Department of Mechanical, Materials and Manufacturing Engineering

The University of Nottingham

Computer Engineering and Mechatronics MMME3085

Solution Sheet 5: Signals

1. How would you classify the following signals:
   a) A varying voltage from the sender unit on a car fuel tank **Analogue**;
   b) The signal from the sensing head of a "digital tachometer" consisting of a light, a phototransistor and a slotted disk (trick question!) **Train of pulses, or digital signal carrying "rate" information**;
   c) A signal from a safety barrier which is 240V AC when the gate is closed and 0V when the gate is open **Digital** (but not to a recognised standard);
   d) A set data sent to a printer down a multi-way cable, one wire for each bit of an 8-bit number **Digital (parallel data)**;
   e) A set of data sent one binary digit at a time, to and from a computer terminal to a mainframe down a pair of wires (with another wire for ground)? **Digital, serial data**

2. A signal is to be measured which is known to be sinusoidal (i.e. containing no higher-order harmonics) and which has a frequency of approximately 10 kHz. What is the minimum sampling rate (in samples per second) which can be used to measure the frequency? How would your answer change if the form of the signal were unknown and it was desirable to estimate its shape as well as its frequency? **Need sampling rate of at least 20 kS/s for estimating frequency. For shape we would need at least 100 kS/s**

3. A signal is made up of components at 30 kHz, 90 kHz and high-frequency noise in the range 210-230 kHz. What would be observed on a signal captured using a piece of data acquisition equipment at its maximum sampling rate of 100 kHz? If this were the highest-specification signal capture device available, what modifications could you make to your instrumentation in order to take meaningful readings of frequency of the fundamental? **We would see signal components at 10 kHz and 30 kHz and noise in the range 10kHz-30 kHz. A low-pass filter (attenuating or reducing frequencies say above 50 kHz) would reduce or avoid this aliasing issue.**

4. A piece of experimental equipment produces a signal with frequencies of 1 kHz, 7 kHz, 21 kHz, 28 kHz and 35 kHz.

   a) A sound card with a sampling frequency of 44.1 kHz is used to digitise the signal for recording. On the basis of this information, which frequencies would you expect to be present in the signal digitised using this card? What is the name of the undesired phenomenon occurring here? **1 kHz, 7 kHz, 9.1 kHz, 16.1 kHz, 21 kHz.**

   b) In practice, no evidence of the 28 kHz or 35 kHz signals is found in the recording and the 21 kHz signal is considerably weaker than expected. Explain how this can indicate that the sound card incorporates a crude attempt to avoid the problem identified in (a). **It incorporates a low pass (anti-aliasing) filter with a cut-off frequency aiming at around 22.05 kHz or lower, but this will not have sharp cut-off and it will attenuate the signal at 21 kHz.**

   c) Identify a better approach to solving the problem than that used in (b) in order to enable all the desired frequencies to be recorded. **Purchase a data acquisition system with a higher sampling rate.**

5. What kind of analogue input configuration would/could you use for the following situations:
   d) For a materials testing machine which gives a -10/+10v signal relative to that machine's ground: **Differential**
   e) For a battery-operated sensor (which is not connected to ground) **Single-ended**
   f) For measuring the voltage seen by a motor which is driven by a semiconductor bridge, where either of the lines used as inputs to the motor can be arbitrarily at 0v or 30v potential with respect to ground, with this connection changing on the fly. **Differential**

6. What kind of input (differential, single-ended non-referenced etc.) would you use in the following situations:
   a) To capture data from a hand-held, battery-operated pressure measurement device **Single-ended: the signal source is "floating"**
   b) To capture data from several channels of load and strain data from a tensile testing machine with its own earthed chassis and power supply and a bank of outputs all grounded with respect to that chassis **Differential would work but is not really necessary; single-ended non-referenced would probably be adequate provided the earthing arrangements on the machine really are common.**
   c) To capture signals from six separate earthed experimental rigs. **Differential inputs would be necessary as they cannot be regarded as having a common earth or ground.**

7. There is a suspicion that one or more of the analogue inputs to an Arduino Mega 2560 is not working correctly. To check correct operation quickly, the analogue inputs are connected to the 3.3 V output. What value read from the ADC would indicate correct operation?
   ADC = 3.3×1024/5 = 674.86 (can't have non-integer value so likely to be 674 in practice)

8. State what is meant by optical isolation. Outline the principles behind this technique, showing a simple circuit to illustrate how it is achieved.

   State the two main benefits of the technique and identify the kind of situation where it is likely to be used. **See lecture notes.**