# Introduction to the SEMI Standards: SECS/GEM

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# 1 Overview

GEM is a standard implementation of the SECS-II standard, SEMI standard E5. Most equipment in semiconductor (front end and back end), surface mount technology, electronics assembly, photovoltaic, LED, flat panel display, and other manufacturing industries worldwide provide a SECS/GEM interface on the manufacturing equipment so that the factory host software can communicate with the equipment for monitoring and/or controlling purposes. Because the GEM standard was written with very few semiconductor-specific features, it can be applied to virtually any manufacturing equipment in any industry.

# 2 Industrial Usage of the GEM Standard

All GEM-compliant manufacturing equipment share a consistent interface and certain consistent behavior. GEM equipment can communicate with a GEM-capable host using either TCP/IP (using the HSMS standard, SEMI E37) or RS-232-based protocol (using the SECS-I standard, SEMI E4). Often both protocols are supported. A piece of equipment can be monitored and controlled using a common set of SECS-II messages specified by GEM. When equipment has a GEM interface, it takes just minutes (or even seconds) for factory GEM host software to establish communication and begin monitoring the activity of the equipment. This means that equipment manufacturers can spend more time and money improving equipment quality by providing a common interface to all factories. It also means that factories can spend more time and money improving production and processes, rather than setting up communication to the equipment.

There are many additional SEMI standards and factory specifications that reference the GEM standard features. These additional standards are either industry specific or equipment-type specific. Following are a few examples.

## 2.1 Semiconductor Front End

The semiconductor front end (wafer fab) segment of the industry defined a series of standards known as the GEM300 standards that includes SEMI standards E40, E87, E90, E94, E116, E148, and E157, and also references the E39 standard.

Each standard provides additional features to the GEM interface, yet builds upon the features in the GEM E30 standard. 300mm factories worldwide use the underlying GEM standard's data collection features in order to monitor specific equipment activity such as wafer movement and process job execution. The SECS/GEM standard and the additional GEM300 standards are required on almost all 300mm wafer manufacturing tools in order to implement manufacturing automation. This industry segment has been the strongest supporter of the GEM and related SEMI standards.

## 2.2 Semiconductor Back End

Numerous types of equipment in the semiconductor back end (assembly and test) segment of the industry implement the GEM standard. Additional standards have been implemented such as:

- SEMI E122: Standard for Tester Specific Equipment Model (TSEM)

- SEMI E123: Standard for Handler Equipment Specific Equipment Model (HSEM)

## 2.3 Flat Panel Display

The flat panel display (FPD) industry has largely been a long-time user of SEMI standards for connecting manufacturing equipment to its factory information and control systems, but the interfaces are typically company-specific and incorporate custom SECS messages.

Although many of the equipment suppliers to the FPD industry also offer semiconductor equipment, we don't expect the FPD industry to adopt the newer generations of advanced data collection and process control standards in the short term. This is due primarily to the fact that the FPD manufacturing process is not as complex as semiconductor production (more inline), and also because FPD manufacturing was highly automated from the outset.

However, as panel sizes and feature counts continue to increase (consider the large LED-based high-definition televisions), the FPD industry will undoubtedly make use of more and more manufacturing data to maintain product quality and manufacturing efficiency – and the SEMI standards will be there to support them.

## 2.4 Surface Mount Technology

Many types of equipment in the surface mount technology (SMT) industry support the GEM standard, including chip placement, solder paste, oven and inspection equipment. The GEM standard has been used on these equipment types for over 15 years.

## 2.5 Photovoltaic

In 2008, the photovoltaic (PV) industry officially decided to adopt the SECS/GEM standard and submitted a proposal for a new SEMI standard, ballot document #4557. Even prior to adopting the GEM standard, several photovoltaic equipment suppliers were already capable of supporting the GEM standard. The standard is called PV2, and defines a framework that utilizes the SEMI E37 (HSMS), SEMI E5 (SECS-II), SEMI 30 (GEM), SEMI E148 and SEMI E10 (OEE – Overall Equipment Effectiveness) standards.

## 2.6 High-Brightness LEDs

The high-brightness LED (HB-LED) industry is currently working with SEMI to define needed standards through the HBLED Task Force. The adoption of GEM has been accepted and further investigation is taking place concerning the GEM300 and EDA (Equipment Data Acquisition) standards.

