



# *GE Fanuc Automation*

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## *Programmable Control Products*

### *Series 90™-70 Enhanced Hot Standby*

#### *CPU Redundancy User's Guide*

*GFK-1527A*

*May 2000*

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**Caution notices are used where equipment might be damaged if care is not taken.**

### Note

Notes merely call attention to information that is especially significant to understanding and operating the equipment.

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Field Control	Motion Mate	Series Five	VuMaster
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This manual is a reference to the hardware components, configuration and operation of Enhanced Hot Standby CPU Redundancy for the Series 90-70 Programmable Logic Controller. This revision adds information about new redundancy CPUs IC697CGR772 and IC697CGR935, as well as new features available with Release 7.85 of the product. Also, corrections have been made where necessary.

The information in this manual is intended to supplement the information contained in the system installation, programming, and configuration information found in the manuals listed below under Related Publications.

## Content of This Manual

**Chapter 1. Introduction:** introduces a method of CPU Redundancy for the Series 90-70 Programmable Logic Controller, which is referred to as Enhanced Hot Standby CPU Redundancy.

**Chapter 2. System Components:** describes the hardware components for an Enhanced Hot Standby CPU Redundancy system.

**Chapter 3. Configuration Requirements:** defines the special configuration requirements of an Enhanced Hot Standby CPU Redundancy system.

**Chapter 4. Normal Operation:** describes the operation of an Enhanced Hot Standby CPU Redundancy system.

**Chapter 5. Fault Detection:** describes how faults are handled in an Enhanced Hot Standby CPU Redundancy system.

**Appendix A. Cabling:** provides a description and diagram of the Series 90-70 multidrop cable for use in redundancy systems.

## Related Publications

For more information, refer to these publications:

***Genius I/O System User's Manual*** (GEK-90486-1). Reference manual for system designers, programmers, and others involved in integrating Genius I/O products in a PLC or host computer environment. This book provides a system overview, and describes the types of systems that can be created using Genius products. Datagrams, Global Data, and data formats are defined.

***Genius Discrete and Analog Blocks User's Manual*** (GEK-90486-2). Reference manual for system designers, operators, maintenance personnel, and others using Genius discrete and analog I/O blocks. This book contains a detailed description, specifications, installation instructions, and configuration instructions for discrete and analog blocks.

***Series 90-70 PLC Installation Manual*** (GFK-0262). This book describes the hardware components in a Series 90-70 PLC system, and provides the details of system installation.

**Logicmaster 90-70 Programming Software User's Manual** (GFK-0263). A programming software user's manual for system operators and others using the Logicmaster 90-70 software to program, configure, monitor, or control a Series 90-70 PLC system.

**Series 90-70 PLC CPU Instruction Set Reference Manual** (GFK-0265). Reference manual which describes operation, fault handling, and programming instructions for the Series 90-70 PLC.

**Series 90-70 System Manual for Control Software Users** (GFK-1192). Provides an overview of hardware and software features of the Series 90-70 PLC.

**Series 90-70 Remote I/O Scanner User's Manual** (GFK-0579). Reference manual for the Remote I/O Scanner, which interfaces a drop containing Series 90-70 modules to a Genius bus. Any CPU capable of controlling the bus can be used as the host. This book describes the Remote I/O Scanner features, configuration, and operation.

**Series 90-70 Bus Controller User's Manual** (GFK-0398). Reference manual for the bus controller, which interfaces a Genius bus to a Series 90-70 PLC. This manual describes the installation and operation of the Bus Controller. It also contains the programming information needed to interface Genius I/O devices to a Series 90-70 PLC.

**Control User's Guide** (GFK-1295). Describes configuration and programming software using Control Programming. Control software, release 2.1 or later is required to configure Ethernet Global Data as described in this manual.

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# Chapter 1

## Introduction

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This chapter introduces the method of CPU Redundancy for the Series 90-70 Programmable Logic Controller, which is referred to as Enhanced Hot Standby CPU Redundancy. The contents of this chapter describe:

- ❑ Enhanced Hot Standby CPU Redundancy
- ❑ Components of the Enhanced Hot Standby Redundancy System
- ❑ Control Strategies
- ❑ Basic Enhanced Hot Standby Operation
- ❑ Basic CPU Redundancy Systems

## Definition of Terms

<b>Active Unit</b>	The unit that is currently controlling the process.
<b>Backup Unit</b>	That unit that is synchronized with the active unit and able to take over the process.
<b>CPU Redundancy</b>	A system with two PLC CPU units cooperating to control the same process.
<b>Critical Component</b>	A component whose failure causes the PLC (either active or backup) where it resides to stop.
<b>Hot Standby</b>	A feature of Genius devices whereby the device prefers output data from the Bus Controller at Serial Bus Address 31. When outputs from that Bus Controller are not available, the device takes output data from the Bus Controller at Serial Bus Address 30. If outputs from neither Controller are available, the device places its outputs in the designated default state.
<b>Primary Unit</b>	The unit in which the externally redundant Bus Controllers' Serial Bus Address is 31.
<b>Redundancy</b>	The use of multiple elements controlling the same process to provide alternate functional channels in case of failure.
<b>Secondary Unit</b>	The unit in which the externally redundant Bus Controllers' Serial Bus Address is 30.
<b>Synchronized</b>	A unit is considered to be synchronized when it has received the latest status information from the Active unit and is running the PLC program in parallel.
<b>Dual Bus</b>	The use of two Genius busses to control the same I/O devices. The busses are linked to the I/O devices by one or more Bus Switching Modules (BSMs). A BSM will automatically switch to the other bus if the active bus has a failure.
<b>Local System</b>	(LEDs on RCM) - The system where the RCM resides. LEDs indicate whether the local unit is ready to become the active unit or is the active unit in a redundancy system.
<b>Remote System</b>	(LEDs on RCM) - The system to which the RCM is connected via the communications cable. LEDs indicate whether the remote unit is ready to become the active unit or is the active unit in a redundancy system.

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## Enhanced Hot Standby CPU Redundancy

CPU Redundancy allows a critical application or process to continue operating if a failure occurs in any single component. An Enhanced Hot Standby CPU Redundancy system consists of two CPUs connected to one or more Genius I/O networks. One PLC is the Primary PLC and the other is the Secondary PLC. The Primary PLC contains all externally redundant Genius Bus Controllers at Serial Bus Address 31; the Secondary PLC contains all externally redundant Genius Bus Controllers at Serial Bus Address 30.

Each PLC *must* have a Redundancy CPU module (IC697CGR772 or IC697CGR935), a Redundancy Communications module and a Bus Transmitter Module. The Redundancy Communications module provides the synchronizing link between the two units. The scanning process of both CPUs is synchronized to minimize bumpless switching from one PLC to the other.

The CPU that currently controls the system is called the active unit, the other CPU is the backup unit. Control automatically switches to the backup unit if certain system failures are detected in the active unit. Control can also be switched manually by pressing a pushbutton on the Redundancy Communications Module, or through the application program. When a manual switch of control occurs, the CPUs switch roles; the active unit becomes the backup unit and the backup unit becomes active.

The system runs synchronously with a transfer of all control data that defines machine status and any internal data needed to keep the two CPUs operating in sync. The transfer of data from the active unit to the standby unit occurs twice per sweep. These CPU to CPU transfers are checked for data integrity.

## Features of Enhanced Hot Standby CPU Redundancy

- Bumpless switching
  - *Synchronized* CPUs
  - 4.7 ms (CGR935), 5.9 ms (CGR772) base sweep time in Run mode
  - One scan switching (in most cases)
  - Configurable backup data size
- No single point of failure (excluding Genius I/O blocks and bus stubs)
- Redundant backup communications
- Online repair of failed component
- Online programming
- Same or different programs in Primary and Secondary units
- Redundancy Communications Module
  - Manual pushbutton for switching control between active and backup CPUs
  - Five Status LEDs
- Status Bits (%S) reflect redundancy status of Primary/Secondary units
- Program control switching
- Memory parity and checksums
- Common I/O on Genius bus
- Genius Dual Bus support
- Background Diagnostics
- Memory Protect Keyswitch

### Using the Redundancy CPU for Non-Redundant Operation

The Redundancy CPU can be used for both redundant and non-redundant applications. The functionality and performance of a Redundancy CPU configured for standalone operation is the same as for a unit that is configured for redundant operation which has no backup currently available. This includes the redundancy informational messages such as those generated when a unit goes to Run mode. Refer to Chapter 3, "Configuring the Redundancy CPU for Non-redundant Operation."

### Compatibility with CPU780

Note that the IC697CGR772 is not compatible with the CPU780. Also, mixing of IC697CGR935 and IC697CGR772 CPUs is not allowed in the same redundant system, since there are several differences between the two models.

## Redundancy CPUs as Compared to Other Series 90-70 CPUs

The Redundancy CPU has several differences in operation compared to other Series 90-70 CPUs.

### Features not Available with Redundancy CPUs

The following features are not available:

- *I/O Interrupts:* This includes the single edge triggered interrupts from the discrete input modules, the high alarm and low alarm interrupts from the analog input modules, and interrupts from third party VME modules. A program that declares I/O Interrupt triggers cannot be stored to a Redundancy CPU.
- *Timed Interrupts*
- *VME Integrator Racks.*
- *Stop I/O Scan mode:* If an attempt is made to place the PLC in this mode, the PLC will reject the selection and return an error.
- *Flash operation: User Flash (Store/Load, Verify) as opposed to Flash firmware upgrade*
- *FBCs and FIP I/O*
- *Timed and Event-triggered Programs:* Logic that contains Timed or Event-triggered programs cannot be stored.
- *Microcycle Mode and Periodic Programs*
- *14-point interrupt module*
- *OVR\_PRE %S reference which indicates whether one or more overrides is active*

### Differences in Operation for Redundancy CPUs

The following features operate differently with the CGR772 or CGR935 than they do with other Series 90-70 CPUs:

- RUN/DISABLED mode. This is explained in chapter 4, *Operation*.
- Configuration of Fault Actions
- STOP to RUN mode transition
- Background Window Time (default is different)
- C Debugger
- Ethernet Global Data operation is enhanced
- Rack 7 is not available

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# Components of the Enhanced Hot Standby Redundancy System

## Enhanced Redundancy CPU Module

To utilize the features described in this manual, an Enhanced Redundancy CPU Module (IC697CGR935 or IC697CGR772) must be installed rack 0, slot 1 of both the Primary and Secondary PLCs. Features of the redundancy CPU that are different from conventional CPUs are listed on the previous page.

## Redundancy Communications Module

Two Redundancy Communications Modules (RCM) are available that provide a path for sharing data between the two CPUs in the redundant system. Catalog number IC697RCM711 is for use in standard Series 90-70 racks and IC687RCM711, which is for use in dual redundant racks (described below).

The RCM module has a pushbutton switch that can be used to manually switch control from the active unit to the backup unit. The switch between units can also be controlled through the application program logic.

In a synchronized system, I/O data is controlled by only one unit (the active unit) but is shared between both units (active and backup units). The Redundancy Communications Module provides a communications path to synchronize the two CPUs. It also provides the communications path for the transfer of I/O data. An RCM must be located in the main rack of both the Primary PLC and the Secondary PLC, or in both sections of a dual redundant rack.

## Redundant Racks

Redundant racks; IC697CHS770 (rear mount) and IC697CHS771 (front mount) have two power supply slots and 12 backplane slots divided into two separate sections, each having a power supply slot and 6 backplane slots. The redundant rack is designed for easy integration of third-party VME modules into a Series 90-70 PLC system. These racks accept all standard Series 90-70 modules and ½ slot VME modules. VME modules require 0.8" spacing and use one slot, while standard Series 90-70 modules use two of the available slots. Cable connection between the required ½ slot RCM modules and the required ½ slot BTM modules (catalog number IC687BEM713) in a redundant rack is through an available 3 foot (0.9 meter) cable, IC697CBL803.

## I/O Systems for Enhanced Hot Standby CPU Redundancy

Both Series 90-70 Local I/O and Genius I/O systems can be present in an Enhanced Hot Standby CPU Redundancy system. The two PLCs need not have matching I/O systems -- they may have different numbers of I/O racks, different I/O modules and different option modules.

## Genius I/O

The redundant portion of the system is based on Genius I/O. A system using standard Series 90-70 racks can have multiple Genius I/O bus networks. A system using the ½ slot redundant racks may have only one bus in the CPU rack. Any Genius device can be placed on the bus (Genius blocks, Field Control, Remote I/O Scanner, VersaMax I/O, etc.). The Genius devices are under control of the active unit in the Redundancy system. The Genius Bus Controller in the Primary Unit has a Serial Bus Address of 31; the Genius Bus Controller in the Secondary Unit has a Serial Bus Address of 30. Data from Serial Bus Address 31 is the preferred data when data is being sent from both units to devices on the Genius bus.

## Local I/O

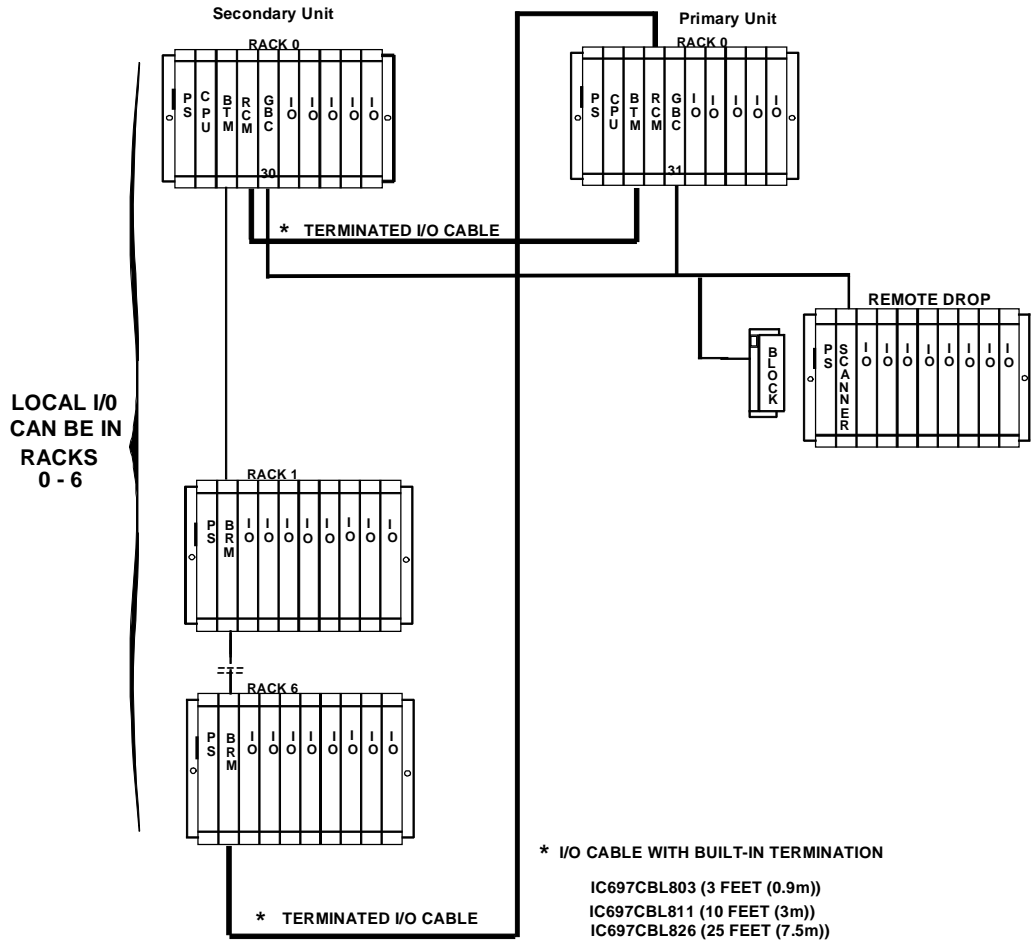
Local I/O can be included in the overall PLC system; however, *it is not* part of the Hot Standby CPU Redundancy system. Control of Local I/O is done normally through the application program. Transfer of this data between the redundancy CPUs is optional. A failure in the Local I/O system will affect the system as described in GFK-0265, the *Series 90-70 Programmable Controller Reference Manual*.

## Cable Connections

In an Enhanced Hot Standby CPU Redundancy system that requires expansion racks, a Bus Transmitter Module in rack 0 is connected by a parallel I/O cable to a Bus Receiver Module in the next rack. The link is continued from this Bus Receiver Module to a Bus Receiver Module in the next rack. This link is continued with a maximum of six expansion racks. The last Bus Receiver is connected via an I/O cable with built-in termination (catalog number IC697CBL803 (3 feet (0.9m)) catalog IC697CBL811 (10 feet (3m)) or IC697CBL826 (25 feet (7.5m))). The last module in the parallel I/O bus link must be a Redundancy Communications Module (RCM). This terminated I/O cable allows replacement of the RCM without interrupting the running system. If no expansion racks are used, the terminated I/O cable is connected directly from the Bus Transmitter Module to the Redundancy Communications Module.

## Enhanced Hot Standby CPU Redundancy System with Local I/O

The following illustration is an example of an Enhanced Hot Standby CPU Redundancy system with Local I/O in standard Series 90-70 expansion racks.



### Note

Rack 7 is not available for I/O modules in an Enhanced Hot Standby CPU Redundancy system.

## Control Strategies

There are two different Control Strategies for Enhanced Hot Standby CPU Redundancy: GHS and GDB.

