Tech Sheet #I 305

Reading Digital Instruments

"**Analog**" is defined as a continuous process while **"Digital**" is processed and displayed in discrete increments. Humans are increasingly being subjected to a digital world that is in contrast with the analog nature of the mental process. In an analog instrument, imagery is integrated with the visual reading, resulting in a small degree of illusion that compounds the "reading error" this can be seen in the Poggendorff illusion by accessing the following site, http://www.uwm.edu/People/johnchay/po.htm. We have all experienced a difference of opinion when reading between the sub-divisions of an analog gauge. In digital form the reading is a discrete number and therefore, outside of dyslexia and double vision, is not subject to interpretive error.

Not all image processing is bad. An experienced user of analog instruments is able to notice trends and subtle changes that are well beyond the instrument accuracy, and is able to use the context to deduce meanings not explicitly stated. [The example of the pointer pointing to 12:00 at the mid-range shows this.]

Digital instruments are gaining prominence for several reasons; they are easy to read, even from a distance; they incorporate many useful functions and features which would be difficult to display in an analog device; and generally they do not have moving parts that are subject to friction and wear. Digital gauges include as standard many of the functions that are optional on mechanical devices. These options, such as min-max hands, dual- or multi-scales, dampening, zero adjustment, and over range protection not easily combined on the same instrument. What is more, their inclusion cannot only lead to confusion in the mind of the user, they can also adversely affect the accuracy and repeatability of the device. A multi-scale pressure gauge, for example, must compromise on the resolution of the inner scales. The min-max hand option and the zero adjust feature both create difficulties when liquid filling is required. From a performance point of view, ambient temperature compensation is achievable with dial thermometers and analog dial pressure gauges by using bimetal compensators and exotic bourdon materials. With digital instruments, the inclusion of a case temperature probe is common and inexpensive, and has the advantage of compensating nonlinearly for a wide span of ambient temperatures. For precision instruments, an ambient temperature profile can be incorporated in memory and can operate automatically and transparently.

Multiple units of measure - Figure 1 shows a four-digit digital display with all segments active. On the right side of the digits, four icons are shown that correspond to four different pressure scales. On the left, four icons are shown that correspond to four different vacuum scales. A selection is made by scrolling through the scales or by operating a switch to set up the digital gauge to the scale that is recognized by the user. [My watch has a button that allows me to select any number of scales, from time-of-day, to day-and-date, to timer, countdown timer, and ever temperature, in °F or °C. Of course, when it comes time to change the watch, twice a year, to

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represent daylight savings, without a manual and a magnifying glass I am liable to change the year or to walk around wondering why my house is only heated to 21 degrees.] Four pressure scales and their corresponding vacuum scales are shown for illustration, some digital gauges are capable of selecting more than four scales. This is especially helpful in refrigeration gauges, since many scales are required to account for the multitude of refrigerants that are being used. In the example illustrated in Figure 2 if (PSI) is selected for the pressure scale then (in Hg) is automatically selected for the vacuum scale. For digital thermometers a single switch is used to select °F or °C.

Min-Max – With a digital device, a single push-button can be used to recall the minimum or the maximum reading. The button can be pushed once for displaying the Min reading, a second time for displaying the Max reading, and held down for a few seconds for resetting. Various methods are used to recall these functions. In addition to scrolling through the min and max readings and resetting, there is no need for worrying about getting back to the actual reading since most routines have an auto-return after some set time of inactivity.

Dampening - A home thermostat that registered and reported each slight tenth-of-a-degree change caused by each minor draft would confuse the user and run up his or her heating bill. The usual methods of using a thermo well on a digital thermometer or a snubber on a digital gauge can be used to smooth out the reading. Some instruments also include an averaging function that has a similar effect as liquid filling a pressure gauge. The averaging can be selected for various time-weighted averages. In a digital instrument, averaging can be done precisely and variably, fitted to the intended use of the instrument.

Zero adjust - Most analog gauges have an adjustable pointer or scale to fine tune the gauge at zero or in the use range. Digital gauges are also capable of zeroing, but some care should be taken since the zeroing becomes a digital offset. When an auto-zero function is used, the offset can only be made at zero, and the deviation from zero is applied at all points of the scale. If the actual pressure is not zero then the zeroing will cause systematic errors. Other methods employ a rotary switch or potentiometer and adjustment is made as an offset at any part of the range. The offset should generally increment plus or minus by units of display resolution to smooth operation.