# 3 GEM Host and Equipment Communication

In a factory GEM implementation there are two parties, the host and equipment. The equipment runs GEM interface software on one of its computers that must implement and comply with the SEMI standards. The factory runs GEM host software that establishes communication with the equipment's GEM interface. A typical host is also called a station controller or line manager. Often the host software is part of the factory's Manufacturing Execution System

(MES). A host system can communicate with one or multiple equipment GEM interfaces at the same time. The host communicates directly with each piece of equipment using either the SEMI E4 SECS-I standard (RS-232-based serial communication) or SEMI E37.1 HSMS-SS standard (TCP/IP based network communication). The HSMS-SS standard is more convenient and better aligned with modern factories, and is therefore used almost exclusively in modern factories.

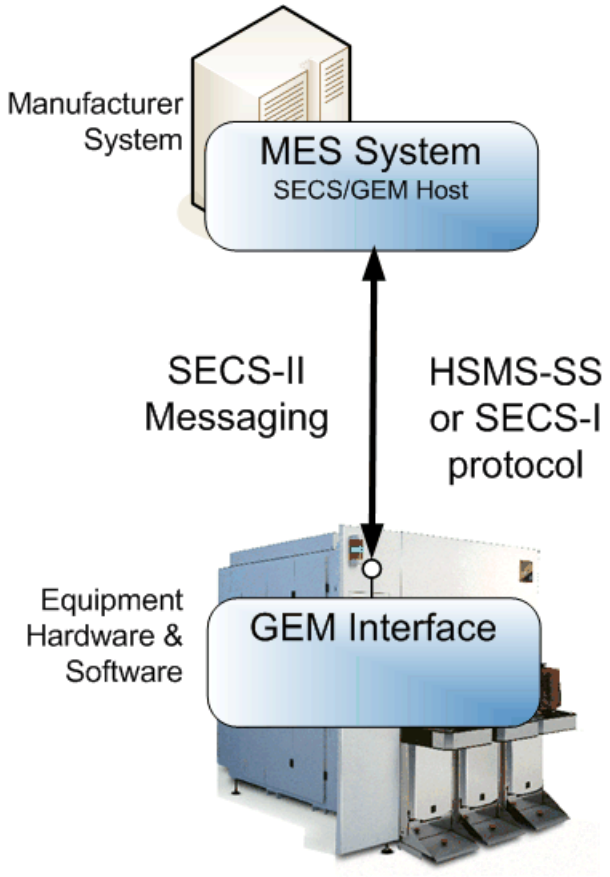


**Figure 3-1: GEM Interface and SECS/GEM Host**

A host does not have to comply with the GEM standard since the standards only set expectations on the equipment. However, in order to make use of the GEM interface, a host must implement the host side of the communication. The GEM standards set clear equipment behavior expectations for each possible host message.

# 4 SECS-II Message Communication

Once low-level communication is established, then the host and equipment can exchange SECS-II messages. A SECS-II message is identified by a stream number (0-255) and a function number (0-255). An odd-numbered function is a *primary* SECS-II message, the first message in a message exchange, called a transaction. The consecutive, even-numbered function is its *secondary* message--the reply to the corresponding primary message. Unless the reply bit is clear (0), a primary message should always be responded to with its complementary secondary message. For most SECS-II messages, a secondary reply message is required. For example, if the host sends an S1,F1 (stream 1, function

1) message to request “Are you there?”, then equipment will send a reply S1,F2 message to indicate “I am here”. Each SECS-II message exchange has a unique transaction ID number. The standards allow message interleaving where there is more than one open, concurrent transaction.

The SEMI E5 SECS-II standard defines the use and format of a large set of standard SECS-II messages, including primary messages and the corresponding secondary messages. Only a subset of these messages is required by the GEM standard. Some SECS-II message transactions may be initiated by only the host, while other SECS-II message transactions may be initiated only by the equipment. A few message transactions may be initiated by either the host or equipment.

In order for a SECS-II message to be valid, it must be initiated by the correct party and have the correct message format (i.e., the structure defined by SEMI E5 standard). The host and equipment can agree to support custom messages to implement custom features. The format of those messages is not defined in SEMI E5, and this practice is highly discouraged when standard messages are sufficient.