### GHS Control Strategy

The GHS control strategy has the following features:

- Multiple single bus Genius I/O networks with redundant controller in each synchronized PLC
- Multiple local single bus Genius I/O networks
- Redundant Genius I/O driven exclusively by the active unit
- Primary Unit is always the Active Unit in synchronized system unless explicitly overridden by user or application; switchover from secondary active to primary active may not be bumpless in certain failure conditions
- Only critical control data must be transferred from Active to Backup CPU
- Compatible with the release 4 based Hot Standby Redundancy Product (CPU780)

### GDB Control Strategy

The GDB control strategy has the following features:

- Multiple dual bus Genius I/O Networks with redundant controllers in each synchronized PLC
- Multiple single bus Genius I/O networks with redundant controller in each synchronized PLC
- Multiple local Genius I/O networks with single or dual buses or controllers
- Active unit does not automatically switch to Primary on resynchronization
- Bumpless switchover with either PLC active
- Critical control data plus all redundant outputs must be transferred from Active to Backup CPU



## Basic Enhanced Hot Standby Operation

In an Enhanced Hot Standby CPU Redundant system, Genius I/O Blocks are normally configured for Hot Standby operation. Genius I/O Blocks can also be configured for the less frequently used Duplex operation, but only with the GDB Control Strategy. When configured for Hot Standby operation, the blocks must choose between outputs from the Genius Bus Controller at serial bus address 31 and the Genius Bus Controller at serial bus address 30. If outputs from both Genius Bus Controllers are available, then the blocks will prefer the outputs from bus address 31. If there are no outputs from bus address 31 for three consecutive Genius I/O bus scans, the blocks will use the outputs from bus address 30. If outputs are not available from either bus address 31 or 30, the outputs go to their configured default (OFF or hold last state).

For Hot Standby CPU Redundant systems, the Genius Bus Controllers in the Primary Unit are normally configured at serial bus address 31 and the Genius Bus Controllers in the Secondary Unit are normally configured at serial bus address 30.

It is possible to configure Genius I/O networks in which there is not a redundant bus controller in the synchronized PLC. It is not necessary for the serial bus addresses to be 31 in the Primary unit and 30 in the secondary for such networks.

In an Enhanced Hot Standby CPU Redundancy system, only the active unit may control the redundant Genius outputs. This is accomplished differently in the two control strategies:

### Output Control with GHS

In the GHS control strategy, the PLC CPU allows only the active unit to control the outputs. When the Primary Unit is active (GBCs at bus address 31), the PLC CPU allows both units to send outputs to the blocks. The result is a bumpless switchover if the Primary Unit fails while it is the active unit.

If the Secondary Unit is active, the PLC CPU automatically disables outputs from the redundant GBCs in the Primary Unit. That means the Genius I/O blocks will only receive outputs from the Secondary Unit (bus controllers at serial bus address 30).

### Output Control with GDB

In the GDB control strategy, both the Primary and Secondary Units send outputs regardless of which one is active. The user is responsible for ensuring that all redundant outputs are transferred from the active unit to the backup unit. Because the same output values will then be present in both units, the blocks will receive the same outputs (regardless of whether the Primary or the Secondary Unit is active). There is no output glitch (data interruption) on switchover since both units are always sending outputs.

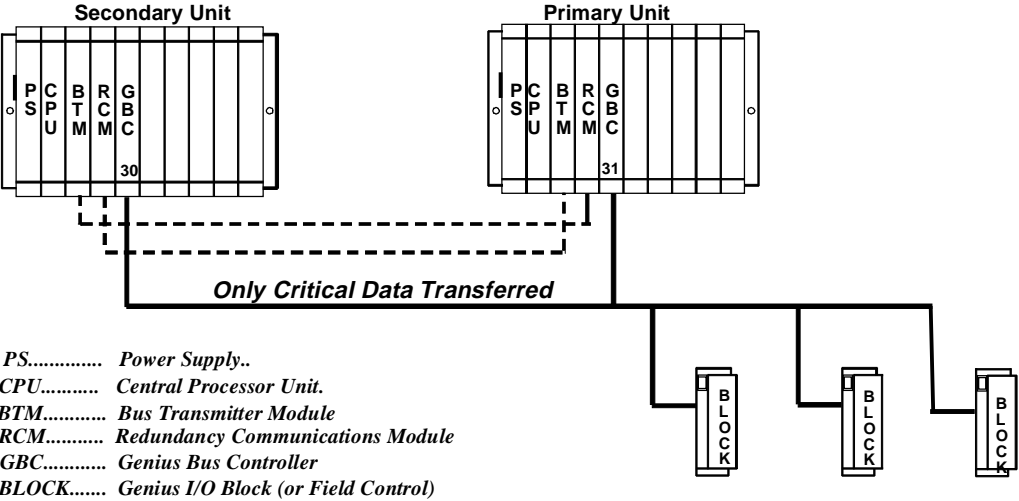
# Basic CPU Redundancy Setups

There are three basic CPU Redundancy setups:

- Single Bus with Preferred Master
- Single Bus with Floating Master
- Dual Bus with Floating Master

## Single Bus with Preferred Master: GHS Control Strategy

This type of system uses a single Genius bus with bus controllers in each PLC. The Primary Unit is always chosen as the active unit when the units initially synchronize.



The single bus with preferred master setup is suitable if:

- A. The application does not require redundant I/O buses, **AND**
- B. It is desirable to minimize the amount of data transferred between units, **OR** It is desirable that the Primary Unit always becomes active at synchronization.

Single Bus with Preferred Master requires selection of the GHS control strategy.

The GBCs must be configured with the following settings. Note that the GBCs can also be configured with Redundant Mode = **NONE** but **RED CTRL** provides more diagnostics and will be preferred in most installations.

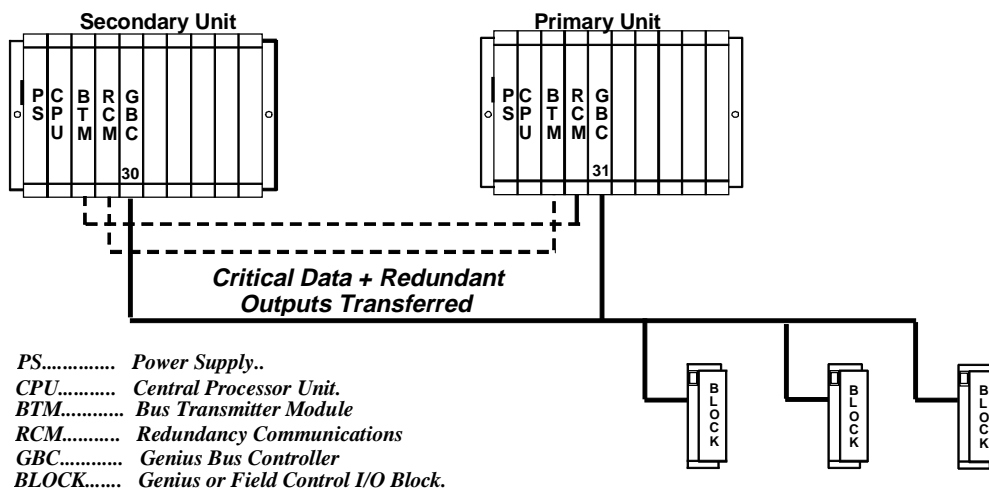
- Redundant Mode = RED CTRL**
- Paired GBC = External**
- Serial Bus Addr = 31** (Primary Unit) or **30** (Secondary Unit)

Assuming that **Redundant Mode** is set to **RED CTRL**, the redundant I/O blocks must be configured with the following settings:

- (Hand-Held Monitor) **CPU Redundancy = HOT STBY MODE**
- (Hand-Held Monitor) **BSM Present = NO**
- (Programming Tool) **Redundancy = YES**

## Single Bus with Floating Master: GDB Control Strategy

This type of system also uses a single bus with bus controllers in each PLC. However, no switchover occurs on initial synchronization to make the Primary Unit the active unit.



The single bus with floating master setup is suitable if:

- A. The application does not require redundant I/O buses, **AND**
- B. It is desirable that the active unit not switch on initial synchronization, **AND/OR**

The system cannot tolerate the potential for a bump in the outputs when switching from the secondary active to the primary active in failure conditions.

Single Bus with Floating Master requires selection of the GDB control strategy.

The GBCs must be configured with the following settings. Note that the GBCs can also be configured with Redundant Mode = **NONE** but **RED CTRL** provides more diagnostics and will be preferred in most installations.

- Redundant Mode = RED CTRL**
- Paired GBC = External**
- Serial Bus Addr = 31 (Primary Unit) or 30 (Secondary Unit)**

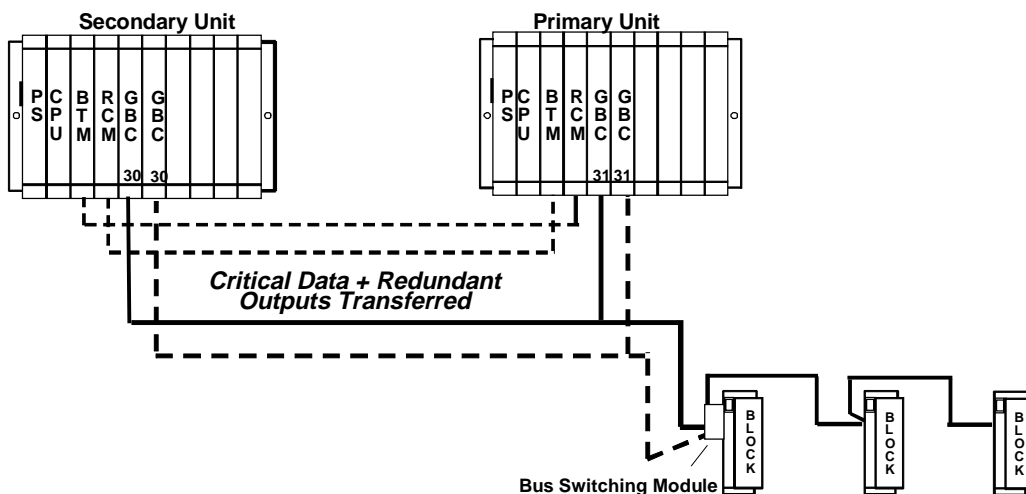
Assuming that **Redundant Mode** is set to **RED CTRL**, the redundant I/O blocks must be configured with the following settings:

- (Hand-Held Monitor) **CPU Redundancy = HOT STBY MODE\***
- (Hand-Held Monitor) **BSM Present = NO**
- (Programming Tool) **Redundancy = YES**

\* Configuration as Duplex mode is also permitted; duplex default also needs to be properly selected. (See “Duplex CPU Redundancy” on page 1-13.)

## Dual Bus with Floating Master: GDB Control Strategy

This type of system uses dual buses with bus controllers in each PLC. No switchover occurs on initial synchronization to make the Primary Unit the Active Unit. Bus Switching Modules (BSMs) are required in accordance with the traditional configuration of a Dual Bus network. This option provides redundancy of both the PLC and the I/O bus.



The Dual Bus with floating master setup is suitable if:

- A. The application requires redundancy of the PLC and I/O bus, **AND**
- B. The Active unit should not switch when the Primary Unit is returned to service.

Dual Bus with Floating Master requires selection of the GDB control strategy.

The GBCs must be configured with the following settings

**Redundant Mode = DB/RC** (Dual Bus/Redundant Controller)

**Paired GBC = INT/EXT** (Internal External)

**Serial Bus Addr = 31** (Primary Unit) or **30** (Secondary Unit)

The I/O blocks must be configured with the following settings:

(Hand-Held Monitor) **CPU Redundancy = HOT STBY MODE\***

(Hand-Held Monitor) **BSM Present = YES**

(Hand-Held Monitor) **BSM Controller = YES or NO** (depending on the block)

(Programming Tool) **Redundancy = YES**

\* Configuration as Duplex mode is also permitted; duplex default also needs to be properly selected. . (See “Duplex CPU Redundancy” on page 1-13.)

## Duplex CPU Redundancy

Only discrete blocks (or Remote I/O Scanners with only discrete modules) can be configured for Duplex CPU Redundancy mode. Blocks or I/O Scanners configured for Duplex mode receive outputs from BOTH bus controllers 30 and 31, and compare them. If devices 30 and 31 agree on an output state, the output goes to that state. If devices 30 and 31 send different states for an output, the block or I/O Scanner defaults that output to its pre-selected Duplex Default State. For example:

Commanded State from Device Number 31	Commanded State from Device Number 30	Duplex Default State in the Block or I/O Scanner	Actual Output State
On	On	Don' Care	On
Off	On	Off	Off
Off	Off	Don't Care	Off
On	Off	On	On

If either device 30 or 31 stops sending outputs to the block or I/O Scanner, outputs will be directly controlled by the remaining device.

## Online Programming

On-line changes to the application program are permitted in both the active unit and the backup unit. The programming device must be connected to the system in which changes are to be made in order to make any on-line changes. Note that all precautions regarding power source and grounding for connecting the programming device must be followed in accordance with instructions in the *Series 90-70 Programmable Controller Installation Manual*, GFK-0262.

A connection and disconnection of the parallel programmer cable should only be made with the programmer properly grounded, and programming software properly booted up and in OFF-LINE mode. For more information, refer to the *Series 90-70 Programmable Controller Installation Manual*, GFK-0262.

## On-Line Repair

An Enhanced Hot Standby CPU Redundancy system permits online repair of failed components without disrupting the process under control. Control status of both the Primary and the Secondary units can be monitored by the LEDs on the Redundancy Communications Module in each system.

When a component of the active unit fails, control switches to the backup unit. The failed component can then be replaced after first removing power from the rack in which it is installed.

After replacement of the failed component and returning power to the rack, the backup unit resynchronizes with the currently active unit. The unit that had failed, which was previously the active unit, determines its role in the system based on configured control strategy.

Online repair is described in more detail in chapter 5.

# Chapter 2

## System Components

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This chapter describes the hardware components for an Enhanced Hot Standby CPU Redundancy system.

- System Racks
- Redundancy CPU
- Redundancy Communications Module
- Bus Transmitter Module
- Bus Receiver Module
- Genius Bus Controller

### For Installation Instructions

For detailed installation instructions for the Series 90-70 PLC, refer to GFK-0262, the *Series 90-70 Programmable Controller Installation Manual*.

## System Racks

The following Series 90-70 I/O racks may be used in a Hot Standby CPU Redundancy System:

- IC697CHS750, 5-slot rear mount - standard rack
- IC697CHS790, 9-slot rear mount - standard rack
- IC697CHS791, 9-slot front mount - standard rack
- IC697CHS770, redundant rack - rear mount
- IC697CHS771, redundant rack - front mount

Use of Series 90-70 VME Integrator racks (IC697CHS782 and IC697CHS783) in a Hot Standby CPU Redundancy System is not supported.

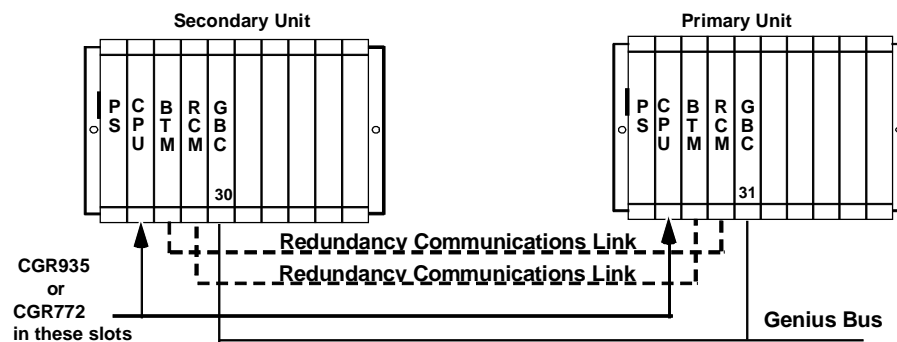
## Redundancy CPU

The redundancy CPUs have been designed specifically for Series 90-70 Hot Standby CPU Redundancy applications.

### Features

The Enhanced Hot Standby CPU supports floating point calculations, offers remote programmer keyswitch memory protection, and has seven status LEDs. Operation of the CPU may be controlled by the three-position RUN/STOP switch on the module, or remotely by an attached programmer. Program and configuration data can be locked through software passwords or manually by the memory protect keyswitch. When the key is in the protected position, a programmer connected to the Bus Transmitter Module can only change program and configuration data.

In a Hot Standby CPU Redundancy system, one CPU is configured as the Primary CPU and the other as the Secondary CPU. The Primary unit and the Secondary unit must each have a Redundancy CPU installed in slot 1 of rack 0.



Not all features of other Series 90-70 CPUs are available in redundancy models. See chapter 4 for details.

## CPU Architecture

The CGR772 and CGR935 have an 80486DX4 microprocessor, on-board memory, and a dedicated VLSI processor for performing Boolean operations. The CGR772 and CGR935 interface to serial ports and the system bus. The microprocessor provides all fundamental sweep and operation control, plus execution of non-Boolean functions. Boolean functions are handled by the dedicated VLSI, Boolean Coprocessor (BCP).

Model	Speed (MHz)	Processor	Input Points	Output Points	Expansion Memory	Floating Point Math
CGR772	96	80486DX4	2048	2048	512K Bytes	Yes
CGR935	96	80486DX4	12288	12288	1 Megabyte	Yes

### Expansion Memory Board

Program and data memory are provided by an attached expansion memory board with 512K Bytes of user memory for CGR772 and 1 Megabyte of user memory for CGR935. The expansion memory board provides RAM memory for program and data storage. Error checking is provided by a CPU checksum routine. Logic program memory is continually error-checked by the CPU as a background task. Memory parity errors are reported to the microprocessor when they occur.

The RAM memory on the expansion memory board is backed-up by the Lithium battery mounted on the CPU module.

### Watchdog Timer

The CPU provides a watchdog timer to catch certain failure conditions. The value of this timer can be set from 10 milliseconds to 1000 milliseconds. The default is 200 milliseconds. The watchdog timer resets at the beginning of each sweep. The watchdog timer should be set to allow for the expected scan *plus* two fail wait times.

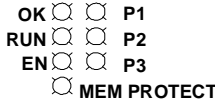


# CPU Features

## Memory Protect Keyswitch

The Memory Protect keyswitch can be used to manually lock program and configuration data from access by a remote programmer (serial or Ethernet). When the key is in the ON position, program and configuration data *can only be changed* by a programmer connected to the Bus Transmitter Module.

## CPU LEDs



**OK:** The OK LED is *ON* when the CPU is functioning properly. The OK LED blinks when the CPU executes power-up diagnostics, when the remote unit is powered-up, or if the system has failed. If the system has failed and the OK LED is blinking, the CPU can still communicate with the programmer (the CPU cannot communicate with the programmer during power-up diagnostics). If the OK LED is OFF, the system has failed and the CPU cannot communicate with the programmer.

