

# Air data - Aircraft altitude control

## Lab work nº2 (part1)

### 1 Objectives

- To understand the role of the Air-Data computer.
- To address the characterization of a (pressure) sensor.
- To simulate the transmission of digital data from the pressure sensor to the air-data computer using the digital avionic data bus.

### 2 Introduction

The Air-Data computer has the purpose to compute the altitude and the speed of an aircraft. Analog quantities are measured and are converted to a digital representation to be transmitted to several systems, in the case of, the static pressure, the total pressure and the total impact temperature, they are the inputs to the Air-Data computer, which provides information to the autopilot to automatically adjust the speed of the aircraft and its altitude.

This lab work has the purpose to address: a) the characterization of a sensor pressure; b) the conversion of the analog to a digital representation and the specification of the word size; c) the simulation of the data transmission using the avionic digital bus Arinc 429.

### 3 The problems to be solved

It is assumed that test experiments were performed to obtain the response of the sensor (output/voltage [V]) for several pressure and temperature conditions. The recorded data must be used to identify a static model that will be used to infer the pressure that acts on the sensor during an aircraft flight.

1. Consider the data that is provided in appendix. Use the least square method to characterize the output of the sensor (voltage) as a function of the pressure and of the temperature. Compute the error between the model and the experimental data.
2. Develop a method to compute the pressure as a function of the voltage and of the temperature. Evaluate the error between the experimental data and the model obtained.
3. The test experiments were performed with -45°C, 25°C and 125°C. Assuming that a 0.1°C of accuracy is needed. compute the number of bits necessary to convert the temperature data into a digital (binary) representation to be transmitted by a digital bus.
4. The characterized pressure sensor will be used to estimate the aircraft (pressure) QNE altitude with the standard atmosphere model. Evaluate model error for the estimation of the pressure altitude and the accuracy of the analog to digital conversion. Present a flight operational criteria for this purpose.

5. Explore the digital avionics 429 bus, define a data network to transmit the needed input data to the Air-Data computer.

## 4 Evaluation

The following points will be considered in the evaluation of this lab work:

1. Analysis and rationality employed.
2. Results obtained.

Report delivery date: Defined in the first theoretical class.

## 5 Synthetic data to be used for sensor characterization

Pressure [mbar]	Output [Volt] at -45°C	Output [Volt] at 25°C	Output [Volt] at 125°C
1.0000000e+01	9.6891912e-02	3.9214138e-02	8.0487284e-02
1.5000000e+01	6.0851900e-02	2.2426346e-02	7.6988551e-02
2.0000000e+01	3.7395234e-02	1.0771168e-01	1.5599585e-02
2.5000000e+01	1.1393540e-01	4.9464483e-02	5.9137552e-02
3.0000000e+01	2.3785157e-02	4.4588951e-02	1.4701188e-01
3.5000000e+01	1.1012565e-01	8.0013170e-02	3.7981724e-02
4.0000000e+01	7.5780823e-02	1.4446871e-01	1.0942118e-01
4.5000000e+01	1.1891421e-01	9.1045177e-02	5.2457714e-02
5.0000000e+01	1.5745503e-01	1.2253808e-01	1.2698883e-01
5.5000000e+01	1.8132342e-01	7.9968573e-02	1.4443765e-01
6.0000000e+01	1.4325421e-01	1.5679809e-01	1.3689275e-01
6.5000000e+01	1.5888049e-01	1.4951198e-01	1.9430109e-01
7.0000000e+01	8.3664964e-02	1.5989808e-01	1.6326326e-01
7.5000000e+01	1.3893389e-01	1.9675427e-01	2.2881573e-01
8.0000000e+01	2.9442284e-01	2.0526728e-01	2.3766409e-01
8.5000000e+01	2.3971441e-01	2.1739275e-01	1.9510525e-01
9.0000000e+01	2.6161016e-01	3.5119408e-01	2.2929842e-01
9.5000000e+01	2.0265181e-01	2.8627189e-01	2.4003381e-01
1.0000000e+02	2.5130987e-01	3.2559117e-01	2.8326019e-01
1.0500000e+02	2.0100899e-01	3.3835876e-01	3.0732601e-01
1.1000000e+02	2.3209178e-01	2.7399005e-01	3.0223021e-01
1.1500000e+02	2.4903023e-01	2.7989896e-01	2.8453107e-01
1.2000000e+02	2.4876790e-01	2.4659760e-01	2.6097740e-01
1.2500000e+02	2.8395577e-01	2.8843658e-01	2.5828123e-01
1.3000000e+02	3.0457423e-01	3.3019425e-01	3.6741545e-01
1.3500000e+02	3.3769783e-01	3.5221405e-01	4.1688049e-01
1.4000000e+02	4.3349382e-01	3.8328499e-01	3.6107504e-01
1.4500000e+02	4.7950391e-01	3.9089416e-01	3.6105251e-01
1.5000000e+02	3.8302689e-01	3.5157274e-01	4.1511855e-01
1.5500000e+02	4.4169029e-01	4.0075645e-01	3.2382861e-01
1.6000000e+02	4.3875983e-01	4.9826069e-01	3.9475517e-01