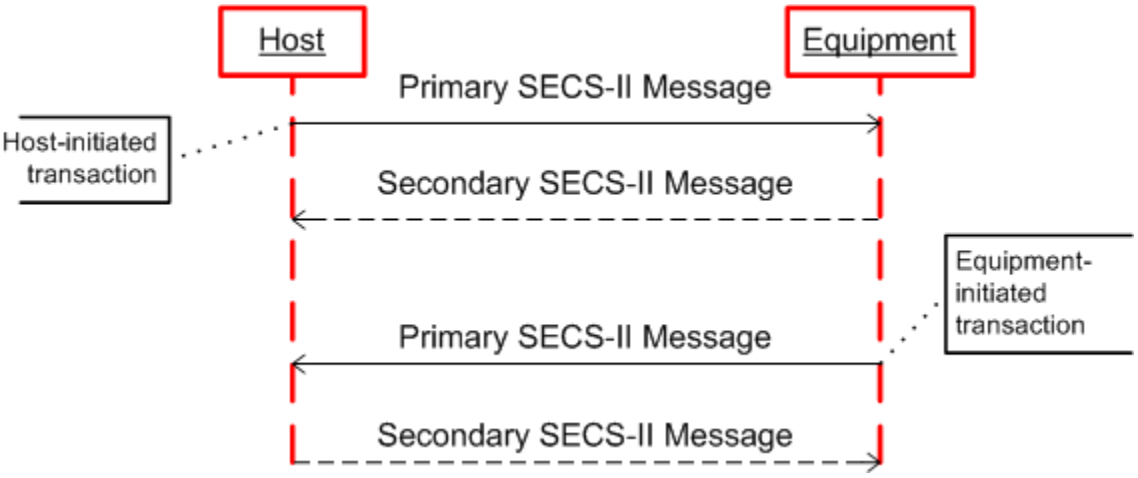


**Figure 4-1: SECS-II Message Transaction**

SECS-II messages are sent as structured binary data to maximize message content while minimizing network bandwidth requirements. For example, when using the SECS-I standard, which employs RS-232 serial communication, the messages size is limited to 7,995,148 bytes (about 8MB). On the other hand, by using the HSMS standard with TCP/IP network communication, the maximum message size is limited to 4,294,967,295 bytes (about 4.3 GB).

The structure of each standard SECS-II message is defined by the SEMI E5 standard. A message can be a simple data element, such as a binary response or an ASCII string. A message can also be a complex list structure with multiple levels of lists in the hierarchy. The SECS-II standard limits a single element within a SECS-II message to 16,777,215 bytes (about 16.5 MB).

# 5 Feature Summary

The key features of the GEM standard are described in the following paragraphs. Minimal GEM compliance requires only a small set of these features to be supported, since many of them described are optional, additional capabilities.

Several of the features have state models to clearly define states, sub-states and transitions between states. The state models make GEM interface implementations consistent and predictable.

The GEM standard defines a number of SECS-II message scenarios, each of which is an ordered sequence of SECS-II message transactions. The SECS-II message scenarios establish an implementation guideline so that the equipment manufacturer can anticipate how the host might use the GEM standard.

## 5.1 Communication

The GEM standard defines how the equipment and the host initially establish communication. It also defines how communication is re-established when communication is broken. An on-line identification method verifies the equipment's hardware and software identity. Terminal service features allow the host operator and equipment operator to exchange text manually typed at a console.

## 5.2 Control

The GEM standard outlines a control state model to define the level of cooperation between the host and equipment operator. Equipment with a GEM interface provides three basic levels of host control, which determine the host's ability to control and monitor the equipment. The equipment operator sets the level of host control.

Remote control capabilities permit the host to send GEM-defined commands like "START," "STOP," "PAUSE," "RESUME," and "ABORT" to control the equipment's processing. The equipment can define additional custom commands. Each command can have one or more arguments with data to clarify the command.

Equipment constant features allow the host to set and retrieve equipment constant values which govern the equipment's behavior. GEM requires a small set of equipment constants to configure the GEM state machines. The equipment can define additional equipment constants to allow the host to configure many aspects of the equipment behavior.

## 5.3 Operation Notification

Collection events and alarms allow the host to monitor equipment operations in detail. Equipment alarms can notify the host when potentially dangerous activity is detected and subsequently resolved. The host determines which collection events and alarms are set for notification, and the equipment sends SECS-II messages to the host for only the specified events and alarms in order to minimize network traffic. Certain events and alarms are required by the GEM standard, but the equipment supplier is expected to define additional events which allow the host to monitor equipment-specific activities effectively.