**RUN:** This LED is ON when the CPU is in the RUN/ENABLE or RUN/DISABLE mode. It is OFF when the CPU is in STOP mode.

**Enabled:** This LED is ON when outputs are enabled and OFF when outputs are disabled.

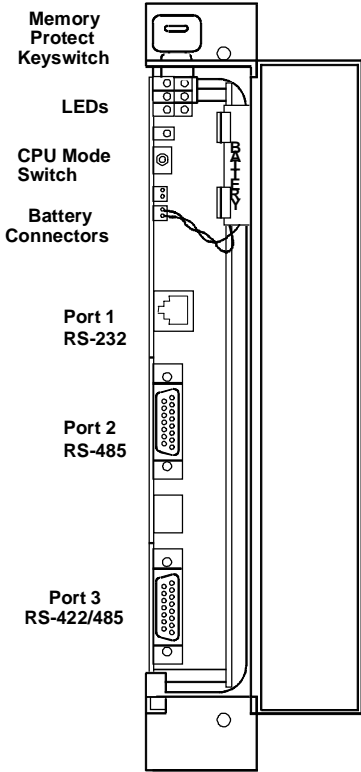
**MEMory PROTECT:** This LED indicates the status of the memory protect keyswitch. It is ON when the keyswitch is in the ON position. It is OFF when the keyswitch is in the OFF position.

**P1, P2, P3:** LED blinks intermittently when there is serial communications on the indicated serial port (Port 1, Port 2, or Port 3).

## Battery Connectors

There are two identical battery connectors. The battery currently installed can remain connected while a new battery is being installed, minimizing the risk of data loss. A Low Battery Warning occurs when the battery needs replacement.

When the CPU is in storage, the battery can be disconnected if there is no application program stored in memory. If a program is stored in memory, the battery should not be disconnected, or the data will be lost.



## CPU Mode Switch

The CPU Mode switch selects the operating mode of the CPU: *RUN/ENABLED*, *RUN/DISABLED*, or *STOP*. The CPU mode can also be controlled from the programmer. However, the CPU Mode switch position restricts the ability of the programmer to put the CPU into certain modes, as shown in the following table.

CPU Mode Switch Position	Allowable Programmer Mode Command
Run/Outputs Enabled	Run/Enabled Run/Disabled Stop
Run/Outputs Disabled	Run/Disabled Stop
Stop	Stop

### Run/Outputs Enabled Mode

In this mode, the CPU executes all portions of the sweep normally.

### Run/Outputs Disabled Mode

In this mode, the CPU executes all portions of the sweep normally, but physical outputs are held in their default state and remain unchanged. Refer to Chapter 4 for important information about Run/Disabled mode in a Hot Standby CPU Redundancy system.

### Stop Mode

In Stop mode, the CPU communicates with the programmer and the devices connected to the serial port, communicates with other communications modules such as the ethernet module, and recovers faulted modules. Values in the I/O tables can be changed using the programming computer.

The STOP/IOSCAN mode *is not a valid mode* in a redundancy system. Refer to Chapter 4 for detailed information.

### Port 1

The RJ-11 connector provides an RS-232 compatible serial port.

### Port 2

The 15-pin D-connector is an RS-485 compatible serial port.

### Port 3

The 15-pin D-connector at the bottom of the module provides an RS-422/RS-485 serial port. For applications requiring RS-232 communications, an RS-232 to RS-422 converter (IC690ACC900) or RS-232 to RS422 miniconverter (IC690ACC901) is available.

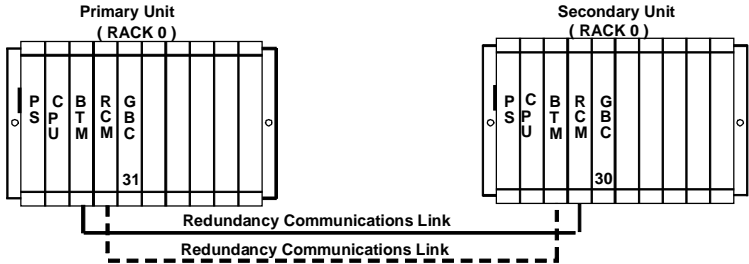
### Note

An RS-422 Isolated Repeater/RS-232 Converter (IC655CCM590) is available for applications requiring ground isolation where a common ground cannot be established between components.

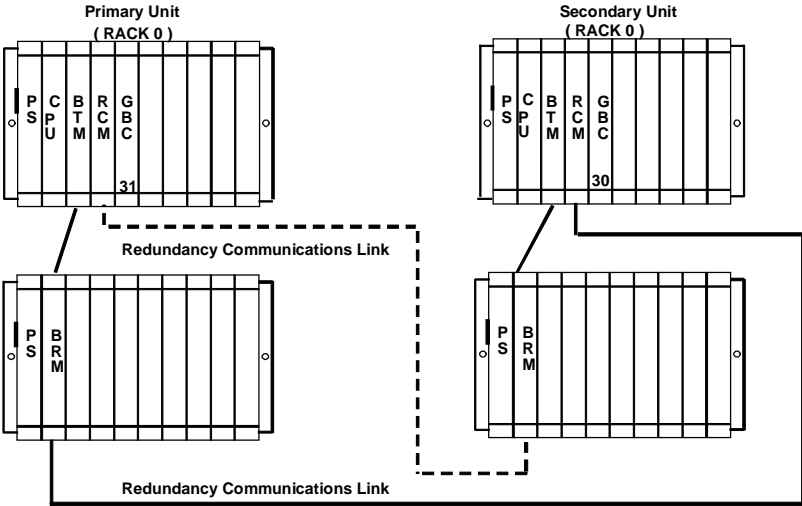
# Redundancy Communications Module

The Redundancy Communications Module (RCM), catalog number IC697RCM711 or IC687RCM711 (½ slot version), provides a communications path for sharing data between the two CPUs in the redundant system. In a synchronized system, I/O data is controlled by one unit (the active unit) but is shared between both units (active and backup units).

An RCM must be in both the Primary PLC and the Secondary PLC. The RCM must reside in rack 0. There can be no empty slot between the RCM and the CPU (there can be other modules).



If the other PLC has only one rack, the Redundancy Communications Module connects directly to the Bus Transmitter Module. If the other PLC has expansion racks, the RCM connects to a Bus Receiver Module in the last rack. The termination plug at the end of the bus is not required since the I/O cables for redundancy systems have termination built-in to the cables.



## Unit Select Pushbutton

The Redundancy Communications Module's pushbutton can be used to manually switch control from the *active* unit to the *backup* unit if the backup unit is *READY*. The switch must be pressed for 1 second and released. Switching between units can also be controlled from the application program with a SVC\_REQ function.

The pushbutton status is checked by the PLC CPU software. After a switch has been requested, you must wait 10 seconds before requesting another switch.

## Connector

The top connector on the Redundancy Communications Module must be connected via an I/O cable to the last rack of the *other* PLC. If no expansion rack is used, it is connected to the lower connector on the Bus Transmitter Module of the other system. The I/O cable with built-in termination is available in three lengths:

- IC697CBL803, 3 feet (0.9 meters)
- IC697CBL811, 10 feet (3 meters)
- IC697CBL826, 25 feet (7.5 meters)

The lower connector is not used.

## RCM Status LEDs

The RCM's five status LEDs are always updated by the appropriate system. The module automatically turns off four of the LEDs (not the board OK LED) if they are not updated within 500ms.

These LEDs report the status of the health of the RCM and control status of the Hot Standby CPU Redundancy system. The status provided by these LEDs can also be read from the application program logic in an area of %S memory (%S33 - %S39). These status bits are read-only.

The term *Local System* below means the system where the RCM resides. *Remote System* is the system to which the RCM is connected via the communications cable. Each RCM has an associated local and remote system.

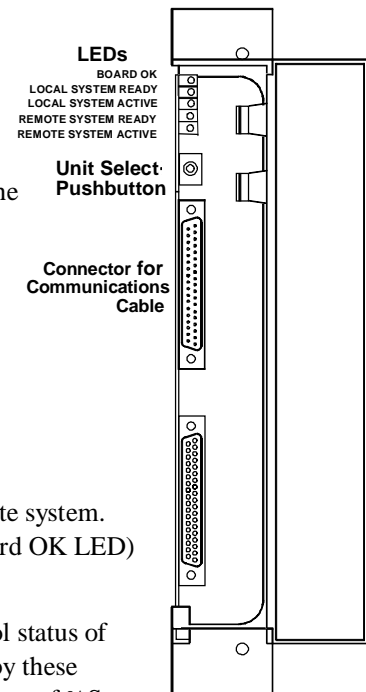
**Board OK:** This LED lights when diagnostics are complete and the RCM has been determined to be operating normally. It stays on unless the RCM fails.

**Local System Ready:** Indicates whether the local system is ready to become the active system in a redundant PLC configuration. If this LED is on, the local system has been configured for redundancy, is in RUN mode, and is able to take control of the redundant system if selected as the active system. The local system **MUST** set the state of this LED at least once each sweep; if it doesn't, the hardware forces the LED off after the timer expires.

**Local System Active:** Indicates whether the local system is the controlling (active) system in a redundancy system. The local system **MUST** set the state of this LED at least once during each sweep; if the local system fails to set the state of the LED, the hardware forces the LED off after the timer expires.

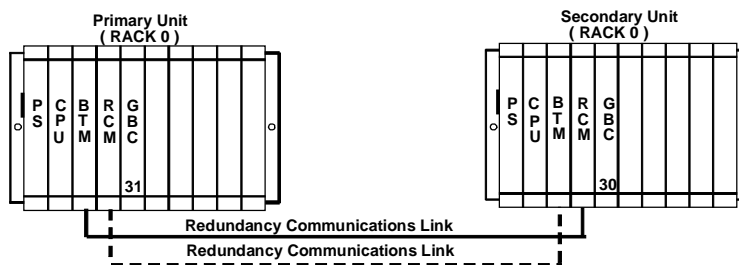
**Remote System Ready:** Indicates whether the remote system is ready to become the active system in a redundant PLC system. If the LED is on, the remote system has been configured for redundancy, is in RUN mode, and is able to take control of the redundant system if selected as the active system. The remote system **MUST** set the state of this LED at least once during each sweep; if the remote system fails to set the state of the LED, the hardware forces the LED off after the timer expires.

**Remote System Active:** Indicates whether the remote system is the controlling (active) system in a redundancy scheme. The remote system **MUST** set the state of this LED at least once during each sweep; if the remote system fails to set the state of the LED, the hardware forces the LED off after the timer expires.



## Bus Transmitter Module

A Bus Transmitter Module (BTM), catalog number IC697BEM713 or IC687BEM713 (½ slot version), must be in rack 0 of both the Primary PLC and the Secondary PLC in a Hot Standby CPU Redundancy system. The Bus Transmitter Module provides a path for Redundancy communications when connected to the Redundancy Communications Module as described previously. Each PLC in the redundancy system (Primary and Secondary) must have a BTM and an RCM in rack 0.



When included as a bus communications module in an I/O expansion system, the BTM is a high speed parallel interface which propagates the I/O bus signals through a cable to a Bus Receiver Module located in the first I/O expansion rack. The BTM also provides a high speed parallel connection to the programmer.

### Connectors

The lower connector on the BTM is used to connect to a Redundancy Communications Module in the other Redundancy system or to a Bus Receiver Module in the first expansion rack. Standard parallel I/O cables are used to make the connection to a Bus Receiver Module. Cables with built-in termination are used to make the connection to a Redundancy Communications Module.

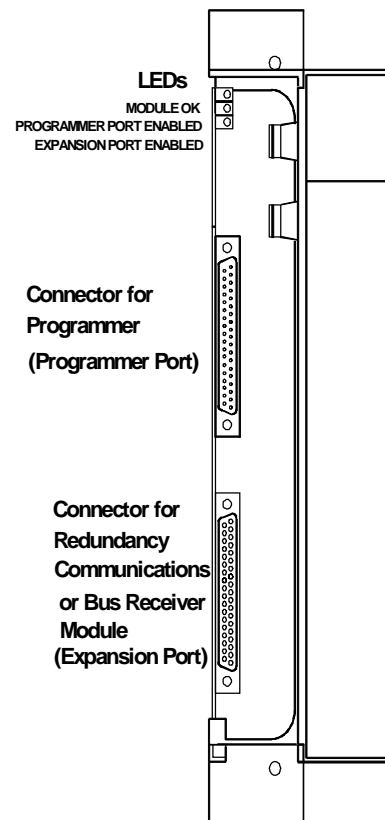
The upper connector provides a parallel connection to a Work Station Interface (WSI) board installed in the programmer for the Series 90-70 PLC.

### Bus Transmitter Module Status LEDs

**Module OK:** The top LED is ON when the CPU software has completed its power-up configuration of the BTM, and has polled (or attempted to poll) each expansion rack in the system. It is OFF when any of these conditions are not met.

**Programmer Port Enabled:** The middle LED is either *blinking* or *ON* when the programmer and the PLC are communicating. It is *OFF* when they are not communicating.

**Expansion Port Enabled:** The bottom LED shows the status of the expansion bus. This LED is either blinking or ON when the BTM is communicating.



## Bus Receiver Module

The Bus Receiver Module (BRM), catalog number IC697BEM711, is the expansion rack interface to the I/O bus. The Bus Receiver Module connects to a Bus Transmitter Module in rack 0 or to a Bus Receiver Module in the previous rack via a parallel I/O bus cable.

In a CPU Redundancy system with expansion racks, the last bus connection is to a Redundancy Communications Module, as explained previously.

### Connectors

The top connector on the Bus Receiver Module is for connection to the previous Bus Transmitter or Bus Receiver Module.

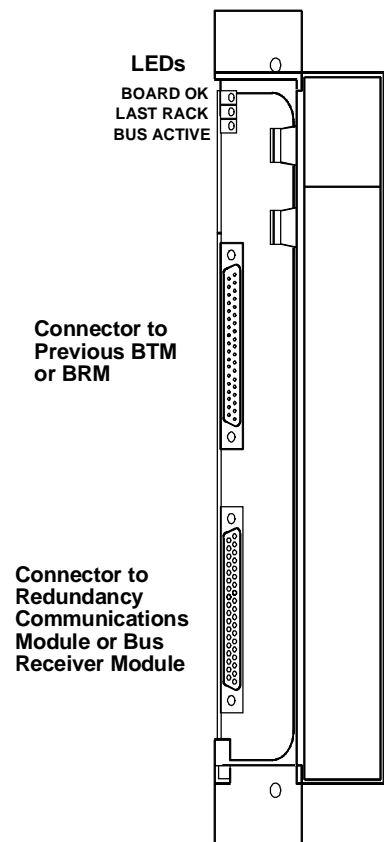
The lower connector on the Bus Receiver Module is for connection to the upper connector of a Bus Receiver Module in the next expansion rack or to the upper connector of a Redundancy Communications Module.

### Cables and Termination

In an expansion I/O system, the cable between Bus Transmitter/Receiver modules is an 18 twisted-pair cable with a ground shield. The total maximum cable length from the CPU rack to the most distant expansion rack (at the same ground potential) is 50 feet. Standard parallel I/O bus cables that meet this specification are available in lengths of 5, 10, 25, and 50 feet.

In a non-redundant PLC system, this bus must be terminated using terminator plug (IC697ACC702) on the bottom connector of the last Bus Receiver. All BRMs are shipped from the factory with a terminator plug installed. For a redundant PLC system, these terminator plugs must be removed from all BRMs.

In a Hot Standby CPU Redundancy system a special I/O cable with built-in termination is used. Do not use the resistor plug with the terminated cable.



### Bus Receiver Module Status LEDs

**Board OK:** The top LED is *ON* when the CPU completes its power-up configuration of the expansion rack and at least one module in that rack responds to the CPU requests for information. It is *OFF* when any of these conditions are not met.

**Last Rack:** The middle LED is *ON* when the terminator plug is installed in the bottom connector of this Bus Receiver Module and is *Off* when it is not installed.

**Expansion Bus Active:** The bottom LED *ON* indicates activity on the expansion bus in the last 500 ms. Otherwise it is off and I/O modules in the rack are held in their default state.

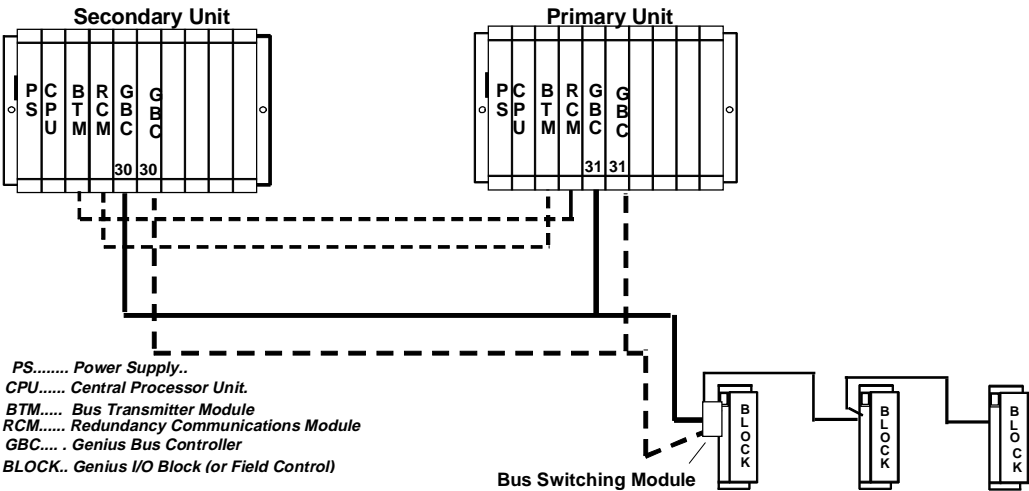
# Genius Bus Controller

The Genius Bus Controller (IC697BEM731) interfaces the Series 90-70 PLC to a Genius I/O bus. The bus controller scans bus devices asynchronously and exchanges I/O data with the CPU once per scan.

