuration options associated with the use of the Vibrating wire sensor operations are the jumper settings used to assign the analogue input signal type and a User assigned parameter used to set the number of channels to scan. The greater the sensors being used the slower it takes for the slower it takes for the instrument to respond.

Maintaining the sensor excitation signal at resonance and in phase to the sensor echo signal ensures a good quality results from the sensors even when there is cable deterioration between the sensor and interface.

Disadvantages

Cable length restriction to 4Km (12,000 ft)

Long cable lengths above 4Km are not possible due to the propagation delay in transmitting the excitation pulse to the sensor. The propagation delay can cause the excitation pulse to be out of phase with the echo and act to reduce the over all signal amplitude.

Keynes controls have cable free systems that can get over the range problem and will do this at a lower cost than installing and maintaining long cable systems installations.

Conclusion

The VibWire-108 is very simple to operate and does not require prior knowledge of the vibrating wire sensor or operating conditions in order to make a measurement.

The instrument supports high impedance sensor circuit loads and will operate correctly even when the line resistance increases considerably above that of the sensor coil. This means that for most practical deployments cable reduction due to damage will have little if any effect on the overall measurements.