## 5.4 Data Gathering

GEM defines six methods of gathering data. The host can gather data from the equipment, but the equipment cannot gather data from the host.

1. A set of status variable values can be requested at any time.

2. A set of equipment constant values can be requested at any time.

3. A report containing status variable, data variable and equipment constant values can be requested at any time.

4. A host can define reports and attach them to collection events so that the report data is transmitted along with the collection event in the same SECS-II message. This feature enables data to be sent to the host as the values become available, thereby reducing the host's obligation to poll for information. This event report data collection also enables the host to gather the data related to each event.

5. The host can define traces so that the equipment periodically transmits the specified status variable values at a set time interval. This feature enables the host to poll the equipment status without having to ask for data at each interval.

6. The host can configure limits monitoring so that the equipment notifies the host whenever a specified variable value transitions across a host-defined limit threshold. This feature eliminates the need for the host to poll critical values in situations where the host is only concerned when the value becomes too high or low. Multiple limit boundaries can be defined.

## 5.5 Process Program (Recipe) Management

A process program "is the set of instructions, settings, and parameters under control of the equipment that determine the processing environment seen by the manufactured object" (SEMI E30, 4.2.6.1). Process program management features include the following:

- Host can download a process program to the equipment for storage on the equipment.
- Host can upload a process program from the equipment for storage on the host.
- Host can delete a process program on the equipment.
- Host can request a list of available process programs.
- Equipment operator can send a process program to the host.
- Equipment operator can request a process program from the host.
- Host can select a process program for execution using a PP-SELECT remote command.
- Equipment will notify the host when a process program is created, edited, deleted, or selected by the equipment operator.

## 5.6 Spooling

Spooling capabilities provide the means for the equipment to queue information intended for the host during a communication failure. When communication is restored, the host can purge or request the queued data. The host can configure which information is queued, how a full queue is handled, the queue size, and how queued information is recovered. The host can also switch spooling features on or off.

## 5.7 Documentation

The GEM standard requires that a GEM interface manual be included with each equipment unit. The manual must include a GEM compliance statement, complete SECS-II message documentation, complete GEM state model documentation and a description of all equipment variables, alarms, collection events, equipment constants and remote commands.

# 6 GEM Compliance

As stated in Section 5.7, equipment that is GEM compliant must include a GEM compliance statement in the documentation. The table below declares not only which features are implemented, but also indicates whether or not implemented features comply with the standards. This means that the equipment can provide a limited GEM implementation and still be considered GEM compliant. Some of the GEM features simply are not appropriate for all manufacturing equipment. If a feature is implemented, but not quite compliant, then the equipment supplier must simply document the exception. Below is a sample GEM compliance statement.

The GEM standard requires relatively few features. If equipment implements a minimum GEM interface with only the required data variables, status variables, equipment constants and collection events, then the GEM interface is only marginally useful. The GEM interface's full value is realized only when the equipment supplier provides additional equipment-specific alarms, data variables, status variables, equipment constants, and collection events.

| GEM Compliance Statement | | |
|---|---|---|
| FUNDAMENTAL GEM REQUIREMENTS | IMPLEMENTED | GEM COMPLIANT (See Note 1) |
| State Models | ☐Yes ☐No | ☐Yes ☐No |
| Equipment Processing States | ☐Yes ☐No | |
| Host-Initiated S1 = F13/F14 Scenario | ☐Yes ☐No | |
| Event Notification | ☐Yes ☐No | |
| On-Line Identification | ☐Yes ☐No | |
| Error Messages | ☐Yes ☐No | |
| Documentation | ☐Yes ☐No | |
| Control (Operator Initiated) | ☐Yes ☐No | |

Note 1: Do not mark "Yes" unless all fundamental GEM requirements are implemented and GEM compliant.