## Location of GBCs and Blocks

For dual bus Genius networks, the Genius bus controllers should be placed at the same end of the bus, as pictured below. In particular, the Secondary Unit must be placed at one end of the bus and the Primary Unit must be placed between the Secondary Unit and the Genius I/O blocks. No I/O blocks or other devices should be located on the bus between the bus controllers. Placing the bus controllers and blocks in this manner minimizes the risk of a bus break between the two CPUs. A bus break between the CPUs could result in only some blocks switching busses, and make the other blocks inaccessible to one of the CPUs. It also allows the Primary Unit to continue to control the I/O in bus failure conditions that might otherwise result in loss of inputs and unsynchronized control of outputs.

Since the recommended configuration still has the possibility of a bus breaking between the two CPUs, you may want to program the application to monitor the status of the busses from the unit configured at the end of the buses and request a role switch or bus switch if the bus is determined to be broken. Locating single bus networks in the same manner has similar advantages.



For fastest switching, all Genius Bus Controllers in the Hot Standby CPU Redundancy system should be in the rack, or in a rack driven by the main rack's power supply. This will cause the Genius Bus Controller to lose power at the same time that the CPU loses power and allow the backup unit to gain full control of the I/O as soon as possible. Each GBC has an output timer, which it resets during every output scan. If the GBC determines that the CPU in its PLC has failed, it will stop sending outputs to its Genius I/O block. This allows the other GBC to take control of the I/O.

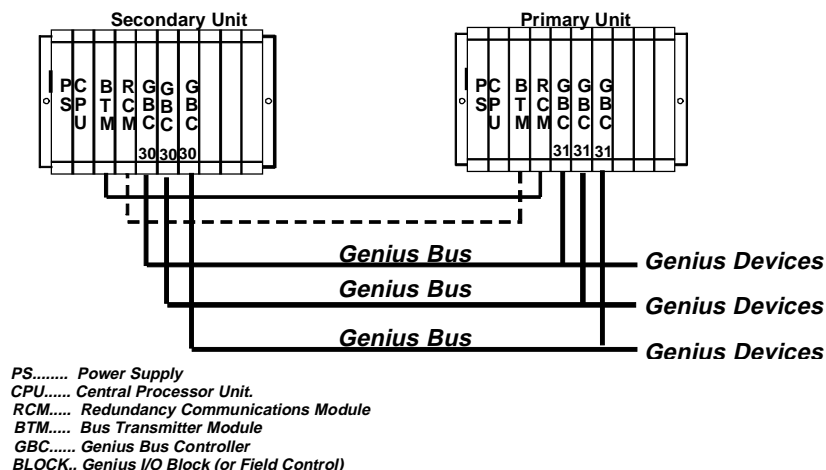
## Single Bus Genius Networks

When using single-bus Genius networks in a Hot Standby CPU Redundancy system, one Genius Bus Controller for the bus must be located in the Primary PLC and one in the Secondary PLC. There can be multiple Genius busses in the system.

The bus controllers in the Primary PLC are assigned Serial Bus Address 31. The bus controllers in the Secondary PLC are assigned Serial Bus Address 30. Data from Serial Bus Address 31 in the Primary PLC is the "preferred" data. If the GHS Control Strategy is used, the Primary PLC is normally the active unit in the redundancy system.

Each bus can have up to 30 Genius devices connected to it. One Serial Bus Address must be reserved for a Hand-held Monitor. Any type of Genius device can be connected to the bus. A Genius I/O device will use outputs from Serial Bus Address 31 in preference to data from Serial Bus Address 30.

When using the GHS Control Strategy, the blocks receive outputs from the bus controllers in the active unit. With the GHS Control Strategy, it is not necessary to transfer outputs from the active unit to the backup unit.



When using the GDB control strategy, all redundant Genius outputs must be transferred from the active to the backup unit. Therefore, outputs are determined by the active unit regardless of which bus controller provides the outputs to the blocks.

As a safety feature, a watchdog timer protects each Genius I/O link. The Genius Bus Controller periodically resets this timer. If this timer expires, the bus controller stops functioning and the Channel OK LED turns off. If this happens in a CPU Redundancy system, the other bus controller provides data to the Genius I/O blocks. The cause of the failure must be fixed to re-establish communications.

## Dual Bus Genius Networks

When using dual bus Genius networks in a Hot Standby CPU Redundancy system, two Bus Controllers for the bus pair must be located in the Primary PLC and two more in the Secondary PLC. There can be multiple dual bus pairs. The bus controllers in the Primary PLC are assigned Serial Bus Address 31. The bus controllers in the Secondary PLC are assigned Serial Bus Address



30. Data from Serial Bus Address 31 in the Primary PLC is the "preferred" data. The GDB control strategy must be used and all redundant Genius outputs must be transferred from the active to the backup unit.

Each dual bus can have up to 30 additional Genius devices connected to it. One Serial Bus Address must be reserved for a Hand-Held Monitor. Any type of Genius device can be connected to this bus. A Genius I/O device will use outputs from Serial bus Address 31 in preference to data from Serial bus Address 30. Outputs are determined by the Active Unit regardless of which bus controller provides the outputs since all redundant Genius outputs must be transferred from the active to the backup unit.

As a safety feature, a watchdog timer protects each Genius I/O link. The bus controller periodically resets this timer. If the timer ever expires, the bus controller stops functioning and its Channel OK LED turns off. If this happens in a Dual Bus Genius network of a CPU Redundant system, the paired GBC in the remote CPU drives the Genius I/O blocks. If the remote unit GBC is not available, the BSMs switch busses and use outputs from the other bus. The cause of the failure must be remedied to re-establish communications.

### Connectors

The Bus Controller has a nine-pin connector for a Hand-Held Monitor. Bus connections are made to a removable terminal board.

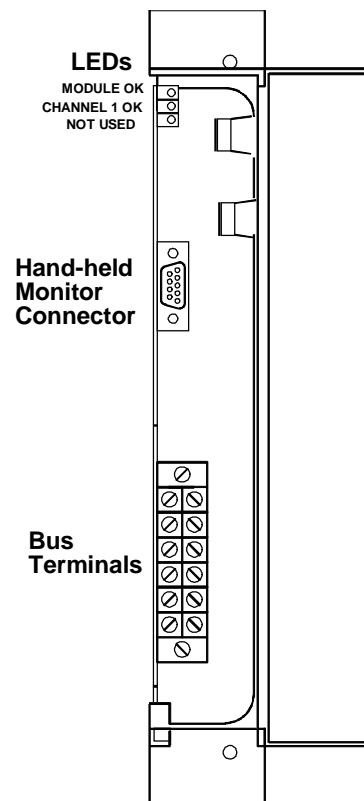
### Bus Controller LEDs

The GBC has three LEDs; the bottom one is not used.

**Module OK:** The top LED is *ON* when the board has successfully completed the power-up diagnostics. If the power-up diagnostics detect a failure or if the board fails during operation, the LED goes *OFF*. The LED *blinks* during the power-up diagnostics.

**CH 1 OK:** The CH 1 OK LED is *ON* after the board has successfully completed the power-up diagnostics and *OFF* if a failure has been detected during the power-up diagnostics or if its bus or bus controller fails while the CPU is running (even in the STOP mode). If the bus controller fails the LED remains off. For a bus failure, such as a broken wire or excessive bus errors, the LED remains off until the failure condition is corrected.

The LED also remains *OFF* until its serial bus address is configured.



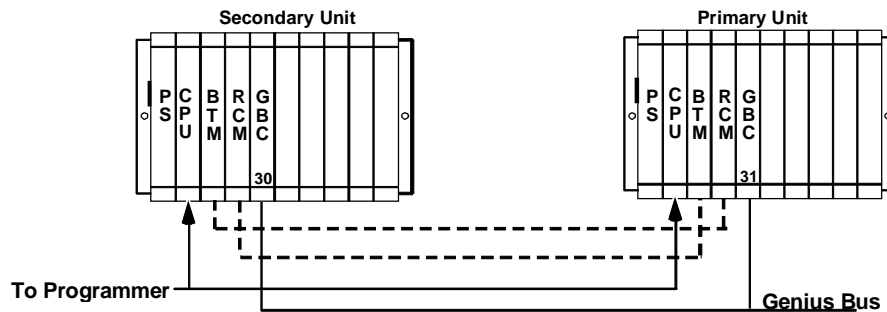
# Chapter 3

## Configuration Requirements

This chapter defines the special configuration requirements of an Enhanced Hot Standby CPU Redundancy system.

### Programmer Connection for Configuration

In a Hot Standby CPU Redundancy system, one CPU is configured as the Primary CPU and the other as the Secondary CPU. The Primary Unit and the Secondary Unit must be configured separately. The programming device must be connected directly to either the Primary or the Secondary Unit to configure that unit. For a new system, STORE configuration first, then logic.



### One Application Program in Both PLCs

Although it is not necessary to use the same application program logic for both PLCs, it is difficult to maintain a system that uses two different programs. If the programs are not the same, logic changes made in one system must be hand-keyed into the program folder for the other PLC. Other than visual inspection, there is no way to tell if changes made in one system have been appropriately made in the other.

### Program Folders in Control Programming Software

With the Control programming software, a single folder may be used if the logic is identical for both CPUs.

## Program Folders in Logicmaster 90

With the Logicmaster programming software, there must be different folders for each configuration. If the logic is identical for both PLCs, a third folder could be used for the logic and reference tables. This results in three folders for the system.

**Folder A** - configuration for the Primary unit.

**Folder B** - configuration for the Secondary unit.

**Folder C** - logic and reference tables for both systems.

## CPU Configuration Parameters

When configuring a system for Hot Standby CPU Redundancy, the following additional parameters must be set up.

Parameter	Default	Choices	Description / Comment
I/O Scan Stop	Must be set to NO		
Watchdog Timer	200ms	10ms to 1000ms	The value selected should allow for the expected scan <i>plus</i> two fail wait times.
<i>Redund Type</i>	Primary	Primary, Secondary	Whether the CPU being configured is the Primary or Secondary CPU in the Redundancy system. One configuration must be set to Primary; the other to Secondary.
Background Timer	5ms in limited window mode	0ms to 255ms	The background window runs several diagnostic tests that can be disabled by setting the timer to 0ms. These tests are run in Constant Window and Constant Sweep mode only if the window/sweep time is large enough.
<i>Fail-wait</i>	60ms	60ms to 400ms	The time one PLC will wait on one Redundancy Communications Module link for the other PLC to respond before faulting that link. The CPU will try both links before continuing its scan. Once the RCM links are marked as failed, one unit or the other must be power cycled to recover them. Storing configuration to either unit could also recover the RCM links.
<i>Control Strategy</i>	GHS (CPU780) GDB (CGR772, CGR935)	GHS or GDB	Genius Hot Standby (GHS) or Genius Dual Bus (GDB).
<i>Shared I/O References</i>	The references within the control of the Redundancy system. See the following paragraphs for more information. The Shared I/O selections must match exactly between Primary and Secondary PLCs.		
Fault Category (configurable when not synchronized only)		Fatal, Diagnostic	Fault actions when the CPUs are not synchronized can be configured to select a safe shutdown or fault tolerant operation in case a failure occurs with no backup ready.

## Configuring Shared I/O References

Shared I/O data is transferred from the active CPU to the backup CPU each sweep. Reference addresses and ranges must be configured for the data to be transferred. There can be up to 20 Kbytes of input data (%I, %AI) and up to 28 Kbytes of output data (%Q, %AQ, %M, %R) transferred.

Input references should be transferred to the backup unit if the program logic requires identical inputs for the two units. Scanning the same Genius I/O blocks in both units is not sufficient to guarantee that the inputs will be identical every sweep.

When using the GDB Control Strategy, it is necessary to transfer all Genius outputs for redundant blocks. Otherwise, the Genius blocks would drive their outputs from the backup when the Primary PLC was serving as the backup.

Parameter	Default	Range	Description
%I Ref Adr	%I00001	00001 to 12288*	Starting address for redundant %I data region. Must be byte aligned.
%I Length	0	0 to 12288*	Bit length of the redundant %I data region. Length must be a multiple of 8.
%Q Ref Adr	%Q00001	00001 to 12288*	Starting address for redundant %Q data region. Must be byte aligned.
%Q Length	0	0 to 12288*	Bit length of the redundant %Q data region. Length must be a multiple of 8.
%M Ref Adr	%M00001	00001 to 12288**	Starting address for redundant %M data region. Must be byte aligned.
%M Length	0	0 to 12288**	Bit length of the redundant %M data region. Length must be a multiple of 8.
%R Ref Adr	%R00001	00001 to %R configured limit	Starting address for redundant %R data region.
%R Length	0	0...%R configured limit	Word length of the redundant %R data region.
%AI Ref Adr	%AI00001	00001 to %AI configured limit	Starting address for redundant %AI data region.
%AI Length	0	0 to %AI configured limit	Word length of the redundant %AI data region.
%AQ Ref Adr	%AQ00001	00001 to %AQ configured limit	Starting address for redundant %AQ data region.
%AQ Length	0	0 to %AQ configured limit	Word length of the redundant %AQ data region.

Limit is 2048 for IC697CGR772; \*\*Limit is 4096 for IC697CGR772

## Finding the Memory Available for Application Program Storage

Shared I/O data is stored in the same memory as application program storage. To find the amount of memory available for application program(s), subtract the overall transfer data amount from the amount of memory (512K bytes for CGR772, 1024K bytes for CGR935) available for the application program.

First, calculate the amounts of input and output data transferred:

Reference Type	Reference Size	If Point Faults are <i>Disabled</i> :	If Point Faults are <i>Enabled</i> :
%I	Bit	$(\%I \text{ length} \times 4) \div 8$	$(\%I \text{ length} \times 5) \div 8$
%AI	Word	$(\%AI \text{ length} \times 2)$	$(\%AI \text{ length} \times 3)$
%Q	Bit	$(\%Q \text{ length} \times 4) \div 8$	$(\%Q \text{ length} \times 5) \div 8$
%M	Bit	$(\%M \text{ length} \times 4) \div 8$	
%AQ	Word	$(\%AQ \text{ length} \times 2)$	$(\%AQ \text{ length} \times 3)$
%R	Word	$(\%R \text{ length} \times 2)$	

Then, add the input amount, the output amount, and an additional 8K bytes for synchronization information:

**total bytes of input data** (%I, %AI) transferred  
 + **total bytes of output data** (%Q, %AQ, %M, %R) transferred  
 + **8 Kbytes** for synchronization information

Last, subtract this amount from the total amount available for the application.

For example, if there are 10 Kbytes of input data transferred and 20 Kbytes of output data transferred, then 10 Kbytes + 20 Kbytes + 8 Kbytes = 38 Kbytes needed for transferred data. This is subtracted from the 1024 Kbytes of total memory on the CGR935:

$1024K - 38K = 986 \text{ Kbytes}$  available for the application program on the CGR935.

## System Communications Window Considerations

The CGR772 and CGR935 model CPUs support the use of high-speed communications modules such as the Ethernet Interface (Type 2). Requests from devices attached to these communications modules are handled in the System Communications Window. Since these requests can be sent in large volumes, there is the potential for the Systems Communications Window to be processing requests for a significant amount of time. One way to reduce the risk of timing out the Redundancy Communications Module/Bus Transmitter Module communications link between the CPUs is to configure the System Communications Window for *LIMITED WINDOW* mode. This sets a maximum time for the Systems Communications Window to run. Other options are to configure the CPU sweep mode as *CONSTANT WINDOW* or *CONSTANT SWEEP*. The CPU will then cycle through the communications and background windows for approximately the same amount of time in both units.

## Configuring the Redundancy CPU for Non-redundant Operation

The Redundancy CPU can be used for both redundant and non-redundant applications. For non-redundant applications, do not configure Redundancy Communications Modules in the system. If a Bus Transmitter Module is configured set the **Remote RCM Present** parameter to NO. Keep all redundancy-related parameters in their default settings.

Genius I/O in the non-redundant system can be configured for either no redundancy or externally paired. (If a GBC redundancy mode other than RED CTRL or NONE is selected, it will be necessary to select the GDB control strategy. When that is done, the programmer may display messages that %Q and %AQ must be included in the data transfer. These warnings can be ignored when configuring the CPU for non-redundant operation).

## Rack Module Configuration Parameters

- Interrupts cannot be ENABLED when the configured CPU is a Redundancy CPU. When a redundant CPU is configured, any interrupts enabled in the configuration are set to DISABLED.
- For redundant applications, a Bus Transmitter Module must be configured and its Remote RCM parameter must be set to YES. (see the previous discussion for non-redundant applications.)
- For redundant applications, a Redundancy Communications Module must be configured in rack 0 of each system. For a given unit, the *Local* RCM is the one configured in that unit; the *Remote* RCM is configured via the Bus Transmitter Module's *Remote RCM* parameter. Remote RCMs appear as being in slot 1 of rack 7. (see the previous discussion for non-redundant applications.)

## Bus Controller Configuration Parameters

- When configuring the PRIMARY PLC, all Genius Bus Controllers configured for redundancy must have Serial Bus Address 31.
- When configuring the SECONDARY PLC, all Genius Bus Controllers configured for redundancy must have Serial Bus Address 30.
- Non-redundant busses with a bus controller in only one of the PLCs do not need to use Serial Bus Address 31 or 30.

For single Genius bus networks, all Genius Bus Controllers in the system must be configured for RED CTRL Redundancy with the redundant pair set to EXTERNAL, or they must be configured for no redundancy.

For Dual Bus Genius networks, all Genius Bus Controllers must be configured for Dual Bus/Redundant Controller (DB/RC).

(It is possible to configure bus controllers in a Redundancy system with Redund Type set to NONE, but this bypasses some important integrity checks, which are desirable for optimum system operation).

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## Genius I/O Block Configuration Parameters

- When using the GHS Control Strategy, if a Genius Bus Controller is set to redundant, then all of its I/O blocks must also be set to redundant.

When using the GDB Control Strategy, if a Genius Bus Controller is set to redundant, then all of its I/O blocks are normally configured as redundant.

- If a Genius Bus Controller is set to non-redundant, all of its I/O blocks must also be set to non-redundant.