1.6500000e+02	4.1367293e-01	4.3147364e-01	3.3891002e-01
1.7000000e+02	4.3542224e-01	4.2159795e-01	4.5036563e-01
1.7500000e+02	4.1684755e-01	4.6336205e-01	4.4848812e-01
1.8000000e+02	5.4300436e-01	5.0220163e-01	4.7474419e-01
1.8500000e+02	5.2261386e-01	4.8840507e-01	4.5868109e-01
1.9000000e+02	5.8287927e-01	5.0214433e-01	4.1540932e-01
1.9500000e+02	5.2595976e-01	5.2093027e-01	5.4466308e-01
2.0000000e+02	5.5587122e-01	5.9806722e-01	4.9306779e-01
2.0500000e+02	6.0978227e-01	5.9969556e-01	5.4118960e-01
2.1000000e+02	6.0415619e-01	5.5144011e-01	5.8692065e-01
2.1500000e+02	6.7901095e-01	5.6742969e-01	5.8657304e-01
2.2000000e+02	6.0326682e-01	5.4332639e-01	5.4529824e-01
2.2500000e+02	7.1431390e-01	6.7475320e-01	5.8306869e-01
2.3000000e+02	6.5832400e-01	6.4116963e-01	5.9992285e-01
2.3500000e+02	6.8276307e-01	6.5195701e-01	6.6358042e-01
2.4000000e+02	6.8756434e-01	6.8521723e-01	6.9070651e-01
2.4500000e+02	7.0113357e-01	6.4207908e-01	6.1178181e-01
2.5000000e+02	8.0729867e-01	6.7381584e-01	6.2906698e-01
2.5500000e+02	7.2529302e-01	7.3489232e-01	6.9063295e-01
2.6000000e+02	8.2617790e-01	7.3125693e-01	7.0094966e-01
2.6500000e+02	7.8676380e-01	6.7819597e-01	7.2479305e-01
2.7000000e+02	8.0729231e-01	7.4678981e-01	6.9039919e-01
2.7500000e+02	8.3369182e-01	8.0549796e-01	6.9457260e-01
2.8000000e+02	8.4272344e-01	8.5502937e-01	7.6117973e-01
2.8500000e+02	8.1054515e-01	8.3266021e-01	8.3007223e-01
2.9000000e+02	8.4176063e-01	8.5220930e-01	8.2197750e-01
2.9500000e+02	9.1730853e-01	8.4441212e-01	8.0802999e-01
3.0000000e+02	9.0696714e-01	8.8965211e-01	8.1371675e-01
3.0500000e+02	9.4392551e-01	9.2059091e-01	8.0045144e-01
3.1000000e+02	9.8210881e-01	8.8007419e-01	8.9814998e-01
3.1500000e+02	9.7959622e-01	9.7656196e-01	9.1292885e-01
3.2000000e+02	9.7497178e-01	8.8513024e-01	8.8859355e-01
3.2500000e+02	1.0078278e+00	9.6812736e-01	9.2757359e-01
3.3000000e+02	1.0845392e+00	9.7870156e-01	9.3979664e-01
3.3500000e+02	1.0760546e+00	1.0724751e+00	9.8302631e-01
3.4000000e+02	1.1003147e+00	1.0117897e+00	1.0287173e+00
3.4500000e+02	1.1236023e+00	1.1728402e+00	9.0922263e-01
3.5000000e+02	1.1449616e+00	1.0501508e+00	9.8473697e-01
3.5500000e+02	1.0953951e+00	1.0508223e+00	1.0111162e+00
3.6000000e+02	1.2453221e+00	1.1921460e+00	9.8045213e-01
3.6500000e+02	1.1591436e+00	1.1162843e+00	1.0375096e+00
3.7000000e+02	1.1866896e+00	1.1255241e+00	1.0993561e+00
3.7500000e+02	1.1446719e+00	1.1606293e+00	1.0539101e+00
3.8000000e+02	1.2682078e+00	1.1333953e+00	1.0176763e+00
3.8500000e+02	1.2677326e+00	1.1340540e+00	1.0789134e+00
3.9000000e+02	1.2726746e+00	1.1861120e+00	1.1492776e+00
3.9500000e+02	1.3099809e+00	1.2342021e+00	1.1251078e+00
4.0000000e+02	1.3402323e+00	1.2968175e+00	1.2118209e+00

