Most commercial $I-V$ software also measures only the light $I-V$ characteristics in the power quadrant. This is not sufficient for analyzing effects of nonohmic contacts requiring forward bias $I-V$ data beyond V_{OC} or voltage-dependent photocurrent collection requiring reverse bias $I-V$ data.

Many groups have developed custom data acquisition systems with commercial components. These systems are reviewed in Reference [2] and consist of electronics to measure the current and voltage and a power supply [1], operational amplifier [120, 121], capacitor [122], or transistors as the load [123–125]. Ideally, the current sense resistor should have a low temperature coefficient and have a power rating at least six times the maximum expected load power to prevent errors from changing ambient temperature or resistor heating. It should be noted that $I-V$ systems built around custom circuits and software could be difficult and time consuming to maintain when the developer is gone. In determining the most appropriate $I-V$ data acquisition system for devices that may range from single research-level cells to arrays, the present and all possible future applications should be considered. Any group that is considering building their first $I-V$ system, upgrading that old reliable $I-V$ system, or expanding their existing capabilities should consider the following factors:

- Desired outputs from the system – tabular and graphical display and hard copy of data, database or update of a simple directory text file, control over format and content of saved data, meteorological parameters.
- Minimum and maximum current and voltage range.
- Cost in time and money available for design and development.
- Cost in time and money available for maintenance (repairs, enhancements, and expansion).
- Compatibility with existing hardware, software, and databases.
- Flexibility to detect and compensate for artifacts – flexibility in bias direction and bias range, manual control, control over premeasurement illumination and bias state.

Assuming that the PV device is actually at SRC, the error in the FF is primarily affected by the connections to the data acquisition system. First and foremost, four-terminal (known as Kelvin) connections should always be used at the positive and negative terminals of the device. Between the point where positive or negative voltage connections are made and the PV sample, any wire or contact resistance will appear as a series resistance, reducing FF and hence P_{max} and η. At the component level of modules and above, wire resistance losses are included. For cells without wires attached, the goal is to simulate as accurately as possible the module-contacting scheme. This generally means placing a current and preferably a voltage probe contact at each wire bond pad. A temperature-controlled vacuum plate is used for compatible structures in which at least one of the positive or negative contacts is on the front surface (monocrystalline and multicrystalline wafers or thin-film devices deposited on a substrate) to provide a large-area, low-resistance contact. This low but finite contact resistance will appear as a power loss in P_{max} unless a separate voltage contact is used. This voltage contact may be a miniature, spring-loaded, blunt-tipped, gold-plated probe; a patterned, metallized Kapton or ceramic; a printed circuit board placed in a narrow slot in the vacuum plate; or some other method. The surface area of this voltage contact will introduce an error in the voltage when light is incident on the cell because of nonuniform heat transfer to the temperature-controlled