DECAGON DEVICES

Application Note

Measuring UMS Tensiometers with non-UMS Control and Data Acquisition Systems

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UMS GmbH (Munich, Germany) designs and manufactures a range of high quality tensiometers for the measurement of soil water tension (water potential). The tensiometer cables are designed for interface with the UMS "Infield 7" readout device. However, there are applications where long-term logging is desired, and therefore a need to connect these tensiometers to data loggers other than the Infield 7. This paper addresses the capabilities of the UMS Tensiometers with respect to their ability to interface with non-UMS data loggers.

UMS Tensiometers use a thin wafer piezoresistive pressure transducer to measure water tension. The resistance of the pressure transducer changes as it is deformed by the pressure difference across it, defined by atmospheric pressure on one side and the tension held on the water in the shaft on the opposite side. An asymmetric Wheatstone full bridge is utilized to analyze the resistance of the thin wafer, which is proportional to the tension in the soil water relative to atmospheric pressure. With the Wheatstone bridge used here:

$$\frac{V_{out}}{V_{in}} \propto \Psi_T \qquad (1)$$

where V_{out} is the signal millivolt output from the pressure sensor, V_{in} is the excitation voltage provided to the pressure sensor, and ψ_T is the tension on the water in the tensiometer shaft immediately adjacent to the pressure transducer.

UMS tensiometers are calibrated with V_{in} = 10.6V DC. When using the 10.6V excitation, there is a linear calibration

$$\psi_T \text{ (kPa)} = V_{out} \text{ (mV)} \qquad (2)$$

with the convention that $\psi_T > 0$ is tension and $\psi_T < 0$ is pressure. Since many popular control and data acquisition devices (e.g. Campbell Scientific data loggers) have 5V DC or user-defined excitation ports readily available, it is often convenient to use these power supplies for excitation rather than 10.6 V. This is accomplished by using the following equation

$$\psi_T = V_{out} * 10.6/V_{in} \qquad (3)$$

where ψ_T is in kPa, V_{out} is in mV, and V_{in} is in volts.

Potential data acquisition pitfalls

Because the pressure transducer is configured in a Wheatstone full bridge, the input voltage and signal mV output cannot be connected to the same reference (ground). Hence, the signal mV output can only be measured using a **differential** voltage measurement. Therefore, do not attempt to make a single-ended measurement of the pressure transducer mV output.

Additionally, both the signal "+" and signal "–" are very close to ½ of the excitation voltage (i.e. if a 5V excitation is used, the signal "+" and "–" will be ~2.5 V above the excitation ground, although only a few mV from each other). If the signal voltage referenced against the excitation ground exceeds the *common mode range** of the logger, the measurement will fail. Therefore, an appropriate excitation voltage must be chosen to avoid exceeding the common mode range. This can be accomplished in two ways. First, the excitation voltage can be limited with a simple voltage divider or by setting the analog output at a small enough value. Alternatively, UMS manufactures a tensiometer power supply (model TV-Batt) that provides a voltage of +5.6V referenced against -5V to provide a 10.6V excitation with the signal output very near 0V compared to the logger ground. The TV-Batt can be powered from 7 -16V DC, and can supply power to up to 60 tensiometers.

* The common mode range is ± 2.5 V for CR10X loggers and ±5V for CR21X and CR23X loggers. Check the specifications in your logger manual to identify the common mode range for other data acquisition systems.

It should also be noted here that any instability in the excitation voltage (e.g. weakening battery power at a remote site) will be reflected in the output as indicated by equation 3 above. It is therefore advisable to either excite the tensiometer pressure transducer with a regulated voltage source, or to record the excitation voltage and correct for drift. Also note that equation 3 is not valid for the UMS model T8 tensiometer, which will output a stable 0-2V with any excitation voltage in the 6-20VDC range.

Cautions

Keep in mind that the UMS tensiometer pressure transducers are rated for excitation voltages from 5-15V DC. We have successfully used the tensiometers with excitation voltages as low as 2.5V, but would not recommend exciting at voltages above the specified range. Also note that allowing the tension on the water in the tensiometer to reach suction below ~85KPa will cause cavitation in the tensiometer requiring refilling before meaningful readings can be made. If the tension reaches ~200KPa, the pressure transducer may be destroyed. With the T5 tensiometer, this can occur within a matter of seconds after removing the porous cup from a moist environment and exposing it to dry air. With the T8, over-tightening of the water column corpus will break the pressure transducer, so care must be taken to hand-tighten it. Additionally, the ceramic cups of the tensiometers can be harmed by exposure to skin oils from direct handling of the cups with bare hands.

Example Programs

Edlog

The following program is an example that can be used with a Campbell Scientific CR21X datalogger or adapted to other Edlog type loggers.

```
;{21X}
;
;Program to read UMS tensiometer pressure
transducers
;
;Wiring (with black adapter cable)
;
;Brown - supply (+) – Ex. Ch. 1
;Blue - supply (-) - Ground
;White - signal (+) - differential channel 1 H
;Thin Black - signal (-) - differential channel 1 L
;Thick Black - shield - ground
;
;The output of this program is in kPa with
negative values indicating suction
;

*Table 1 Program
  01: 1         Execution Interval (seconds)

; The value 2.12 = 10.6V/5V
;
1:  Ex-Del-Diff (P8)
 1: 1        Reps
 2: 4        500 mV Slow Range
 3: 1        DIFF Channel
 4: 1        Excite all reps w/Exchan 1
 5: 1        Delay (0.01 sec units)
 6: 5000     mV Excitation
 7: 1        Loc [ Psi_kPa   ]
```

8: -2.12 Mult
9: 0.0 Offset

**Table 2 Program*
02: 0.0000 Execution Interval (seconds)

**Table 3 Subroutines*

End Program

CR Basic

The following program is an example that can be used with a Campbell Scientific CR1000 datalogger or adapted to other CR Basic type loggers.

```
'CR1000
'program to measure UMS analog tensiometer
(T1, T3, T4, T5) with CR1000 datalogger
'Wiring
'Brown - supply (+) - Ex. Ch. 1
'Blue - supply (-) - Ground
'White - signal (+) - differential channel 1 H
'Thin Black - signal (-) - differential channel 1 L
'Thick Black - shield - ground
Public WP
Units WP=kPa

DataTable(Table1,1,-1)
        DataInterval(0,30,Min,10)
        Sample (1,WP,FP2)
EndTable

BeginProg
        Scan(1,Sec,0,0)
                BrFull(WP,1,mV250,1,Vx1,1,250
                0,False,False,0,_60Hz,-10.6,0.0)
'note that RevEx and RevDiff must both be false
'to read UMS tensiometers note that multiplier of
'-10.6 adjusts the  sign of output to standard
'convention (pressure = positive number and
'tension = negative number)
                CallTable(Table1)
        NextScan
EndProg
```

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