Display Resolution - The example shown is a four-digit display with three decimals and is capable of displaying numerics from 0.000 to 9999. Some displays are configured to have half digits. A 3 ½-digit display would have for the most significant digit a blank or a 1 and would be capable of displaying numerics from .000 to 1999. The capability of the display resolution is usually greater than the resolution provided by the instrument. The resolution is defined as the smallest increment between two readings and is determined by the stated accuracy, and should be equal to or slightly lower than the smallest error as specified in the Full Scale accuracy. The resolution increments follow the 1, 2, 5 rule in order to present a step change that is not confusing. Most users who are not programmers or mathematicians (who have been trained to

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think in binary or hexadecimal logic) tend to think in base 10. If the resolution, for example, were in increments of 3, then successive readings would be 0, 3, 6, 9, 12, 15. This would be bewildering, as we would expect a 10 or a 20 before we expect a 9 or a 21. For a range of 0 to 300 psi and a 1% accuracy the resolution should be 2 instead of 3. Figure 3 shows the increasing pressure progression of a 100-PSI pressure gauge display that has an accuracy of .5%. The display is capable of displaying .1PSI resolution. However, readings may appear to be erratic as the gauge has an inherent uncertainty with less than .5-psi increments.

Leading Zero - The standard convention is to include a leading zero before the decimal. Readings such as (0.0, 0.5, 0.9, -0.2) are acceptable formats for displaying values near zero. Unacceptable readings such as (00.0, 02.5, 00.5, 09.9, -00.2, .5, and -.2) are confusing and should be avoided. It is also a good idea to have the decimal point pronounced, the substitution of a comma for a decimal, though is standard for some European written formats, is not acceptable for digital displays.

Range - The faceplate of a digital instrument should describe the pressure range; it is recommended that a gauge be used most often in the middle of the range to avoid over ranging and to achieve optimal accuracy. Mid-range is easily determined with analog gauges as the indicating pointer is near 12 o'clock. If the pointer is pegged on the stop pin it is well beyond the printed scale and it is obvious that an over-range condition exists. The person specifying the gauge is often not the person who monitors the gauge. Therefore it is helpful for the monitor to be able to understand intuitively both the range and whether the reading is within the range limits. If the top of the range is not printed on the face of the digital gauge, then a label should be applied as a reference for the user. A more sophisticated method would be to distinguish out-of-range readings with a unique and intuitive identifier, such as a blinking reading an auditory alarm or a display of Hi / Lo.

Power Up - Upon power up or with a test mode the display often activates all segments and icons; this is a helpful check that all segments are working. A missing segment can cause a wrong reading or an unintelligible character, a missing upper segment of a numeric can cause a 7 to be a 1, likewise absence of the middle segment can cause an 8 to appear to be a 0.

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FIGURE 1

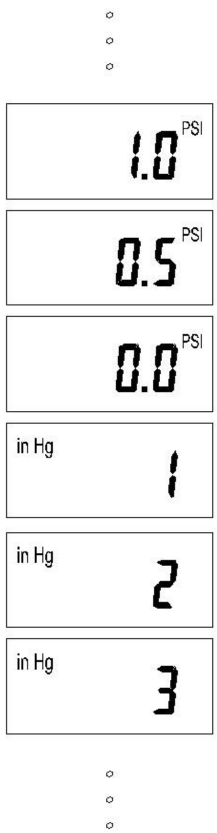

FIGURE 2

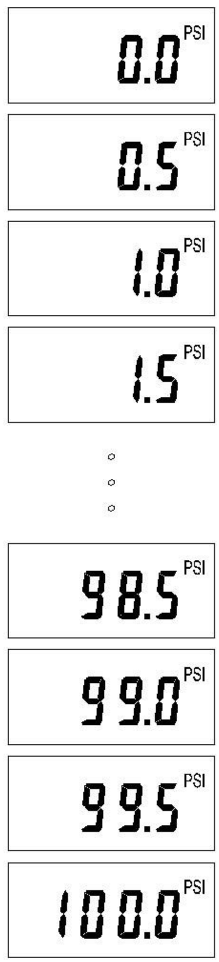

FIGURE 3

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