Note 2: Additional capabilities cannot be marked GEM -COMPLIANT unless the fundamental GEM requirements are GEM compliant.

| ADDITIONAL CAPABILITIES | IMPLEMENTED | GEM COMPLIANT (See Note 2) |
|---|---|---|
| Establish Communications | ☐Yes ☐No | ☐Yes ☐No |
| Dynamic Event-Report Configuration | ☐Yes ☐No | ☐Yes ☐No |
| Variable Data Collection | ☐Yes ☐No | ☐Yes ☐No |
| Trace Data Collection | ☐Yes ☐No | ☐Yes ☐No |
| Status Data Collection | ☐Yes ☐No | ☐Yes ☐No |
| Alarm Management | ☐Yes ☐No | ☐Yes ☐No |
| Remote Control | ☐Yes ☐No | ☐Yes ☐No |
| Equipment Constants | ☐Yes ☐No | ☐Yes ☐No |
| Process Program Management | ☐Yes ☐No | ☐Yes ☐No |
| Material Movement | ☐Yes ☐No | ☐Yes ☐No |
| Equipment Terminal Services | ☐Yes ☐No | ☐Yes ☐No |
| Clock | ☐Yes ☐No | ☐Yes ☐No |
| Limits Monitoring | ☐Yes ☐No | ☐Yes ☐No |
| Spooling | ☐Yes ☐No | ☐Yes ☐No |
| Control (Host-Initiated) | ☐Yes ☐No | ☐Yes ☐No |

Note 1: Do not mark "Yes" unless all fundamental GEM requirements are implemented and GEM compliant.

Note 2: Additional capabilities cannot be marked GEM COMPLIANT unless the fundamental GEM requirements are GEM compliant.

# 7 Frequently Asked Questions

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| Where can I get a copy of the GEM standard? | Official copies must be obtained through SEMI. SEMI offers excellent internet services at their website. Standard documents can be ordered or downloaded for a fee at the SEMI website: http://www.semi.org/ |
| How does a system become GEM certified? | There is no official GEM certification. GEM compliance is self-proclaimed. Software programs are available for testing GEM equipment such as TESTConnect and SECSConnect. Note that GEM compliance does not require all GEM features to be implemented. For example, some equipment may not implement remote commands and process program management, yet they can still be GEM compliant if they correctly implement the GEM Fundamental Capabilities. |

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| Can more than one host establish communication with a single piece of equipment simultaneously? | Yes, but not many GEM interface software products support that capability. Cimetrix CIMConnect software product has a built-in multiple client (multi-host) feature that simplifies the process of communicating with more than one SECS/GEM host at a time using HSMS-SS or SECS-I communication. When using HSMS-SS, each client uses a unique port. |
| How long does it take to implement a SECS/GEM interface? | Building the SECS/GEM interface from the beginning can take a few person-years to develop custom software that will be production worthy in a variety of factories. It is much more cost-effective to purchase a commercial software product. There are commercial GEM software products available such as the Cimetrix CIMConnect product, which many consider to be the best product on the market. |
| How fast is a SECS/GEM interface? | Current versions of the standard allow the host to setup trace data collection with the message rate specified in milliseconds. In practice, some factories request data at rates of about 10Hz, or 1 set of data every 100ms. Because the SECS-II and HSMS message format is very efficient, a lot of data can be transferred using little network bandwidth. The precise data rates depend on many factors such as the network, the GEM software in both the host and equipment systems, and the computer hardware. Older versions of the GEM standard were limited to 1 Hz trace data collection. |
| What are the most important features in a GEM product? | There are many important features, but here are some of the key ones:<br><br>**Customer Support**<br><br>The GEM interface will likely be a mission-critical capability for production. There are many details in the SEMI standards that take years to master. Before selecting a product, make sure that the product is backed by a solid company with a responsive, experienced customer support team.<br><br>**Performance**<br><br>Some products use much less CPU than others for the same set of tasks. A product that uses less CPU can achieve higher data collection rates. As factories attempt manufacturing process optimization, they rely on more and more data collection from the equipment. Select a product that can use computing and networking resources most efficiently and can meet both today's and tomorrow's throughput requirements.<br><br>**Supporting Multiple Clients**<br><br>In recent years, the importance of supporting multiple clients has increased. For example, PV manufacturers documented the need for an "IT interface of the equipment that allows an arbitrary number of clients to connect to the equipment in order to gather data from the equipment (all kinds of data collection) and to interact with the equipment (remote control, etc.)". Choose a product that has multiple client access as a built-in feature such as CIMConnect.<br><br>**Client-Server Architecture**<br><br>A GEM interface interacts with all of the components within the equipment. Purchase a product with a client-server architecture so that all of the components can interact directly with the GEM software. This foundation will reduce the time, cost, and complexity of software development. |