This chapter discusses:

- Powerup of a Redundant CPU
- Resynchronization of the Redundant CPU
- GHS Control Strategy
- GDB Control Strategy
- %S References for CPU Redundancy
- Scan Synchronization
- Switching Control to the Backup unit
- RUN Disabled Mode
- Background User Checksum and Background Window Timing Instructions
- Miscellaneous Operation Information
- Genius Bus Controller Switching
- Ethernet Global Data in a Redundancy CPU



## Powerup of a Redundant CPU

When a redundant CPU is powered up, it performs a complete hardware diagnostic check and a complete check of the application program and configuration parameters. This causes the powerup time of a redundant CPU to be significantly longer than the normal powerup time of a non-redundant CPU. If the Primary and Secondary systems power up together each CPU will recognize this fact so that the Primary system will become the active and the Secondary system the backup.

Powerup consists of the following sequence of steps:

1. Powerup self-test is always performed.
2. CPU operating system is initialized and PLC memory is validated.
3. Diagnostics called during full powerup tests are performed.
4. System Configuration is verified.
5. System is interrogated and initialized.
6. Presence of other CPU is detected.
7. Redundancy Communications Modules are initialized.
8. Complete application program is verified.
9. CPU synchronizes with redundant CPU.

When the Secondary Unit powers up, if it does not detect the Primary Unit, the Secondary Unit waits up to 15 seconds for the Primary Unit to power up. If the primary unit has not completed its powerup sequence within 15 seconds, the Secondary Unit assumes the Primary Unit is not present. If at this time, the Secondary Unit transitions to RUN mode, it does so as an active unit without a backup unit.

If the Primary Unit completes its powerup sequence before the Secondary Unit, the Primary Unit does not wait for the Secondary unit to complete its powerup sequence. If the Primary Unit is set up to transition to RUN on powerup (that is, was powered-down in RUN mode), it transitions to a stand-alone unit without waiting for the Secondary unit. The Secondary Unit, upon completion of its powerup sequence, establishes communications with the Primary Unit. If transitioning to Run mode, it synchronizes with the Primary Unit.

In either case, if one CPU fails to notify the other CPU that it is either present or powering up, the other CPU, if transitioning to RUN, becomes the active unit and runs without a backup unit. Resynchronization occurs after the powerup sequence is complete.

### Note

If the system should be fully redundant upon powerup, the Secondary Unit must complete power-up first but no more than 15 seconds before the Primary Unit. The way to be sure this happens is to apply power to the Secondary Unit first.

## Incompatible Configurations

When two units have incompatible configurations stored (for example, both units configured for PRIMARY or differing blocks for data transfer), then only one of the units can go to RUN mode. If the other unit attempts to go to RUN mode or both units attempt to go to RUN mode at the same time, a FATAL incompatible configuration fault will be logged.

If one unit is configured for CPU Redundancy and the other has no configuration, then both units may go to RUN mode at the same time *but* they will not be synchronized and only the unit that has been configured will drive outputs.

## Resynchronization of a Redundant CPU

When a CPU attempts to get back in synchronization with the currently active CPU, resynchronization occurs. Resynchronization occurs any time a CPU transitions from STOP to RUN mode. The process starts by determining which role each CPU is to play, based on configured control strategy and PRIMARY/SECONDARY configuration as shown in the table below.

Control Strategy	Behavior during Resynchronization
<b>GHS</b>	The Primary Unit (with Serial Bus Address 31) is always preferred. A switch occurs from the Secondary Unit each time the Primary Unit resynchronizes. Until the resynchronization is complete, the Primary Unit acts as backup. The Primary Unit switches to active just <i>prior</i> to logic execution. Outputs will be driven that sweep by the Primary Unit.
<b>GDB</b>	The active CPU remains active after resynchronization without regard to whether it is in the Primary or Secondary unit. The transitioning unit becomes the backup.

If both systems are transitioning at the same time, the Primary Unit becomes the active CPU and the Secondary Unit becomes the backup.

During resynchronization, the CPUs exchange information about roles and configuration. If the transitioning CPU detects that the role or configuration is not in agreement, that CPU is not permitted to go to RUN mode. If both CPUs are transitioning, neither CPU is permitted to go to RUN mode. The following items must be in agreement:

1. One CPU must be configured as Primary, the other as Secondary.
2. Both CPUs must be configured for the same control strategy (GHS or GDB).
3. Both CPUs must have the same Shared I/O redundancy points configured.
4. If point faults are enabled on one CPU, they must also be enabled on the other if %I, %Q, %AI, or %AQ data is transferred.

At this point, the active unit is the one that has been in control and the backup unit is the one that is resynchronizing. The transfer of all configured control data from the active unit to the backup occurs unless both units are transitioning at the same time (transfer always goes from the running unit to the resynching unit. In addition to the configured control data, the FST\_SCN and FST\_EXE %S references as well as internal timer information for each common (that is, present in both CPUs) sub-block are transferred from active to backup. Only the internal timers and

FST\_EXE references for program blocks with the same name are transferred from the active to the backup CPU. The result is that if one CPU is already in Run mode and the other is transitioning to Run mode, the FST\_SCN and matching FST\_EXE bits are *not* set on the first scan of the transitioning unit. These bits are considered system bits and set if one unit comes up alone, or if both units come up together.

No transfer of data occurs at this point if both units are transitioning to Run mode. Instead, the normal clearing of non-retentive data happens and the FST\_SCN and FST\_EXE references are set as in the non-redundant CPU models.

The timer information and the FST\_EXE %S reference bits are not continuously transferred. The timer information and FST\_EXE references are transferred only at resynchronization time. Timer information is calculated each sweep from the universal Start of Sweep Time transferred every sweep.

## GHS Control Strategy

In the GHS Control Strategy, the Primary Unit (with bus address 31), is always the preferred CPU. The Secondary Unit (with bus address 30) has outputs enabled to its Genius bus controllers at all times, whether it is in control or not. This is necessary to prevent glitching of the outputs when a switch occurs. The Primary Unit, on the other hand, must disable its outputs whenever control is manually switched to the Secondary Unit. The Primary Unit must re-enable its outputs if it is again selected as the active unit. Glitching of the outputs does not occur on a switch from the Secondary to the Primary Unit when it is done manually. However a glitch may occur if the switch is made automatically due to a failure in the Secondary Unit.

*For this reason, the primary CPU should normally be selected as the active unit. Any time the Primary Unit transitions from STOP to RUN mode, the Primary Unit assumes control from the Secondary Unit after resynchronization. This is handled automatically by the CPU operating system.*

The Primary Unit in the GHS Control Strategy becomes a functioning backup if control is manually switched to the Secondary Unit. After this happens, the Secondary Unit remains the active unit and the Primary Unit remains the backup until another manual switch is commanded, or until either unit transitions from STOP to RUN mode. A STOP to RUN mode transition always occurs when the unit is power cycled and proceeds directly to RUN mode or when commanded to transition by either the programmer or the toggle switch. A failure of the Secondary Unit while it is active may result in a glitch in the outputs.

## GDB Control Strategy

Unlike the GHS Control Strategy, the GDB Control Strategy does not have a preferred unit. Outputs are always enabled for both units (unless explicitly disabled) so that bumpless switching is possible regardless of which unit is currently the active unit.

If both units power up together and go to RUN mode, the Primary Unit becomes the active unit and the Secondary Unit becomes the backup unit.

If one of the units is already in RUN mode and the other unit goes to RUN mode, then the unit already in RUN mode remains the active unit and the transitioning unit becomes the backup unit. The behavior is the same whether the unit going to RUN is the Primary Unit or the Secondary Unit.

If dual busses are configured, failure of one of the Genius trunk cables results in the blocks switching to the other bus. The bus can then be repaired. Failures of the Genius stub cables (the

portion of the bus between the BSM and the blocks) result in loss of the blocks downstream from the failure on that bus stub.

Bus failures in single bus networks result in loss of the blocks downstream from the bus failure.

When using the GDB control strategy, the user is required to transfer all redundant Genius outputs to the backup unit so that both units drive the same output values.

## %S References for CPU Redundancy

%S33 through %S39 and %SB18 reflect the status of the Redundancy units. The table below describes these %S references, and shows their expected states in the Primary and Secondary Units, assuming Primary is active and Secondary is backup.

%S Bit	Definition	Nickname	Description	Expected State	
				Primary Unit	Secondary Unit
%S33	Primary Unit	PRI_UNT	Set if the local unit is configured as the primary unit; otherwise; it is cleared. For any given local unit, if PRI_UNT is set, then SEC_UNT cannot be set.	ON	OFF
%S34	Secondary Unit	SEC_UNT	Set if the local unit is configured as the secondary unit; otherwise; it is cleared. For any given local unit, if SEC_UNT is set, then PRI_UNT cannot be set.	OFF	ON
%S35	Local System Ready	LOC_RDY	Set if local unit is ready to become the active unit; otherwise it is cleared.	ON	ON
%S36	Local System Active	LOC_ACT	Set if local unit is currently the active unit; otherwise it is cleared. For any given local unit, if LOC_ACT is set, then REM_ACT cannot be set.	ON OFF (1)	OFF ON (1)
%S37	Remote System Ready	REM_RDY	Set if remote unit is ready to become the active unit; otherwise it is cleared.	ON	ON
%S38	Remote System Active	REM_ACT	Set if remote unit is currently the active unit; otherwise it is cleared. For any given local unit, if REM_ACT is set, then LOC_ACT cannot be set.	OFF ON (1)	ON OFF (1)
%S39	Logic Equal	LOGICEQ (LOGIC=)	Set if the logic program for both units in the redundant system is the same; otherwise the bit is cleared.	ON	ON
%SB18	Redundant Informational Message, Fault Logged	RDN_MSG	Set if a redundant informational message was logged. It can be cleared in reference tables, logic, or by clearing the fault tables.		

(1) Condition if secondary is active unit.

%S references can be read from the application program, but cannot be altered or overridden. These references are always OFF when no configuration has been stored. Once you have completed configuration of the Redundancy system and STORED the configuration, the state of these %S references is set and is maintained in STOP or RUN mode.

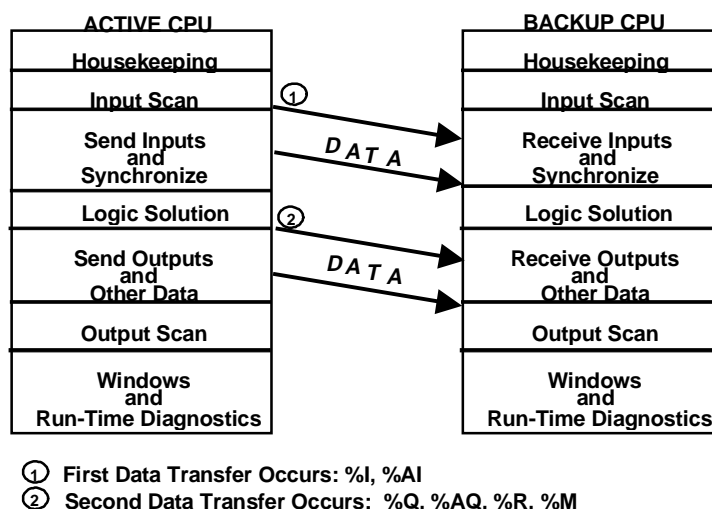
References %S35, %S36, %S37, and %S38 correspond to LEDs on the Redundancy Communications Module. External indicators can also be used to monitor the status of %S35 through %S38 (Local Ready/Active, Remote Ready/Active) through the application program logic.

### OVR\_PRE %S Reference Not Available

The OVR\_PRE %S reference which indicates whether one or more overrides is active *is not* supported by the Redundancy CPU and should not be used.

## Scan Synchronization

The figure below shows the sweep components for the active and the backup CPUs.



There are two communication points in the sweep. The *first communication point* is immediately after the inputs are scanned. At this point in the sweep the newly-read inputs are sent from the active CPU to the backup CPU and synchronization information is passed. In the *second communication point*, the rest of the data (outputs, internal references, registers) is sent from the active PLC to the backup. These data transfers are automatic; they require no application program logic (but **do** require proper configuration).

Data can be transferred on either Redundancy Communications Module link. If one link fails, the transfer switches to the other link without causing a loss of synchronization.

## Input Data and Synchronization Data Transfer to the Backup Unit

Immediately after the Input Scan, the active unit sends the selected input data (%I, %AI) to the backup unit. For discrete data, the status, override, and transition information is transferred. If point faults are configured, point fault data is also sent.

The data is transferred in blocks. Each block is checked for data integrity. The backup CPU holds the transferred data in a temporary area until all the data has been received and verified. Then the backup CPU copies the data into the actual PLC memories. If the full transfer fails to complete properly, the backup unit disregards the data in the temporary area and instead uses the values it obtained during its own input scan.

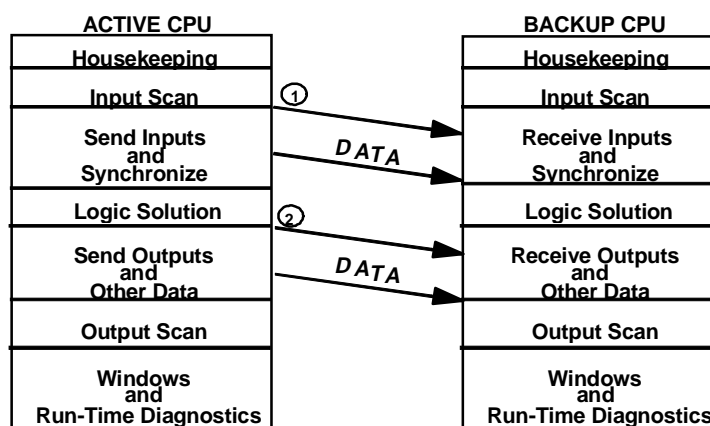
## Sweep Time Synchronization

During the first transfer, the active unit automatically sends a synchronizing message to the backup unit. This message contains the Start of Sweep Time. The CPUs stay synchronized because the active unit waits for the backup CPU to respond to the synchronizing message before starting its sweep.

The Start of Sweep Time message transfer repeatedly coordinates the elapsed time clocks (upon which timers are based) in the redundant CPUs. The system time is continuous as long as one of the two systems is running. When a switchover occurs, the same time continues to be kept in the new active unit.

## Output Data Transfer to the Backup Unit

After the initial data transfer, both CPUs operate independently until the end of the program logic solution. Before the output scan starts, a second automatic data transfer occurs. In this time, the active unit transfers the selected control and output data to the backup unit. This includes the %Q, %AQ, %R, and %M memories. For discrete data, the status, override, and transition information is transferred. If point faults are configured, point fault data is also sent.



- ① First Data Transfer Occurs: %I, %AI
- ② Second Data Transfer Occurs: %Q, %AQ, %R, %M

The data is transferred in blocks. Each block is checked for data integrity. The backup CPU holds the transferred data a temporary area until all the data has been received and verified. Then the backup CPU copies the data into the actual PLC memories. If the full transfer fails to complete properly, the backup unit disregards the data in the temporary area and instead uses the values it obtained during its own logic solution.

After the second data transfer, the active and the backup CPUs independently perform their output scans and run their programmer and system communication windows. They continue to operate independently until they synchronize again after the next input scan.

## Data Transfer Time

When a system is synchronized, there are additions to the sweep time (compared to a similar non-redundant CPU model) for synchronization activities and for transferring data from the one unit to the other. The amount of time for transferring data depends on the type and amount of data transferred. These additions are shown in the following tables.

Transfer times can vary slightly based on length of transfer or combinations of reference types; most systems will see slightly better performance than that listed here.

**Transfer Time Table for Redundancy CPU - IC697CGR935**

Synchronized base sweep addition	4.7 ms
Transfer of data from active to backup with point faults disabled Discrete References (%I, %M, %Q) Registers (%R, %AI, %AQ)	1.5 ms / 1K references (bits) 4.2 ms / 1K registers (words)
Transfer of data from active to backup with point faults enabled Discrete I/O References (%I, %Q) Other Discrete References (%M) I/O Registers (%AI, %AQ) Other Registers (%R)	1.7 ms / 1K references 1.5 ms / 1K references 6.2 ms / 1K registers 4.2 ms / 1K registers

**Transfer Time Table for Redundancy CPU - IC697CGR772**

Synchronized base sweep addition	5.9 ms
Transfer of data from active to backup with point faults disabled Discrete References (%I, %M, %Q) Registers (%R, %AI, %AQ)	1.5 ms / 1K references (bits) 4.6 ms / 1K registers (words)
Transfer of data from active to backup with point faults enabled Discrete I/O References (%I, %Q) Other Discrete References (%M) I/O Registers (%AI, %AQ) Other Registers (%R)	1.7 ms / 1K references 1.5 ms / 1K references 6.7 ms / 1K registers 4.6 ms / 1K registers

The configuration of the background window time defaults to 5 ms for redundant CPU models. This must be added to the base sweep time unless a different value is configured.

## Fail Wait Time

The active and backup CPUs synchronize their execution twice each sweep: once before logic execution and once afterwards. Certain failures of one CPU such as power failure are detected by the remote CPU as a failure to reach the synchronization point on time. The maximum time to wait for the remote CPU is known as the *Fail Wait* time. The duration of this time must be specified during configuration of both the Primary and Secondary Units and can range from 60 ms to 400 ms (in increments of 10 ms), with the default being 60 ms.

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The configured Fail Wait time for the system must be based on the maximum expected or allowable difference in the two CPUs reaching a synchronization point. For example, if one CPU might spend 20ms in the communications phase of the sweep and the other unit might spend 95ms in communications in the same sweep, the Fail Wait time must be set to at least 80ms ( $80 > 95 - 20$ ) to prevent accidental loss of synchronization. Differences in the logic execution window or other phases must also be considered when selecting a Fail Wait time. Some applications limit the possible difference during the communications window by using Constant Sweep mode or Constant Window mode, or by setting the system communications window to LIMITED and selecting a small window time.



## Programming a Data Transfer from Backup Unit to Active Unit

Optionally, the program logic can be used in both CPUs to transfer eight bytes (4 registers) of data from the backup unit to the active unit before the next logic solution.

To initiate this transfer, the backup unit executes SVCREQ #27 (Write to Reverse Transfer Area). This command copies eight bytes of data from the reference in the backup unit specified by the PARM parameter. Note that SVCREQ #27 only works when its CPU is the backup unit. When its CPU is the active unit, SVCREQ #27 has no effect.