4.0500000e+02	1.3403999e+00	1.3191289e+00	1.1695201e+00
4.1000000e+02	1.2454517e+00	1.3092948e+00	1.2194464e+00
4.1500000e+02	1.3629791e+00	1.3578840e+00	1.2045355e+00
4.2000000e+02	1.3814131e+00	1.4351252e+00	1.2722551e+00
4.2500000e+02	1.4263383e+00	1.3754974e+00	1.1995648e+00
4.3000000e+02	1.4178686e+00	1.4080715e+00	1.3498807e+00
4.3500000e+02	1.4567605e+00	1.3771236e+00	1.2938667e+00
4.4000000e+02	1.4760224e+00	1.4578079e+00	1.3158674e+00
4.4500000e+02	1.4864560e+00	1.3842383e+00	1.2830165e+00
4.5000000e+02	1.5418370e+00	1.4367199e+00	1.3591204e+00
4.5500000e+02	1.5397229e+00	1.4358786e+00	1.3753853e+00
4.6000000e+02	1.5930214e+00	1.4685477e+00	1.3489256e+00
4.6500000e+02	1.5558330e+00	1.5921036e+00	1.4404559e+00
4.7000000e+02	1.6650095e+00	1.5242195e+00	1.5165726e+00
4.7500000e+02	1.5892261e+00	1.5361324e+00	1.5029593e+00
4.8000000e+02	1.6337969e+00	1.6160139e+00	1.4720947e+00
4.8500000e+02	1.6080958e+00	1.5825818e+00	1.5165553e+00
4.9000000e+02	1.6637974e+00	1.6294014e+00	1.5223973e+00
4.9500000e+02	1.7625971e+00	1.6599902e+00	1.5503976e+00
5.0000000e+02	1.7533439e+00	1.6240176e+00	1.4704569e+00
5.0500000e+02	1.7187081e+00	1.6661290e+00	1.5368296e+00
5.1000000e+02	1.7998150e+00	1.7795552e+00	1.5817848e+00
5.1500000e+02	1.7735000e+00	1.7291126e+00	1.6387174e+00
5.2000000e+02	1.7407340e+00	1.7819508e+00	1.6480677e+00
5.2500000e+02	1.8264318e+00	1.8186568e+00	1.6495629e+00
5.3000000e+02	1.9507000e+00	1.8123328e+00	1.5873002e+00
5.3500000e+02	1.9028974e+00	1.8160909e+00	1.6371953e+00
5.4000000e+02	1.8382566e+00	1.8849519e+00	1.7686536e+00
5.4500000e+02	1.9693578e+00	1.8044160e+00	1.7410226e+00
5.5000000e+02	2.0427824e+00	1.9264414e+00	1.7568788e+00
5.5500000e+02	1.9862435e+00	1.8148743e+00	1.7634043e+00
5.6000000e+02	2.0055732e+00	1.8713882e+00	1.9144104e+00
5.6500000e+02	2.0595954e+00	1.9277803e+00	1.7912589e+00
5.7000000e+02	2.0259404e+00	1.9643012e+00	1.8340687e+00
5.7500000e+02	2.0955756e+00	1.9245871e+00	1.8824278e+00
5.8000000e+02	2.2094876e+00	2.0448180e+00	1.9352076e+00
5.8500000e+02	2.0962727e+00	2.0332965e+00	1.8981255e+00
5.9000000e+02	2.1587403e+00	2.0151148e+00	1.9635482e+00
5.9500000e+02	2.1968645e+00	2.0344298e+00	1.9861486e+00
6.0000000e+02	2.2225279e+00	2.0670123e+00	1.9782699e+00
6.0500000e+02	2.2643459e+00	2.0954085e+00	1.9366598e+00
6.1000000e+02	2.2456164e+00	2.1475712e+00	2.0433766e+00
6.1500000e+02	2.2488184e+00	2.1740539e+00	2.0371033e+00
6.2000000e+02	2.3011140e+00	2.1761884e+00	2.1170965e+00
6.2500000e+02	2.2511727e+00	2.2202104e+00	2.0431432e+00
6.3000000e+02	2.3450096e+00	2.2212788e+00	2.0987486e+00
6.3500000e+02	2.4682623e+00	2.2785595e+00	2.1008460e+00
6.4000000e+02	2.3817363e+00	2.3580751e+00	2.0694914e+00