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| Can changes be made to the GEM standard? | The GEM standard is an active SEMI standard managed by the GEM300 task force. Periodically changes to the GEM standard are submitted for discussion and for ballot approval. Changes must be approved according to SEMI's standard processes. Anyone can join the GEM300 task force, vote on the changes to the standard, and submit recommendations. Cimetrix currently holds the co-chair position for the North American GEM300 task force. More information is available from the following websites:<br><br>SEMI - www.semi.org<br><br>Cimetrix - www.cimetrix.com |
| Where can I ask questions about the GEM standard? | You are welcome to email questions to support@cimetrix.com. |
| How much network bandwidth does a GEM interface require? | While the equipment determines how much information is available to the host, ultimately the host determines the bandwidth utilization by enabling the desired collection events and alarms and by disabling the undesired ones. The host also determines the amount and frequency of data gathering, recipe management, remote commands, and other features. If all of the events and alarms are disabled, then a GEM interface connection will be nearly silent. |

# 8 GEM Terminology

| Term | Description |
|---|---|
| Alarm | "An alarm is related to any abnormal situation on the equipment that may endanger people, equipment, or material being processed" [SEMI E30, 2]. GEM allows the host to be notified when alarm conditions are detected and cleared. |
| Collection Event | A collection event is a "detectable occurrence significant to the equipment" that "is considered to be significant to the host". [SEMI E30, 2] GEM allows the host to be notified when a collection event occurs. This allows the host to track the equipment's activity. |
| Data Variable | Data variables "…may only be valid upon the occurrence of a particular event". [SEMI E5, 6.6]. The host can gather data variable values from the GEM equipment. The data variable values provide information specifically related to the event. |
| Equipment Constant | Equipment Constants are "settable by the Host"[SEMI E5 6.6]. The host can gather equipment constant values from the GEM equipment. The host can also set equipment constant values on the GEM equipment to control the equipment's behavior. |
| GEM Equipment | An "intelligent system which communicates with a host" [SEMI E4, 2.1] and complies with the GEM standard. |
| Host | "An intelligent system which communicates with the equipment." [SEMI E4, 2.1]. The host can be viewed as a line management system. GEM does not intend to define how the host should behave. The GEM standard defines the set of messages a host must use when interacting with GEM equipment. A host can communicate with multiple GEM equipment, and Cimetrix CIMConnect enables the process of equipment communicating with more than one host. |

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|---|---|
| HSMS-SS | SEMI standard High-Speed Message Service-Single Session, which defines TCP/IP network communication used by GEM for host/equipment communication. It has effectively replaced the SECS-I standard. Only one host client can use a specific port at a time. |
| PV2 (PVECI) | GUIDE FOR PV EQUIPMENT COMMUNICATION INTERFACES, an approved SEMI standard specifically for photovoltaic equipment suppliers. |
| Process Program | (see Recipe) |
| Recipe | A set of instructions for the equipment that serve some specific purpose (wafer processing, calibration, equipment test, etc.). |
| Report | "A set of variables predefined by the equipment or defined by the host…". The host uses reports to gather status variable, data variable, and equipment constant values. The host can request a report explicitly or attach a set of reports to a collection event. |
| Status Variable | "Status variables may include any parameters that can be sampled in time such as temperature or quantity of a consumable." [SEMI E5, 6.5] "Status values … always contain valid information." [SEMI E5, 6.6]. The host can gather status variable values from the GEM equipment. |
| SECS-I | SEMI Equipment Communications Standard 1 Message Transfer - defines RS-232 serial communication used by GEM for host/equipment communication. It has been phased out due to inherent speed limitations, and replaced by the HSMS standard. |
| SECS-II | SEMI Equipment Communications Standard 2 Message Content. GEM is a specific implementation of the SECS-II standard. SECS-II defines most concepts and functionality used in the GEM standard. Many SECS-II capable systems are not GEM compliant. |
| SECS-II Message | All GEM equipment and host communication is accomplished using SECS-II messages. Each unique SECS-II message is identified by its stream number (S) and function number (F). The SECS-II standard defines a large set of SECS-II messages specifying each one's purpose, content, and usage. The GEM standard defines how to use a subset of these SECS-II messages, while allowing other SECS-II messages to be used in addition to this subset. |