The active unit stores the transferred data in a temporary buffer. The program in the active unit must include SVCREQ #28 (Read from Reverse Transfer Area), which copies the eight bytes of data from the temporary buffer to the reference specified by the PARM parameter. SVCREQ #28 only works in the active unit. It has no effect when its CPU is the backup unit.

There is always a one-sweep delay between sending data from the backup unit using SVCREQ #27 and reading the data at the active unit using SVCREQ #28.

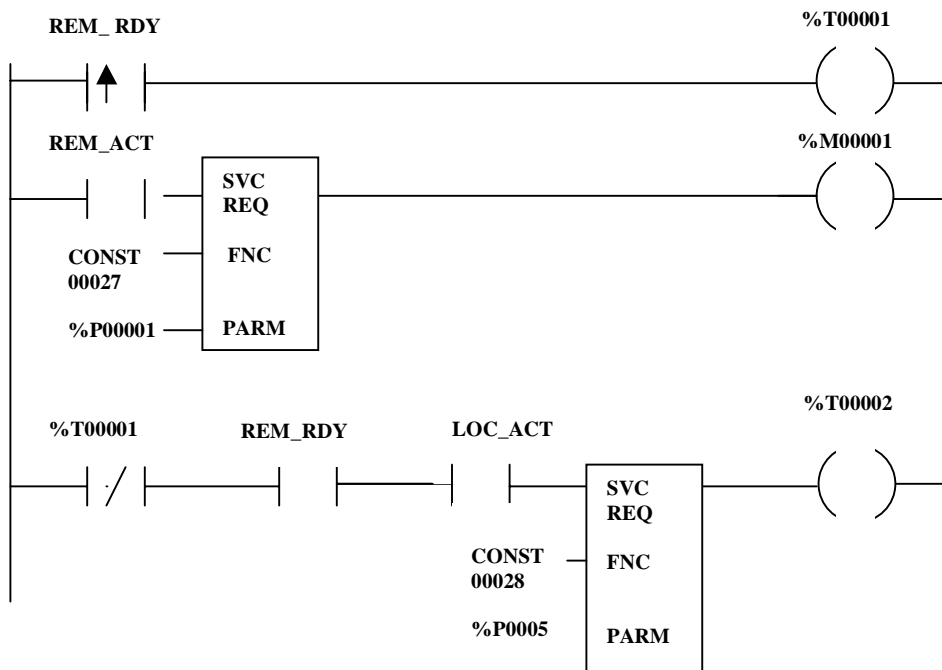
This data copied from the buffer is not valid in the following cases:

- during the first scan after either unit has transitioned to RUN;
- while the backup unit is in STOP mode;
- if the backup unit does not issue SVCREQ #27.

The data should not be used if REM\_RDY is off or if REM\_RDY is transitioning to on.

### Data Transfer Example

The following rungs would be placed in the program logic of both units. In this example, the backup unit would send %P0001 through %P0004 to the active unit. The active unit would read the data into %P0005 through %P0008. %P0001 through %P0004 on the active unit and %P0005 through %P0008 on the backup unit would not change. %T0002 would be set to indicate that the operation was successful and that the data could be used.



## Disabling Data Transfer Copy in Backup Unit (SVCREQ #43)

Service Request function block #43 can be used on the backup to allow the backup unit to bypass the copy of the shared I/O data from the active unit. This function can be used to help determine if the active and backup CPUs are arriving at the same results.

This function is useful only when issued in the backup CPU. It is ignored if issued when the units are not synchronized, or if it is issued in the active unit.

SVCREQ #43 disables the copy of data for 1 sweep beginning with the output data transfer and ending with the input data transfer of the next sweep. The copy can be disabled for multiple sweeps by invoking SVCREQ #43 once each sweep for the appropriate number of sweeps.

The special resynchronization data transfer always occurs, even if SVCREQ #43 is invoked in the first sweep after synchronization (this data transfer includes all shared inputs, all shared outputs, and internal data which must be exchanged) since the resynchronization data transfer occurs before the start of logic execution.

This function can be set up to disable the copies for all transfers or just the output transfers. If just the output copy is disabled, the two units can still use the same set of inputs on each unit. This makes it possible to test the ability of the two units to derive the same results from the same inputs.

In all cases, the configured data transfers are still transferred over the Redundancy Communications Module / Bus Transmitter Module link every sweep and the rendezvous points are still met. The effect of SVCREQ #43 is to disable the copy of the data from the transfer to the actual reference memories configured.

### Warning

**When SVCREQ #43 is in effect, the backup unit will still take control of the system in event of a failure or role switch. Switches to the backup unit may cause a glitch (momentary interruption of data) of the outputs since the two units may not be generating the exact same results.**

Consider disabling outputs on the backup unit while SVCREQ #43 is in effect. Disabling outputs on the backup unit eliminates the risk of an unsynchronized switch of control (which can cause a glitch in the outputs) if the active unit fails or loses power while the input/output copies are disabled. However, if the active unit does fail or loses power while outputs are disabled on the backup unit, the system's outputs will go to their default settings. A secondary effect of disabling outputs on the backup unit is that the unsynchronized fault action table is used by the active unit to determine which faults are fatal.

### Note

If the CPU is already in RUN/ENABLED mode, a command to disable its outputs will not take effect until one sweep after the command is received. Therefore, disable the outputs at least one sweep before you enable SVCREQ #43.

SVCREQ #43 can be used with both the GHS and the GDB Control Strategies. However, with the GDB Control Strategy, it cannot be used to disable output data transfer on the Primary unit when outputs are enabled on the Primary Unit. If that is attempted, the function block is rejected.

A fault is logged the first time SVCREQ #43 is used as a warning that the PLCs are not completely synchronized.

The reverse data transfer, if any, is unaffected by this function block.

Enabling logic should be used with SVCREQ #43. A contact with a non-transferred reference should be part of this enabling logic. That will allow the function block to be turned on/off directly without being overwritten by the value from the active unit.

If the function block is invoked multiple times in a single sweep, the last call is the one that determines the action taken.

## Command Block for SVCREQ #43

The command block for the Disable Data Transfer Copy service request function block (SVCREQ #43) is as follows:

Format	Address
Disable Copies Selection	Address +2

The first parameter is a word that represents the input parameter format for this Service Request. It must be set to 0.

The second parameter is the word that specifies which data transfers to disable: Input and Output or Output only. The valid values are:

Disable input and output copies	1
Disable output copy only	2

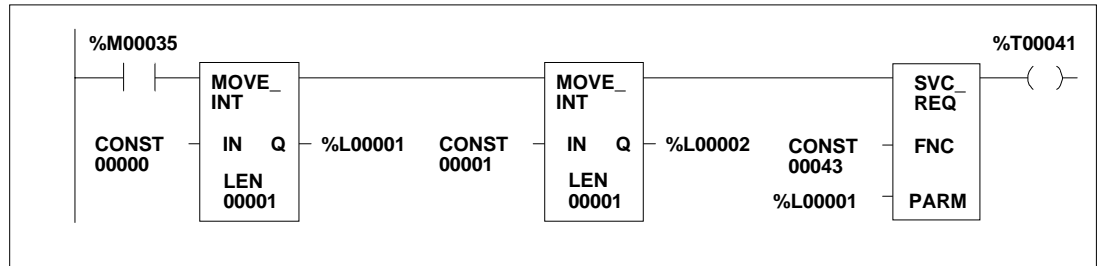
Successful execution occurs unless:

1. The Format parameter is non-zero
2. The Disable Copies Selection parameter is neither 1 nor 2.
3. The function block was invoked when the two units in a redundant system were not synchronized.
4. The function block was issued on the active unit.
5. The CPU does not support the function block

Unsuccessful execution will not turn on power flow for the function block.

## Example

In the following example, when %M00035 is on, the input and output copies are disabled.



## Backup Qualification with SVCREQ #43

Service Request function block #43 can be used to help determine if the backup PLC unit is collecting inputs properly (that is, validate the input scan). It can also be used to help determine whether the backup PLC unit is calculating outputs and internal variables properly (that is, validate the logic solution). Instructions are given below.

### Validating the Backup PLC's Input Scan

To determine whether the backup PLC is collecting inputs properly, follow these steps:

1. Activate SVCREQ #43 on the backup CPU, passing "0, 1" to disable the input and output data transfer copies.
2. Observe the backup unit's %I and %AI reference tables. The values in these tables correspond to the inputs that the backup is currently collecting.
3. Visually compare the backup unit's %I and %AI reference tables with the active unit's tables. Pay special attention to the %I and %AI references that are configured to be shared between the two units.
4. When you are satisfied that the backup unit is collecting inputs properly, disable the rung that calls SVCREQ #43.

### Validating the Backup PLC's Logic Solution

To determine whether the backup PLC is calculating outputs and internal variables properly, follow these steps:

1. Activate SVCREQ #43 on the backup CPU, passing "0, 2" to disable the output data transfer copy.
2. Observe the backup unit's %Q, %AQ, %M, and %R reference tables. The values in these tables correspond to the inputs that the backup is currently calculating.
3. Visually compare the backup unit's %Q, %AQ, %M, and %R reference tables with the active unit's tables. Pay special attention to the %Q, %AQ, %M, and %R references that are configured to be shared between the two units.
4. When you are satisfied that the backup unit is calculating outputs and internal variables properly, disable the rung that calls SVCREQ #43.

## Switching Control to the Backup Unit

Control switches from the active unit to the backup unit if:

1. the active unit has a failure;
2. the pushbutton switch on the Redundancy Communications Module is pressed;
3. a switch is commanded from the application program.
4. the active unit is placed in Stop mode or powered off.

### Switching Times

The amount of time needed to switch control from the active unit to the backup unit depends on the reason for the switch.

If the active PLC CPU fails or loses power, switching occurs after the backup unit determines that the active unit failed to rendezvous at the synchronization point. Failure to rendezvous may take up to 2 failwait timeouts (one for each link) to determine. Control does not transfer until both Redundancy Communications links have been tried unsuccessfully.

If the RCM switch is pressed, or if the application program commands a role switch (see below) or if the CPU detects a fault, the switch occurs at the start of the next sweep. The delay is up to 1 sweep. There may be an input and an output scan after fault detection. A control takeover due to failure or loss of power can occur at any time. However, a manual role switch may not occur within 10 seconds of a previous manual role switch.

### Commanding a Role Switch from the Application Program (SVCREQ #26)

The application program can use SVCREQ #26 to command a role switch between the redundant CPUs (active to backup *and* backup to active). The switch occurs on the next sweep if the units are synchronized.

When SVCREQ #26 receives power flow to its enable input, the PLC is requested to perform a role switch. Power flow from SVCREQ #26 indicates that a role switch will be attempted on the next sweep. Power flow *does not* indicate that a role switch has occurred or that a role switch will definitely occur on the next sweep. The 10-second limitation allows these SVC\_REQs to be in both units such that only a single switch occurs if the request is made by both units at approximately the same time. The PARM parameter is ignored by SVC\_REQ #26; however the programming software requires that an entry be made for PARM. You can enter any appropriate reference here; it will not be used.

### Example

In this example application, a switch on a control console is wired to input %I0001. In the program logic, the reference for %I0001 is used as the input to the SVCREQ #26 function block. When the switch is closed, logic power flows to SVCREQ #26, causing a role switch between the units.



# RUN Disabled Mode

RUN/DISABLED mode causes all physical outputs to go to their default state in that PLC. Inputs are still scanned and logic is solved. A CPU in RUN/DISABLED mode *may be* the active unit.

## RUN Disabled Mode for GHS Control Strategy

There are several guidelines for using RUN/DISABLED mode when using the GHS Control Strategy.

1. If a unit is in RUN/DISABLED mode, its LOC\_RDY %S reference and the remote unit's REM\_RDY %S reference are not set and the corresponding LEDs on the Redundancy Communications Modules are OFF. This indicates that the unit (with LOC\_RDY reference off) is not available to drive outputs.
2. You cannot command a role switch from an active unit that is in RUN/ENABLED mode to a unit that is in RUN/DISABLED mode. The Redundancy Communication Module role switch pushbutton and SVCREQ #26 are ignored if a role switch is attempted in this situation.
3. If the units are transitioned so that the Primary Unit is active with outputs disabled and the Secondary Unit is the backup with outputs enabled, the Primary Unit continues to solve logic and transfer outputs to the backup, and the backup unit drives the transferred outputs.
4. If units are transitioned in any manner where the Secondary Unit is active with outputs disabled and the Primary Unit is the backup with outputs enabled, the units automatically switch roles, so that Primary Unit becomes active in RUN/ENABLED mode.
5. If a unit is in RUN/ENABLED mode and the other unit is in RUN/DISABLED, the unit in RUN/ENABLED does not use its synchronized fault action table. Instead, it uses the user-configurable fault actions since there is no backup available to drive outputs.

**Note**

If the backup unit is in RUN/DISABLED mode, the backup unit continues to NOT drive outputs upon failure of the active unit and *therefore is not a true backup.*

### Example 1: Role switches allowed on both units

	Primary Unit	Secondary Unit
<b>Role</b>	Active	Backup
<b>Operating Mode</b>	RUN/ENABLED	RUN/ENABLED
<b>OK LED on RCM</b>	ON	ON
<b>LOC_RDY LED on RCM and %S Bit</b>	ON	ON
<b>LOC_ACT LED on RCM and %S Bit</b>	ON	OFF
<b>REM_RDY LED on RCM and %S Bit</b>	ON	ON
<b>REM_ACT LED on RCM and %S Bit</b>	OFF	ON

### Example 2: Role switches allowed on both units

The Secondary unit drives the outputs in this example.

	Primary Unit	Secondary Unit
<b>Role</b>	Active	Backup
<b>Operating Mode</b>	RUN/DISABLED	RUN/ENABLED
<b>OK LED on RCM</b>	ON	ON
<b>LOC_RDY LED on RCM and %S Bit</b>	OFF	ON
<b>LOC_ACT LED on RCM and %S Bit</b>	ON	OFF
<b>REM_RDY LED on RCM and %S Bit</b>	ON	OFF
<b>REM_ACT LED on RCM and %S Bit</b>	OFF	ON

### Example 3: Role switches not allowed on either unit

	Primary Unit	Secondary Unit
<b>Role</b>	Active	Backup
<b>Operating Mode</b>	RUN/ENABLED	RUN/DISABLED
<b>OK LED on RCM</b>	ON	ON
<b>LOC_RDY LED on RCM and %S Bit</b>	ON	OFF
<b>LOC_ACT LED on RCM and %S Bit</b>	ON	OFF
<b>REM_RDY LED on RCM and %S Bit</b>	OFF	ON
<b>REM_ACT LED on RCM and %S Bit</b>	OFF	ON

### Example 4: Role switches allowed on both units

	Primary Unit	Secondary Unit
<b>Role</b>	Active	Backup
<b>Operating Mode</b>	RUN/DISABLED	RUN/DISABLED
<b>OK LED on RCM</b>	ON	ON
<b>LOC_RDY LED on RCM and %S Bit</b>	OFF	OFF
<b>LOC_ACT LED on RCM and %S Bit</b>	ON	OFF
<b>REM_RDY LED on RCM and %S Bit</b>	OFF	OFF
<b>REM_ACT LED on RCM and %S Bit</b>	OFF	ON

### Example 5: Role switches allowed on both units Secondary Unit Active

**Note:** Secondary unit *active* is not a recommended mode of operation when using the GHS Control Strategy.

	Primary Unit	Secondary Unit
<b>Role</b>	Backup	Active
<b>Operating Mode</b>	RUN/ENABLED	RUN/ENABLED
<b>OK LED on RCM</b>	ON	ON
<b>LOC_RDY LED on RCM and %S Bit</b>	ON	ON
<b>LOC_ACT LED on RCM and %S Bit</b>	OFF	ON
<b>REM_RDY LED on RCM and %S Bit</b>	ON	ON
<b>REM_ACT LED on RCM and %S Bit</b>	ON	OFF

### Example 6: Role switches not allowed on either unit, Secondary Unit Active

**Note:** Secondary unit *active* is not a recommended mode of operation when using the GHS Control Strategy.

	Primary Unit	Secondary Unit
<b>Role</b>	Backup	Active
<b>Operating Mode</b>	RUN/DISABLED	RUN/ENABLED
<b>OK LED on RCM</b>	ON	ON
<b>LOC_RDY LED on RCM and %S Bit</b>	OFF	ON
<b>LOC_ACT LED on RCM and %S Bit</b>	OFF	ON
<b>REM_RDY LED on RCM and %S Bit</b>	ON	OFF
<b>REM_ACT LED on RCM and %S Bit</b>	ON	OFF

### Example 7: Role switches allowed on both units, Secondary Unit Active

**Note:** Secondary unit *active* is not a recommended mode of operation when using the GHS Control Strategy.

	Primary Unit	Secondary Unit
<b>Role</b>	Backup	Active
<b>Operating Mode</b>	RUN/DISABLED	RUN/DISABLED
<b>OK LED on RCM</b>	ON	ON
<b>LOC_RDY LED on RCM and %S Bit</b>	OFF	OFF
<b>LOC_ACT LED on RCM and %S Bit</b>	OFF	ON
<b>REM_RDY LED on RCM and %S Bit</b>	OFF	OFF
<b>REM_ACT LED on RCM and %S Bit</b>	ON	OFF



## Example 8: Invalid

The following situation is not valid. If detected, the units switch roles automatically and behave as in Example 3 above.

	<b>Primary Unit</b>	<b>Secondary Unit</b>
<b>Role</b>	Backup	Active
<b>Operating Mode</b>	RUN/ENABLED	RUN/DISABLED

## RUN Disabled Mode for GDB Control Strategy

The following guidelines apply to using RUN/DISABLED mode with the GDB Control Strategy.