6.4500000e+02	2.4445713e+00	2.3544034e+00	2.1235302e+00
6.5000000e+02	2.4759707e+00	2.3272594e+00	2.1095399e+00
6.5500000e+02	2.4972171e+00	2.3740163e+00	2.2784375e+00
6.6000000e+02	2.5097849e+00	2.3860963e+00	2.2428651e+00
6.6500000e+02	2.5065477e+00	2.3997949e+00	2.2799510e+00
6.7000000e+02	2.5730632e+00	2.4290040e+00	2.2868850e+00
6.7500000e+02	2.5946722e+00	2.5113439e+00	2.3464026e+00
6.8000000e+02	2.6176085e+00	2.4691387e+00	2.3852079e+00
6.8500000e+02	2.6617975e+00	2.5238041e+00	2.3312045e+00
6.9000000e+02	2.6564191e+00	2.5660257e+00	2.3319234e+00
6.9500000e+02	2.6419873e+00	2.5244299e+00	2.4381298e+00
7.0000000e+02	2.6854381e+00	2.5304905e+00	2.5072026e+00
7.0500000e+02	2.7714441e+00	2.6478322e+00	2.4316573e+00
7.1000000e+02	2.8117062e+00	2.6576801e+00	2.4334780e+00
7.1500000e+02	2.7711360e+00	2.6459799e+00	2.5008564e+00
7.2000000e+02	2.7695393e+00	2.7388331e+00	2.4733557e+00
7.2500000e+02	2.8093032e+00	2.7316285e+00	2.5036557e+00
7.3000000e+02	2.9190577e+00	2.7281264e+00	2.5858057e+00
7.3500000e+02	2.9425813e+00	2.7526357e+00	2.5737739e+00
7.4000000e+02	2.9646149e+00	2.7761468e+00	2.6277102e+00
7.4500000e+02	2.9997074e+00	2.7782833e+00	2.6104910e+00
7.5000000e+02	2.9864209e+00	2.9590428e+00	2.6783063e+00
7.5500000e+02	3.0217403e+00	2.7830755e+00	2.6928250e+00
7.6000000e+02	3.0724579e+00	2.9123083e+00	2.7241858e+00
7.6500000e+02	3.1086710e+00	2.9279470e+00	2.7749194e+00
7.7000000e+02	3.2031659e+00	2.9024787e+00	2.7873552e+00
7.7500000e+02	3.0878064e+00	2.9750201e+00	2.7151869e+00
7.8000000e+02	3.1599427e+00	3.0234076e+00	2.8747921e+00
7.8500000e+02	3.2016387e+00	3.0759631e+00	2.7766015e+00
7.9000000e+02	3.1648603e+00	3.0659770e+00	2.7805582e+00
7.9500000e+02	3.1800482e+00	3.1119445e+00	2.9145966e+00
8.0000000e+02	3.2759257e+00	3.1863498e+00	2.8699613e+00
8.0500000e+02	3.2692005e+00	3.1384007e+00	2.8504185e+00
8.1000000e+02	3.3268474e+00	3.1469754e+00	2.9498752e+00
8.1500000e+02	3.3168393e+00	3.1398081e+00	3.0506458e+00
8.2000000e+02	3.3808611e+00	3.2593534e+00	3.0382036e+00
8.2500000e+02	3.4181333e+00	3.2320960e+00	3.0555676e+00
8.3000000e+02	3.3526291e+00	3.3378267e+00	3.0105086e+00
8.3500000e+02	3.5036003e+00	3.3110840e+00	3.0466612e+00
8.4000000e+02	3.4197251e+00	3.3306372e+00	3.1416978e+00
8.4500000e+02	3.5420700e+00	3.3413187e+00	3.1837068e+00
8.5000000e+02	3.5621956e+00	3.3713473e+00	3.2010923e+00
8.5500000e+02	3.6005529e+00	3.3693904e+00	3.2047538e+00
8.6000000e+02	3.6832469e+00	3.4728465e+00	3.1676337e+00
8.6500000e+02	3.5879701e+00	3.4600635e+00	3.2272849e+00
8.7000000e+02	3.6529343e+00	3.5313021e+00	3.3103463e+00
8.7500000e+02	3.6800483e+00	3.4658495e+00	3.3439466e+00
8.8000000e+02	3.8048883e+00	3.5766463e+00	3.3299177e+00

