New Broadband Shortwave Solar Radiation Data Collection System for the Southern Great Plains

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Background

To improve the data recovery from the Solar and Infrared Radiation Observing System (SIROS), a new data logging system was needed. Experience had shown the original multifilter rotating shadowband radiometer (MFRSR)-based logger and in-line amplifiers were unreliable and difficult to maintain. The National Renewable Energy Laboratory (NREL) was given the task of developing a new system that used off-the-shelf technology, was traceable to the National Institute of Standards and Technology (NIST), and highly reliable. We chose Campbell Scientific, Inc. (CSI) equipment because of the proven performance for 20 years at the NREL Solar Radiation Research Laboratory, 13 years in the U.S. Department of Energy (DOE)/NREL Historically Black Colleges and Universities solar measurement network, and more recently with the DOE/Saudi Arabia solar network. When using a pure CSI system, we have been able to attain better than 98% data retrieval rates.

Concept

The new Solar Infrared Station (SIRS) is based on the CSI model CR10X-1M programmable data logger. With supporting hardware and communication software, the system provides SIRS with 2-second sampling, and 20-second and 1-minute outputs from 6 radiometers. The data system is compatible with the World Meteorological Organization's Baseline Surface Radiation Network (BSRN) performance specifications. A 4-Mbyte Personal Computer Memory Card International Association (PCMCIA) data storage device permits up to 15.3 days of independent data backup. The programmable capabilities of the logger were used to provide all radiometric data in engineering units (Watts per square meter) and daily records of the instrument serial numbers and calibration factors. The CSI system design features allow for future expansion.

Implementation

During the development phase, a complete SIRS prototype was assembled and tested at NREL using the same equipment that would be installed in the field except for the modem and data collection system. The site data system does not use a CSI modem or the CSI telecommunication software. It required approximately 2 months to assemble, program, and test the system at NREL. All troubleshooting was accomplished at this time to ensure the system would work upon installation. Electronic test fixtures consisting of a power supply, voltage divider, and switching network were built to simulate instrument signals. The fixtures were used at NREL to test the hardware hookup and program reliability. These fixtures also provide the field technicians with portable equipment for operation checks and troubleshooting during SIRS installations. After each site was installed, these fixtures were used to test the operation of the SIRS system prior to leaving the site.

Details

One of the most difficult parts of this task was programming the data logger to output the irradiance in W/m^2 from the precision infrared pyrgeometer (PIR). The precision spectral pyranometer (PSP), normal incidence pyrheliometer (NIP), and the PIR each require a differential measurement of the thermopile output with the appropriate multiplier (correction factor) for producing engineering units. Additionally, the PIR requires the instrument case and dome temperature measurements to produce the final irradiance in W/m^2. To measure the thermistors in the dome and the case, we designed a voltage divider network that incorporated the thermistors. By exciting the divider network with a known voltage (2 VDC) and having a known common resistor (100KΩ), as part of the divider network, we could then measure the voltage drop across the thermistors. The 100KΩ resistor was selected to limit current flow in the circuit, thereby limiting self-heating of the thermistor. By using Ohms and Kirchoff Laws, we were able to determine the resistance (Ω) of the thermistors. With data provided by the thermistor manufacturer, we were able to correlate the resistance to a temperature (°K). We were then able to take the temperature and thermopile voltage and calculate the irradiance measured by the PIR.

To calculate the irradiance of the PIR, use the formula:

$$I\left(W/m^2\right) = \frac{V}{1000 * C1}\sigma Tc^4 + C2\sigma(Tc^4 - Td^4)$$

where V = PIR thermopile voltage in mV
Tc = PIR case thermistor temperature in °K
Td = PIR dome thermistor temperature in °K
C1 = calibration coefficient V/(W/m^2)
σ = 5.67 x 10^{-8} [W/(m^{2}K^4)] = Stephan-Boltaman Constant
C2 = PIR dome correction coefficient.

To calculate the resistance and temperature of the PIR, use the formula:

$$°K = \frac{10,000}{A + B * X + C * X^3}$$

where A = 10.425 E-04
B = 2.37 E-04
X = 5 * ln(10) + ln[V/(2000-V)]
C = .00164 E-04
V = voltage drop across PIR dome or case thermistor (mV)
the thermistor resistance in KOhms = [V/(2000-V)] * 100.