1. If a unit is in RUN/DISABLED mode, its LOC\_RDY %S reference and the remote unit's REM\_RDY %S reference are not set and the corresponding LEDs on the Redundancy Communications Modules are OFF. This indicates that the unit (with LOC\_RDY reference off) is not available to drive outputs.
2. If a unit is in RUN/ENABLED mode and the other unit is in RUN/DISABLED mode, the unit in RUN/ENABLED mode does not use its synchronized fault action table. Instead, it uses the user-configurable fault actions since there is no backup available to drive outputs.
3. Since redundant outputs must always be transferred from the active unit to the backup unit when using the GDB control strategy, if outputs are enabled on either unit, the outputs of the active unit are driven by the Genius I/O blocks.

### Note

If the backup unit is in RUN/DISABLED mode, the backup unit continues NOT to drive outputs upon failure of the active unit and *therefore is not a true backup*.

# Background User Checksum and Background Window Timing Instructions

Performing User program Checksum verification and Background Window Diagnostics adds time to the sweep; the more checksums and diagnostics that are performed each sweep, the longer the sweep will take. For example, setting the Words to Checksum to 216 adds about 0.6 ms to each sweep in a CGR935 (216 words x 2 bytes/word x 0.0014 ms/byte = 0.6 ms).

For users wanting to compare Program Checksum verification and Background Window Diagnostics within a set amount of time (for example, 60 seconds), the following formula can be used to estimate the necessary settings for Words to Checksum and Background Window Time. These calculations can be used for Normal Sweep mode or Constant Window mode. They are not valid for Constant Sweep mode.

## Finding the Words to Checksum Each Sweep

First, you should determine the number of words to checksum each sweep.

$$\text{Words per Sweep} = \frac{\text{Program Size} \times \text{Sweep Time}}{[\text{Max. Completion Time} - (\text{Program Size} \times F) - C] \times 2}$$

Where:

- *Words per Sweep*: The number of words to set in the PLC Configuration to be checksummed each sweep. The number calculated must be rounded up to the next number divisible by 8 (8, 16, 24, etc.).
- *Program Size*: The sum of the sizes of the user programs in bytes. If there is a ladder logic program, add 11,000 bytes to account for internal memory usage that is not included in the user program memory displayed by the programmer. The 11,000 bytes is an approximate number typical for most LD programs. If a more accurate number is desired, use the file size of the \_main.dec file instead of the 11,000. The \_main.dec file can be found on disk inside of your folder's directory structure.
- *Sweep Time*: The sweep time in milliseconds when the number of checksum words is set to zero and the Background Window timer is set to zero.
- *Maximum Completion Time*: The amount of time in milliseconds that you want to have full coverage of these diagnostics. For example, 1 minute is 60,000ms.
- *F*: the number of milliseconds per byte of program checksummed (see following table).
- *C*: the total time in milliseconds needed to perform background diagnostics (see following table).

	<b>CGR772</b>	<b>CGR935</b>
Milliseconds per byte of program checksummed (F)	.0064 ms/byte	.0014 ms/byte
Time to perform Background Diagnostics (C)	3479 ms	376 ms

### Example

The example below calculates Words per Sweep for a CGR935. It uses the following data:

User Program Size = 239000  
 Program Size = User Program Size + 11000 = 239000 + 11000 = 250000 bytes  
 Sweep Time = 100 ms  
 Max Completion Time = 60000 (1 minute)

$$\text{Words per Sweep} = \frac{250000 \times 100}{[60000 - (250000 \times 0.0014) - 376] \times 2} = 208.4$$

**Words per Sweep = 216 (rounded up to next number divisible by 8)**

### Finding the Background Window Time

Next, use the calculated Words per Sweep in the following formula to determine how long to set the background window time.

$$\text{Background Window Time} = \frac{C \times (\text{Sweep Time} + \text{Words per Sweep} \times F \times 2)}{(\text{Max. Completion Time} - C)}$$

Here, the background window time is the time in milliseconds that you should set the background window timer. The other elements in the formula are described above. For our example, the background window time is:

$$\text{Background Window Time} = \frac{376 \times (100 + 216 \times 0.0014 \times 2)}{(60000 - 376)} = 0.63\text{ms}$$

**Background Window Time = 1ms (rounded up to next ms)**

### Finding the Total Sweep Time

The final sweep time can therefore be estimated to be:

$$\text{Final Sweep Time} = \text{Sweep Time} + (\text{Words per Sweep} \times F \times 2) + \text{Background Window Time}$$

For our example, the sweep time is:

$$\text{Final Sweep Time} = 100 + (216 \times 0.0014 \times 2) + 1 = 101.6\text{ms}$$

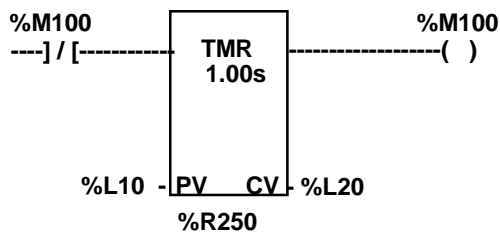
## Miscellaneous Operation Information

### Timer and PID Function Blocks

Timer and PID function blocks remain in lock step between two synchronized units provided:

- A. Enabling logic is identical on both units. This includes power flow, frequency of calling sub-block, and so forth.
- B. The sub-block in which the function block occurs has the same name in both units. Note that `_MAIN` is always common.
- C. Reference registers (3 for timers, 40 for PID) and reset references for each timer and PID function block are included in the data transfer lists.

For example, if the following ladder logic is identical in sub-blocks on both units, `%M100`, `%R250`, `%R251`, and `%R252` must all be transferred on resynchronization to keep both units running timers synchronously:



### Timed Contacts

When both systems are synchronized, timed contacts (`%S3`, `%S4`, `%S5`, `%S6`) have exactly the same value in both units. For example, whenever `T_SEC` is on in one unit, it also is on in the other unit as long as both units are synchronized.

### Multiple I/O Scan Sets

I/O scan sets are configured by editing the CPU Hardware Configuration using Control software. Refer to the Control online Help system for detailed information on configuration of I/O scan sets. Control programming software Release 2.00 or later is required to configure this feature.

The Redundancy CPU supports the configuration of multiple scan sets. However, it is strongly recommended that the redundant I/O be configured in the default scan set (Scan set 1) which is scanned every sweep. The I/O scan set feature allows the scanning of I/O points to be more closely scheduled with its use in user logic programs.

I/O Scan sets that are not scanned every sweep are not guaranteed to be scanned in the same sweep in the Primary and Secondary CPUs. For example, if the Primary and Secondary CPUs each have

a scan set that is scanned every other sweep (that is, PERIOD=2), then the Primary CPU might scan its scan set in one sweep and the Secondary CPU scan its scan set in the next.

Use of non-default scan sets can cause variance in the time the units get to the rendezvous points. This should be considered when determining the failwait time.

## C Debugger

The Embedded C debugger may be used for debugging Standalone C programs and EXE blocks. Use of the embedded C debugger in a Redundancy CPU is limited to when the system is not synchronized. The CPU will reject any attempt to establish a debugger session while the units are synchronized. If the debugger is active on one unit while the two units are not synchronized, then any attempt to synchronize the two units will fail. Specifically, if the unit in RUN mode has a debugger session active and the other unit is commanded to go to RUN mode, the unit commanded to go to RUN will log a fault and go to STOP/FAULT mode.

## STOP to RUN Mode Transition

A resynchronization will occur at all *STOP* to *RUN* mode transitions. The time to perform this resynchronization may be larger than *STOP* to *RUN* transitions on non-redundancy CPUs. The *STOP* to *RUN* mode transition has two separate paths.

1. If the CPU performing the transition is doing so alone or both CPUs are transitioning at the same time, then a normal *STOP* to *RUN* mode transition is performed (clear non-retentive memory and initialize FST\_SCN and FST\_EXE).
2. If the other CPU is active when this CPU performs a *STOP* to *RUN* mode transition, then non-retentive references will be cleared followed by a resynchronization with the active CPU.

## Background Window Time

In a redundancy system, this value may be set to zero. Unlike other CPU models which have a default of 0mS, the default value for the Redundancy CPU is 5ms.

Setting the background window time to zero disables the verification of the Series 90-70 CPU operating system software and the CPU self-tests.

## Sequential Function Chart Programming (SFC)

SFC Program Blocks can be used in the program logic. However, the redundant CPU system will not attempt to coordinate and synchronize the execution of the SFC charts between the two CPUs. For example, if one of the units is in Run mode at the time the other is placed in Run mode, the running unit will typically be in the middle of its chart, and the transitioning unit will typically be at the beginning of its chart. As a result, the SFC state and paths taken by the two CPUs will be different and the backup unit will not be able to take over exactly where the active unit left off.

## Genius Bus Controller Switching

Genius Bus Controllers stop sending outputs to Genius I/O blocks when no output data has been received from the PLC CPU for a period equal to two times the configured watchdog timeout.

If the CPU in the Primary Unit becomes inoperative in an uncontrolled fashion (for example, because of a power failure), the Genius Bus Controllers detect this within twice the watchdog setting, and stop sending outputs to the Genius blocks. After three Genius I/O bus scans of not receiving data from the Genius Bus Controllers at Serial Bus Address 31, the Genius blocks start driving data from Serial Bus Address 30 (the Secondary Unit) if available.

For example, if the system has a 200ms watchdog timeout and 5ms Genius bus scan time, and the Primary Unit main rack loses power, the Genius Bus Controllers in expansion racks will wait 400ms and then stop updating outputs on Genius blocks. After 15ms, the blocks will begin driving outputs based on data from the Secondary Unit. Note that any Genius Bus Controllers in the main rack would stop driving outputs immediately since they would also lose power. Genius blocks on these busses would begin driving data from the Secondary Unit within 15ms.

### Note

For the GHS Control Strategy, if the Secondary Unit is the active unit, outputs are disabled in the Primary Unit. Outputs from Serial Bus Address 31 are not immediately available in this case. Therefore, the outputs could go temporarily to their default state on failure of the Secondary Unit. For this reason, the Primary Unit should normally be selected as the active unit when using the GHS Control Strategy.

### Note

For fastest switching, all Genius Bus Controllers in the Hot Standby CPU Redundancy system should be in the main rack, or in a rack driven by the main rack's power supply. This causes the Genius Bus Controller to lose power at the same time that the CPU loses power. This, in turn, allows the backup unit to gain full control of the I/O as soon as possible.

For single bus Genius networks, if outputs are not available on Serial Bus Address 30 or 31, then the block's outputs revert to default or hold last state (as configured).

For dual bus networks, if outputs are not available on Serial Bus Address 30 or 31, then the BSM will switch to the other bus. If outputs are not available on either bus, then the block's outputs revert to default or hold last state (as configured).

## Ethernet Global Data in a Redundancy CPU

Ethernet Global Data is enhanced to provide optimal use with Redundancy CPUs. Configuration of Ethernet Global Data requires the use of Control Programming software, release 2.1 or later.

### Ethernet Global Data Consumption

Either or both of the PLC units in a synchronized system can consume Ethernet Global Data. Consumption by individual units requires separate Ethernet Global Data configurations for the two units and therefore separate folders. If an exchange should be consumed by both units in a redundant system, the exchange must be multicast and the exchange must be configured to be consumed in each of the two units.

A single folder may be used for Ethernet Global Data configuration if there are no exchanges consumed or produced only by one of the two units.

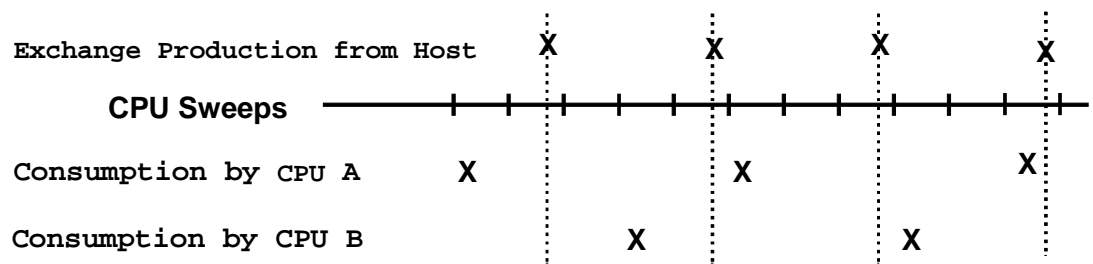
Consumption of configured Ethernet Global Data exchanges occurs in RUN mode regardless of the Active/Backup state of the CPU and regardless of whether or not the units are synchronized.

The consumption of the Ethernet Global Data exchanges occurs independently on the two CPUs even when the same exchange is consumed in both units. The Ethernet modules obtain a copy of multicast exchanges at the same time, but polling of the exchange in the two CPUs may be phased by one or more sweeps. This can result in the two units seeing different values for the same exchange in a given sweep.

For example, an exchange might be consumed by the CPUs at a rate of 500ms. If the CPUs had a sweep time of 100ms, the same exchange might be seen 400ms later in one CPU than in the other. It may or may not be from the same exchange produced by the host.

### Example

The diagram below shows an example with a sweep time of 100ms and an exchange that is produced every 300ms and consumed every 500ms.



If data from the exchanges must be seen identically on the two units, the reference data for the exchanges can be transferred from the active unit to the backup unit during the input data transfer. That transfer occurs shortly after the Ethernet Global Data consumption portion of the CPU sweep. Exchange variables transferred must be placed into %I or %AI memory to participate in the input data transfer.

## Ethernet Global Data Production

When the two units of a CPU Redundancy system are synchronized, Ethernet Global Data exchanges are produced only by the active unit. This reduces the amount of traffic on the Ethernet network and simplifies the handling of the exchange by the consumer. In particular, the consumer is able to consume the exchanges in the same way as for exchanges from non-redundant systems.

If the exchanges are to be produced by both units, the units must be configured to have the same producer ID. This way, the consumer does not need to know which unit is producing the exchanges. The configuration of unique production exchanges for the two units is not recommended since the exchanges would only be produced when the unit was active and not when it was backup.

If a unit stops being the active unit, it stops producing Ethernet Global Data exchanges so that the other unit can start producing the EGD exchanges. The new active unit, if any, delays starting production of Ethernet Global Data exchanges long enough to let the other unit stop producing. This is necessary so that both units are not producing Ethernet Global Data exchanges at the same time. That could become confusing to the consumer.

The following formula gives the maximum time after a unit becomes the active unit before it starts producing a given Ethernet Global Data exchange. Note that in certain failure conditions, it may take up to 1 sweep + 2 failwait timeouts for the backup unit to detect the failure of the active unit so that it can become the active unit.

Software Watchdog Timeout +  
1 Network Production Period for the Exchange +  
2 CPU Sweeps +  
220 ms

If both communications links between the Redundancy Communications Modules and Bus Transmitter Modules fail, both units are marked as Active Units and attempt to produce Ethernet Global Data exchanges. If the application cannot tolerate this situation, then it must detect that both units are active and shut down one of the units with a service request function block or other means. The program logic can detect this by sending a running counter from one unit to the other via discrete I/O modules or other means and then checking if the counter still increments after both links have been lost.

If outputs are disabled on the active unit, neither unit produces Ethernet Global Data.

## SNTP Timestamping

Ethernet Global Data exchanges can be timestamped using either the PLC CPU's local clock or using a *Simple Network Time Protocol* (SNTP) clock from a user-provided server on the Ethernet network. SNTP clock timestamping for a given Ethernet Global Data exchange is selected by enabling timestamp synchronization in the configuration of the corresponding Ethernet module. If timestamp synchronization is disabled for a given Ethernet module, then Ethernet Global Data exchanges produced by that module are timestamped with the PLC CPU's local clock.



# Chapter 5

## *Fault Detection*

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This chapter describes how faults are handled in a Redundancy system.

- Configuration of Fault Actions
- Fault Detection
- Fault Response
- Faulting RCMs, Losing Links, and Terminating Communications
- Fault Actions in a CPU Redundancy System
- Online Repair

## Configuration of Fault Actions

Whenever the system is synchronized with a backup unit available, the decision as to which faults are FATAL and therefore will cause a switch to the backup CPU are made by the operating system and are not configurable. However, you can configure whether or not a standalone CPU (after failure of the other CPU) will stop if another fault occurs.

You can select the fault actions (either diagnostic or fatal) for when a given CPU is operating without a backup available. This will allow you to choose between fault tolerant operation and a safety system where a shutdown is preferred. For Control programming software users, refer to the Control Online Help for information on how to select fault actions.

For Logicmaster 90-70 users, fault actions can be viewed and changed during CPU configuration by pressing Fault Category (F5), which will display the Fault Category Configuration screen. To change a fault category, cursor to the category to be changed in the CFG (left) column. Use the Tab key to toggle the entry (D/F) for the fault action. After completing the changes, press the Enter key to save your changes.

Setting fault actions to diagnostic for faults that are fatal in the synchronized case allows for the possibility that a less healthy unit could remain the active unit even after a more healthy backup unit is placed in Run mode. For example, if you were to configure "Loss of or Missing Rack" failures as diagnostic, the following scenario could occur:

1. If an expansion rack fails when the units are synchronized, the unit with the rack failure will transition to STOP/FAULT mode and the other unit will become a stand-alone unit.

2. If an expansion rack fails after a unit becomes a stand-alone unit, a diagnostic fault will be logged on that unit but the unit will stay in RUN mode and continue to control the process.
3. If after the above situation occurs, the other unit transitions to RUN, the unit with the failed expansion rack will stay in RUN mode and may, depending on the configuration, remain in control of the process. You may want to include logic to shut down the faulted unit or request a role switch if this is an undesired operation.

Also, a unit with the fault actions set to diagnostic may be placed in RUN mode and become the active unit even though it may have a diagnostic fault, which would be logged as fatal in a synchronized system.

For example, if an expansion rack fails while in STOP mode or while transitioning to RUN mode, a diagnostic fault is logged; however, the unit will still transition to RUN and may, depending on configuration, become the active unit. You may want to include logic to shut down the faulted unit or request a role switch if this is an undesired operation.

## Fault Detection

The detection of faults and failures falls into three basic categories:

1. faults and failures that are detected immediately
2. faults and failures that are detected as soon as possible, but not necessarily within the current sweep
3. faults and failures that are detected in the background.

Faults and failures that are detected immediately are those that are identified within the current sweep. These faults include I/O data corruption, single bit RAM failures, power supply failures, processor failures, VME bus failures, and no response from an addressed VME module.

