

THE DC-SE TRANSDUCER AS A MICRO-POWER CREEP-METER

Several earthquake faults in California exhibit a form of surface slip known as creep. This slow slip of the fault is responsible for the fracture of subsurface pipes, cables and for ongoing damage to structures misfortunate enough to be constructed on the fault. The first and most famous of these structures to be identified as damaged by creep is the old Cienega Winery south of Hollister California that continues to be severed at a rate of a few cm each year.



Figure 1. Creep of the San Andreas Fault at the Cienega Winery (now the de Rose Winery) south of Hollister, California, has cut through the winery structure, and since 1956 has cracked and offset a culvert there by more than 3 feet.

A creep-meter is an instrument designed to monitor the offset of a creeping fault. Sample rates are typically 1 minute to 10 minutes, and precision is usually 1-10 μm . Creepmeters are buried obliquely across a fault at a depth of 30 cm to 2 m and consist of a length standard - an inextensible rod or tensioned wire- fixed firmly to one side of the fault, held in tension on the other side of the fault by a device that measures the changing displacement of the free end of the rod relative to a second fixed point.

Although various transducers have been used to measure the changing displacement, LVDTs are often favored, because they are immune to occasional flooding as occurs frequently in subsurface installations. In this application we describe the use of a Schaevitz DC-SE transducer, whose low power consumption (6 mA at 9V) is ideal for its incorporation in unattended creepmeters.

We lower the average power consumption yet further (to a few μW) by using the DC-SE in a switched mode. We found that the DC-SE attains full signal voltage within approximately 5 ms of power-up (Figure 2), making possible 12-bit accuracy recording by an ONSET *Microstation*. This 4-channel data logger has a 512 Mb memory permitting year long operation at 5 minute sample intervals. The *Microstation* switches on the LVDT 10 ms prior to storing the average of 32 samples measured in the succeeding 2.5 ms. Data are downloaded annually using a portable PC or a Palm computer (easier to read in direct sunshine).

An odd feature of the DC-SE is that the power-ground is 1 V above the signal-ground. Thus in this switched mode of operation (necessary to exploit the open-collector switched ground of the *Microstation*) the DC-SE output is not 0-5 Volts but 1-6 Volts. However, we discovered that the actual output from the DC-SE in this mode extends from 0.2 V to 6.8V in an extended non-linear region extending 25% beyond the factory calibrated region (± 4.5 mm in the DC-SE 1000). Accordingly we calibrated this range and find it to differ smoothly from the factory-calibration by less than 12%. Although each transducer must be calibrated in this range, the non-linearity increases monotonically, and the digitally recorded data can easily be converted to a linear signal

in subsequent analysis using a digital "look-up" table. In practice, digital data are rarely obtained in this region since the creepmeter is adjusted manually each year to lie within its linear range.

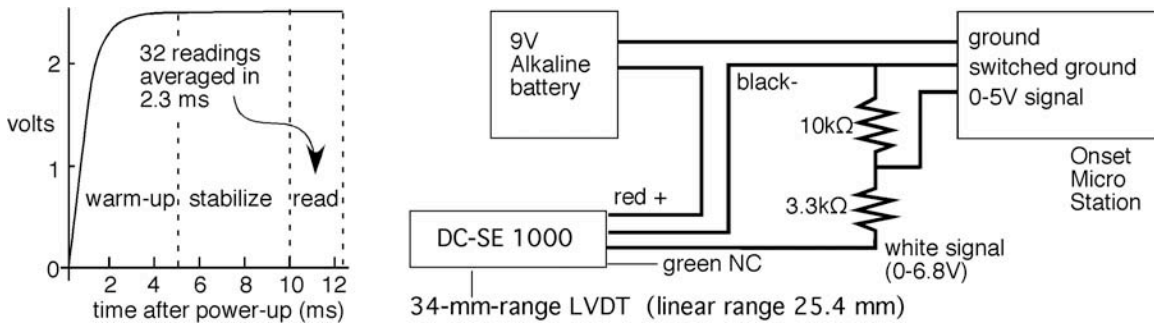


Figure 2 Power-up and sample timing for the *Schaevitz* DC-SE 1000 using the open-collector switched-mode of an *ONSET Microstation* data logger. The potential dividing circuitry is to record the 25% extended non-linear range of the DC-SE 1000. Alkaline cells power the system for a year unattended.

To prevent the data from going over-range on the 0-5V *Microstation* data logger we include a voltage-divider to reduce maximum voltage from 6.8V to 5 V (Figure 2). Also, to facilitate manual adjustment by field crews we color-code, using black and green heat-shrink tube, the linear, and non-linear ranges on the 4-40 shaft that supports the core. Visual inspection permits accurate mechanical adjustment without voltmeter. The DC-SE 1000 permits a full measurement range of 34 mm (25 mm /linear) and the *Microstation* provides a least-count resolution of $\approx 10 \mu\text{m}$. The equivalent thermal sensitivity of the complete transducer and recording system is less than $1 \mu\text{m}/^\circ\text{C}$.

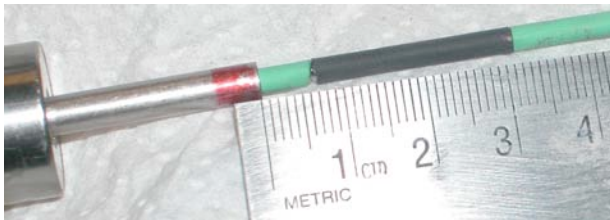


Figure 3 A heat-shrink, color-coded shaft facilitates mechanical adjustment of the DC-SE 1000. The black region corresponds to the factory-calibrated linear range of 25.4 mm. The full range including a non-linear region is 39 mm. For linear operation the black region must be partly or entirely within the body of the transducer left.

The average power consumption of the system is $\approx 1.5 \mu\text{W}$ for a ten minute sample rate (temperature and creep), making possible remote operation of the creepmeter for a year on 6 alkaline AA cells. In practice, we use six D-cells or Lithium cells to ensure operation in the presence of extreme temperatures. The entire recording system, batteries and desiccant are packaged in a 4-inch PVC tube with a sealed rubber cap. To ensure continued operation and additional protection from corrosion during the rainy season in California, the DC-SE is coated with silicon grease.

A cautionary note: the DC-SE series is not protected against incorrect polarity reversal of its power leads.

Roger Bilham
 Dept of Geological Sciences, University of Colorado, Boulder CO 80309-0399.
 bilham@colorado.edu