Due to the complexity and uniqueness of the SIRS design, the manufacturers of the radiometers and data loggers have requested copies of the program and detailed information about the specific hardware configuration.

To date, all SIROS sites have been converted to SIRS.

Quality Radiometers + Reliable Data Loggers + Credible Data Processing System = Quality Data.

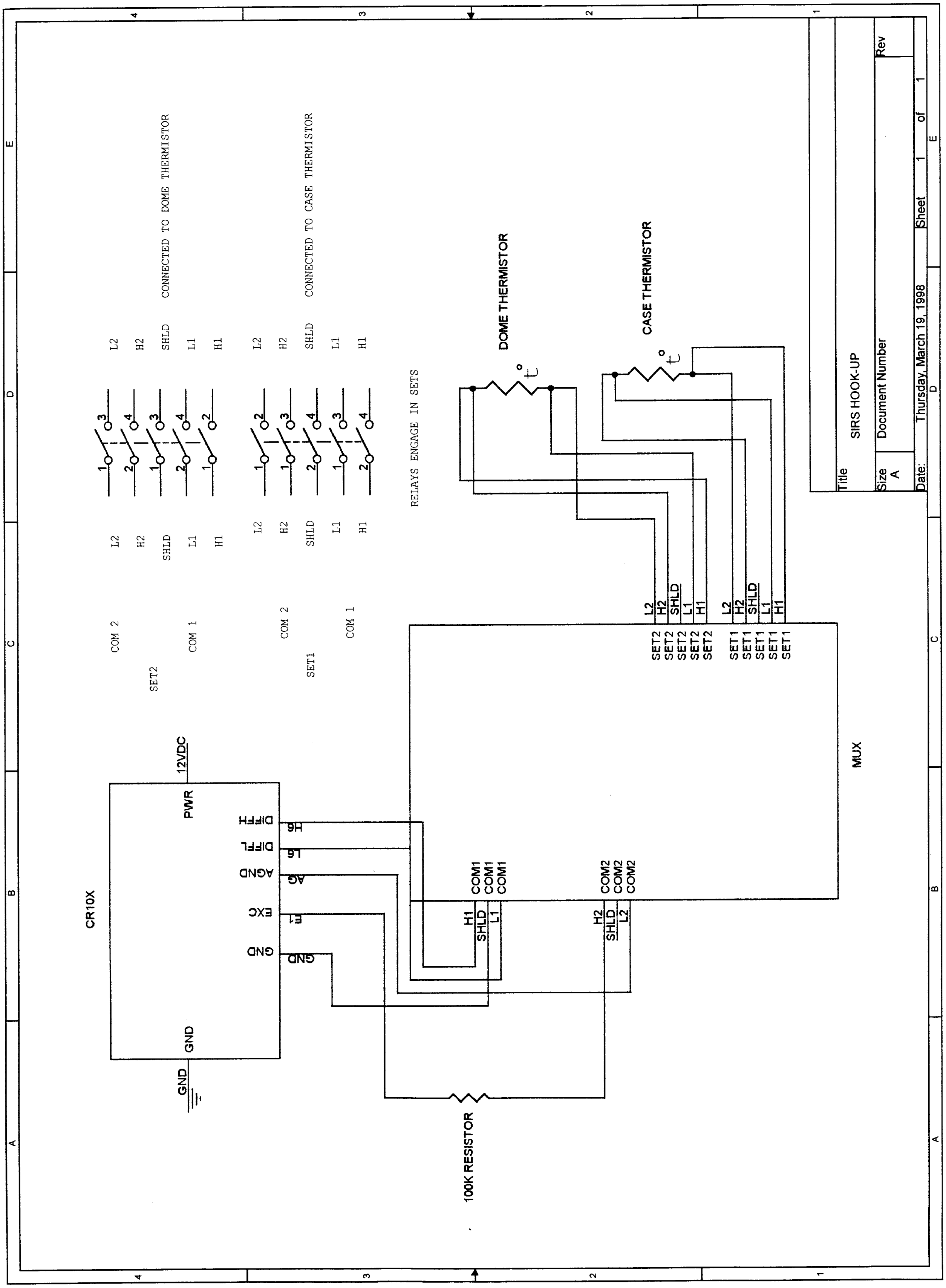

Figure 1. Wiring diagram for the connection of the PIR thermopile and thermistors to the CR10X-1M datalogger.