8.8500000e+02	3.8256850e+00	3.5546218e+00	3.3448211e+00
8.9000000e+02	3.8313159e+00	3.5572564e+00	3.3809257e+00
8.9500000e+02	3.7693385e+00	3.6398592e+00	3.3748248e+00
9.0000000e+02	3.8448725e+00	3.7032433e+00	3.4549903e+00
9.0500000e+02	3.9159888e+00	3.7491897e+00	3.4566418e+00
9.1000000e+02	3.9398317e+00	3.7865530e+00	3.4934523e+00
9.1500000e+02	3.9298824e+00	3.7508924e+00	3.4956659e+00
9.2000000e+02	4.0492033e+00	3.7569062e+00	3.5415600e+00
9.2500000e+02	3.9951859e+00	3.9474937e+00	3.5311767e+00
9.3000000e+02	4.0659343e+00	3.8326208e+00	3.6478648e+00
9.3500000e+02	4.1633054e+00	3.8561042e+00	3.5995144e+00
9.4000000e+02	4.1839674e+00	3.9334921e+00	3.6665231e+00
9.4500000e+02	4.1366737e+00	3.9009719e+00	3.5875770e+00
9.5000000e+02	4.2073266e+00	3.9474348e+00	3.7333023e+00
9.5500000e+02	4.2770770e+00	3.9429081e+00	3.7064543e+00
9.6000000e+02	4.2013391e+00	4.0266060e+00	3.7738715e+00
9.6500000e+02	4.3116974e+00	4.0196141e+00	3.7598150e+00
9.7000000e+02	4.3807813e+00	4.1110343e+00	3.8322796e+00
9.7500000e+02	4.3779508e+00	4.1334772e+00	3.8116287e+00
9.8000000e+02	4.4196780e+00	4.1275399e+00	3.8439161e+00
9.8500000e+02	4.4015677e+00	4.1717386e+00	3.8507165e+00
9.9000000e+02	4.3815414e+00	4.1949918e+00	3.8575296e+00
9.9500000e+02	4.4370445e+00	4.2556787e+00	3.9632262e+00
1.0000000e+03	4.5629051e+00	4.2534913e+00	4.0190932e+00
1.0050000e+03	4.5353495e+00	4.3218812e+00	4.0096531e+00
1.0100000e+03	4.5992413e+00	4.3080067e+00	4.0056142e+00
1.0150000e+03	4.5569539e+00	4.3970392e+00	4.0148016e+00
1.0200000e+03	4.5590663e+00	4.3981573e+00	4.0504362e+00
1.0250000e+03	4.5810653e+00	4.3538817e+00	4.1899300e+00
1.0300000e+03	4.7097650e+00	4.4755318e+00	4.1516340e+00
1.0350000e+03	4.6446833e+00	4.5375482e+00	4.1334187e+00
1.0400000e+03	4.8236555e+00	4.5821527e+00	4.1610760e+00
1.0450000e+03	4.8457768e+00	4.5723715e+00	4.2054082e+00
1.0500000e+03	4.8452803e+00	4.6545741e+00	4.2559532e+00
1.0550000e+03	4.9087589e+00	4.6549759e+00	4.3755750e+00
1.0600000e+03	4.8966159e+00	4.7439687e+00	4.3254659e+00
1.0650000e+03	4.8615836e+00	4.7022483e+00	4.3034173e+00
1.0700000e+03	4.9641911e+00	4.7431845e+00	4.3540005e+00
1.0750000e+03	4.9764416e+00	4.7738693e+00	4.3734111e+00
1.0800000e+03	5.0885959e+00	4.8112968e+00	4.4970507e+00
1.0850000e+03	5.0864543e+00	4.8549443e+00	4.5540186e+00
1.0900000e+03	5.1237060e+00	4.8970771e+00	4.5652457e+00
1.0950000e+03	5.1269271e+00	4.8474671e+00	4.5194580e+00
1.1000000e+03	5.1409824e+00	4.8680138e+00	4.6122598e+00