Faults and failures that are detected as soon as possible, but not necessarily within the current sweep, include a group of faults that are detected asynchronously to the PLC sweep (Genius faults) or those faults that require a timeout larger than one sweep time to detect the failure. These faults are typically detected within one second and include all Genius faults (circuit faults, loss of block, and so forth).

Faults and failures that are detected in the background will typically be detected within 30 seconds. These faults include address or data line failures, multiple bit RAM failures, firmware failures, and communication device failures.

### Note

The actual time to run all diagnostics tests is determined by configuration parameters as described in Chapter 4. This time might be more or less than 30 seconds.

## PLC Fault Table Messages for Redundancy

The following table lists messages, descriptions, and corrective actions for error codes associated with the redundancy fault group. These error codes can be viewed by selecting Ctrl-F on the corresponding redundancy fault (in Logicmaster 90-70) or double-click on the corresponding fault (in Control). The entire fault data (including these error codes) can also be accessed with a SVC\_REQ and other applications that communicate with the CPU.

<b>Error Code</b>	<b>Message</b>	<b>Fault Description</b>	<b>Corrective Action</b>
1	Primary Unit is Active and Secondary Unit is Backup.	The primary and secondary units have switched roles.	None required.
2	Secondary Unit is Active and Primary Unit is Backup.	The secondary and primary units have switched roles.	None required.
3	Primary Unit is Active; No Backup Unit Available.	The primary unit has transitioned to RUN mode and is running as a stand-alone unit.	Secondary unit <b>MUST</b> be placed in RUN mode with a comparable configuration in order to have a synchronized system.
4	Secondary Unit is Active; No Backup Unit Available.	The secondary unit has transitioned to RUN mode and is running as a stand-alone unit.	Primary unit <b>MUST</b> be placed in RUN mode with a comparable configuration in order to have a synchronized system.
5	Primary Unit Has Failed; Secondary Unit is Active w/o Backup.	Primary unit has recorded a fatal fault, has been powered down, or has lost ability to communicate with the secondary unit while acting as the active or backup unit. Secondary unit will continue running as a stand-alone unit.	If primary unit has also logged the fault "Secondary Unit Has Failed: Primary Unit is Active w/o Backup", then communications has been broken between the two units and must be repaired. If a fatal fault has been logged in the primary unit, the indicated fault must be repaired. Power may have to be cycled on one of the units in order to re-establish communications and return to a synchronized system.
6	Secondary Unit Has Failed; Primary Unit is Active w/o Backup.	Secondary unit has recorded a fatal fault, has been powered down, or has lost ability to communicate with the primary unit while acting as the active or backup unit. The primary unit will continue running as a stand-alone unit.	If secondary unit has also logged the fault "Primary Unit Has Failed: Secondary Unit is Active w/o Backup", then communications has been broken between the two units and must be repaired. If a fatal fault has been logged in the secondary unit, the indicated fault must be repaired. Power may have to be cycled on one of the units in order to re-establish communications and return to a synchronized system.
7	Synchronization Failure; Both Units are Active.	A communications failure between the two units has caused each unit to become stand-alone units. Communications has since been restored.	One of the units should be power cycled to return to a synchronized system. <b>NOTE:</b> The Genius blocks will respond to the unit that is using Serial Bus Address 31.
8	Unable to Switch Redundancy Roles	An attempt to switch redundancy roles was made when it was not possible to perform the switch.	None required.

<b>Error Code</b>	<b>Message</b>	<b>Fault Description</b>	<b>Corrective Action</b>
9	Primary and Secondary Units are Incompatible	The local unit cannot be placed in RUN mode when its redundancy configuration is incompatible with the remote unit. This error is logged when (1) Store of an incompatible configuration is attempted and (2) attempting to synchronize with an incompatible configuration. This error is also logged when the local unit and/or the remote unit has a C debugger session active and the units are attempting to synchronize.	Modify the configuration or terminate the C debugger session.
10	CPU to CPU communications terminated	Synchronization protocol has been violated.	If this fault is also accompanied by an RCM failed fault, replace the failed RCM; otherwise power cycle the CPU or CPUs.
11	Redundant Link has timed out	The RCM has timed out while waiting on communications from the other unit.	Power cycle the back-up CPU (CPU not controlling the process); increase the fail wait time.
12	Units Are Not Fully Synchronized	Due to actions taken by the user, the two units in a CPU redundant system are not fully synchronized. This means the backup unit is not executing with the same inputs and/or outputs as the active unit while the units are synchronized due to data transfers being disabled.	Enable the data transfer copy on the backup unit
>12	CPU Redundancy Status has Changed	A change in the status of the system has occurred.	Corrective action to be taken depends on the error code.

The following table lists messages, descriptions, and corrective actions for error codes associated with redundancy in other fault groups.

<b>Group</b>	<b>Error Code</b>	<b>Message</b>	<b>Fault Description</b>	<b>Corrective Action</b>
Loss of Option Module	57	Redundant link hard failure occurred.	The RCM has been faulted due to an error while accessing memory.	Power cycle the rack with the faulted RCM. If the RCM's BOARD OK LED is on, replace the cable between the RCM and the BTM. If the RCM's BOARD OK LED is off, replace the RCM.
PLC Software	148	Units contain mismatched firmware; update recommended.	The firmware in the redundant CPUs has different revision levels. Having different revisions of firmware in the CPUs is intended for short-term synchronization only as some change in the behavior of the system may be experienced when mixing revisions.	Upgrade the CPUs so that they have the same revision of firmware according to the firmware upgrade procedure.

## Fault Response

The Enhanced Hot Standby CPU Redundancy system detects and reports failures of all critical components so that appropriate control actions may be taken. All components that acquire or distribute I/O data or that are involved in execution of the control logic solution are considered critical components.

In a Redundancy system, fault actions are not configurable as they are in a non-redundancy system. A FATAL fault in the active unit causes a switch of control to the backup unit. A DIAGNOSTIC fault allows the currently-active system to continue operating as the active system.

Faults within the PLC may be such that:

1. the PLC has a controlled shutdown,
2. the PLC has an uncontrolled shutdown, or
3. the PLC continues to operate.

If the PLC detects an internal fault and has a controlled shutdown, a fault is logged in the fault table, the other PLC is notified of the fault, and the faulted PLC goes to stop mode and stops driving outputs. This does not normally occur until the top of the sweep following the failure. The exception is when the failure occurs during the input scan. In that case, upon notification, the backup system immediately takes over and starts driving outputs.

If the PLC has an uncontrolled shutdown, the PLC logs a fault if it can and proceeds as described above. If the backup PLC detects that the active PLC has failed to synchronize, it assumes the active unit has failed after timing out all (both) available links. The backup then starts driving outputs and controlling the process. If a fault exists within the PLC that has not been detected, the system eventually detects the fault through the background diagnostic procedure. When the fault is detected, the PLC proceeds with the orderly shutdown process if it can.

If the two PLCs fail to synchronize, because the timeout is set too short, the two systems start to act independently. A fault is logged at the time synchronization failure occurs.

## Faulting RCMs, Losing Links, and Terminating Communications

There are distinct differences between losing a redundant communications link and faulting an RCM.

### Faulting the Redundancy Communications Module

*Faulting the Redundancy Communications Module* occurs only when a hardware-related failure such as a parity error or VME bus error exists.

The following actions are taken when a Redundancy Communications Module is faulted:

1. Loss of Module fault is logged in the PLC Fault Table.
2. All LEDs on the Redundancy Communications Module are turned OFF. The LEDs on the other Redundancy Communications Module continue to be updated as long as that RCM is OK.
3. The module fault contact is set. If the failed Redundancy Communications Module is in the local main rack, then the SLOT\_0X fault contact is set (X is the slot number for the Redundancy Communications Module). If the failed RCM is in the other unit's main rack, then the SLOT\_71 fault contact is set.
4. The corresponding communications link is no longer used. If the other link is still operating, that link is used for all further data transfer, and the units can remain in synchronization.
5. If no other communications link is available, the unit functions as a standalone unit when in RUN mode.

After replacement of the faulted Redundancy Communications Module, power must be cycled to restore the RCM to service.

### Losing a Link

*Losing a Link* occurs when a link timeout occurs (that is, no data received in the expected time period). Since the system is not certain that a lost link is due to a hardware failure, the Redundancy Communications Module is not faulted. Some possible causes for a link timeout are:

1. Remote unit has failed and is unable to communicate.
2. Configured fail-wait timeout is too short and a long sweep or communications window has resulted in a link timeout. Normally the other link will continue to function in this case and the PLCs remain synchronized. If the condition continues, the remaining communications link will timeout in a subsequent sweep.
3. A hardware problem is present that prevents data from being transferred but is not detectable by error checking mechanisms such as parity errors (there are no known problems in this category).

The following actions are taken when a link has timed out.

1. Link Timeout fault is logged in the PLC Fault Table.
2. The OK and Local LEDs on the Redundancy Communications Module in the RCM to BTM link that failed continue to be maintained (that is, they will stay ON and the Local LEDs reflect the state of the Local unit) but the Remote LEDs are turned OFF. The LEDs on the other RCM continue to be updated as long as that RCM is OK.
3. The module fault contact is set. If the failed link is through the Redundancy Communications Module in the local main rack, then the SLOT\_0X fault contact is set (X is the slot number for the Redundancy Communications Module). If the failed link is through the Redundancy Communications Module in the other unit's main rack, then the SLOT\_71 fault contact is set.
4. The corresponding communications link is no longer used. If the other link is still operating, then that link will be used for all further data transfer and units can remain in synchronization.
5. If no other communications link is available, then the unit functions as a stand-alone unit when in RUN mode.

A power cycle or storing a hardware configuration to either unit is required to restore the link to service. In this case, if the RCM is at fault, it will need to be replaced before power is restored.

## Fault Actions in a CPU Redundancy System

Fault actions in the Hot Standby CPU Redundancy System are handled differently than fault actions in a non-redundant system. Whenever there is a ready backup unit in the system, the fault actions taken are not those normally specified in the configuration.

When the two CPUs are synchronized the following faults are considered FATAL and will cause the affected unit to transition to STOP/FAULT mode.

- any fault that degrades performance
- any fault that causes loss of control of I/O

The configurable fault actions are applied whenever the system is running in stand-alone mode in case you prefer fault tolerance (availability) versus safety (depending on the application).

### Note

In a CPU redundancy system a *Fatal* fault from a Genius Bus Controller causes the active unit to transition to *STOP/FAULT* mode. All *Diagnostic* faults allow the CPU to continue to operate.

## Configurable Faults

The table below shows the configurable faults and their fault action defaults. There are three fault actions: *Fatal*, *Non-Fatal*, and *Conditionally Fatal*. Fatal always stops the PLC, Non-Fatal never stops the PLC and Conditionally Fatal stops the PLC depending on other information in the fault. Note that Non-Fatal and Diagnostic have the same meaning.

Fault Group	Table Type	Description	Not Synchronized Fault Action		Synchronized Fault Action (fixed)
			Default	Configurable	
LOSS_RACK	PLC	Loss of or Missing Rack	Non-Fatal	Yes	Fatal
LOSS_IOC	I/O	Loss of or Missing IOC	Non-Fatal	Yes *	Fatal
LOSS_IO_MOD	I/O	Loss of or Missing I/O Module	Non-Fatal	Yes	Non-Fatal
LOSS_OTHR_MOD	PLC	Loss of or Missing Option Module	Non-Fatal	Yes	Non-Fatal
SYS_BUS_ERROR	PLC	System Bus Error	Fatal	Yes	Fatal
IOC_FAULT	I/O	IOC or I/O Bus Fault	Non-Fatal	Yes	Conditionally Fatal
CNFG_MIS_MTCH	Both	System Configuration Mismatch	Fatal	Yes	Non-Fatal
IOC_SOFTWR	I/O	IOC Software Failure	Fatal	Uses LOSS_IOC setting	Conditionally Fatal

The two fault groups IOC\_FAULT and IOC\_SOFTWR faults are fatal to the system (force the PLC to *STOP FAULT* mode) if the fault is *Fatal* to the Genius Bus Controller that logged the fault. When a module logs a fault it notifies the PLC whether or not it can continue by placing *Fatal* or *Diagnostic* in the fault action of the fault entry. The PLC shuts the Genius Bus Controller down on all *Fatal* faults.

\* Even if the LOSS\_IOC fault is configured as Fatal for non-synchronized operation, the PLC will not go to STOP/FAULT mode unless *both* Genius Bus Controllers of a dual bus pair fail.



## Non-Configurable Fault Group

The table below shows the non-configurable faults and their fault action defaults.

Fault Group	Table Type	Description	Fault Actions	
			Not Synchronized	Synchronized
SYS_BUS_FAIL	PLC	System bus failure.	Fatal	Fatal
NO_USER_PRG	PLC	No User's Program on Power-up.	Non-Fatal	Non-Fatal
BAD_USER_RAM	PLC	Corrupted User RAM detected on Power-up.	Fatal	Fatal
WIND_CMPL_FAIL	PLC	Window Completion Failure in Constant Sweep Mode (i.e., all windows failed to receive their allotted time).	Non-Fatal	Non-Fatal
PASSWD_FAIL	PLC	Password Access Failure.	Non-Fatal	Non-Fatal
NULL_SYS_CNFG	PLC	NULL System Configuration for RUN Mode.	Non-Fatal	Non-Fatal
CPU_SOFTWR	PLC	PLC CPU Software Failure.	Fatal	Fatal
TOO_MANY_IOCS	PLC	More than the allowable number of I/O Bus Controllers were found in the system.	Fatal	Fatal
SEQ_STORE_FAIL	PLC	<i>Communication</i> failure during a store operation by the programmer. This fault results when the start-of-store sequence was received but not an end-of-store sequence.	Fatal	Fatal
ADD_RCK	PLC	Addition of Extra Rack	Non-Fatal	Non-Fatal
ADD_IOC	I/O	Addition of or Extra IOC	Non-Fatal	Non-Fatal
ADD_IO_MOD	I/O	Addition of or Extra I/O Module	Non-Fatal	Non-Fatal
ADD_OTHR_MOD	PLC	Addition of, Reset of, or Extra Option Module	Non-Fatal	Non-Fatal
IO_MOD_FAULT	I/O	I/O Module Fault	Non-Fatal	Non-Fatal
CPU_HARDWR	PLC	CPU Hardware Failure	Fatal	Fatal
MOD_HARDWR	PLC	Module Hardware Failure (for example, Serial Port Failure on PCM)	Non-Fatal	Non-Fatal
MOD_OTHR_SOFTWR	PLC	Option Module Software Failure	Non-Fatal	Non-Fatal
PRG_BLK_CHKSUM	PLC	Program Block Checksum Mismatch	Fatal	Fatal
LOW_BATTERY	PLC	Low Battery in the System	Non-Fatal	Non-Fatal
CNST_SW_EXCD	PLC	Constant Sweep Exceeded	Non-Fatal	Non-Fatal
PLC_FTBL_FULL	PLC	PLC System Fault Table Full	Non-Fatal	Non-Fatal
IO_FTBL_FULL	PLC	I/O Fault Table Full	Non-Fatal	Non-Fatal
APPLICATION_FLT	PLC	User Application Fault	Non-Fatal	Non-Fatal

## Fatal Faults on Both Units in the Same Sweep

It is very unlikely that a fatal fault would occur on both units in the same sweep. If that should happen, however, the CPU will consult the synchronized fault action table for one unit and the not-synchronized fault action table for the other. That will allow one of the units to stay in Run mode when the synchronized fault action is Fatal and the not-synchronized fault action is Non-Fatal.

## On-Line Repair

With a Hot Standby CPU Redundancy system, most system component failures can be repaired by replacing the failed component while the system is online. These online repair procedures are possible because of the role-switching capability of the units in the system. Status of the Primary and Secondary Units is determined by observing the LEDs on the Redundancy Communications Module.

There are two basic situations regarding the active and backup units that you should be aware of when a component needs to be replaced.

1. *If the failure is in the active system*, control switches to the backup system. Power can then be removed from the rack containing the failed component. When the component is replaced, power is restored to the rack, and the CPU is returned to RUN mode, the CPU becomes synchronized with the current active unit.
2. *If the failure is in the backup system*, remove power from the rack containing the failed component and replace the component. When power is restored to the backup unit and the CPU is returned to RUN mode, it becomes synchronized with the active unit.

The following paragraphs describe how the system can be repaired without interruption of control. The replacement of each replaceable component is described.

### Note

If maintenance is to be performed on the active unit in a synchronized system, control should be switched to the other unit before powering down. This will allow for an orderly transfer of control.

After repairing a defective unit:

1. Power-up the CPU rack in STOP mode.
2. Verify that the Remote Ready and Remote Active LEDs are on while in STOP mode.
3. Verify that the Local Ready and Local Active LEDs are on in the Active unit.
4. Clear the fault tables of the repaired unit.
5. Put the repaired unit in RUN mode.

## Maintaining Parallel Bus Termination

It is important when doing online repair to maintain parallel bus termination on the active unit. This is the reason a terminated parallel cable (IC697CBL803, IC697CBL811 or IC697CBL826) is used, and why the Redundancy Communications Module *must* be the last device on the parallel bus. The terminated end of the cable may be safely removed from a de-energized RCM. The terminated cable should be considered an integral part of the unit it terminates.

## On-Line Repair Recommendations

It is advised when doing online repair to power-off the entire PLC system (of the suspect unit), including ALL RACKS. Change the suspect part, and power-up in STOP mode. Verify that the links are operational before switching to RUN (%S bits and RCM LEDs are updated in STOP mode).

## Power Supply

The power supply has adequate internal fault detection, which causes it to automatically shut down if there is a failure.

A power supply failure is indicated by the absence of the OK indication at the power supply. There are a small number of failures that can result in a false indication or no indication. The probability of these occurring are extremely low compared to the major failure items of the power supply.

In the event of a power supply failure, the backup CPU takes control of the system. The power supply can be replaced with power removed from its rack without interruption to the application being controlled.

### Caution

**Before replacing a power supply, be sure to disconnect main power to the rack, since incoming power will be present on the power supply terminals**

When the power supply is replaced, power can be returned to the rack. The CPU will then obtain synchronization with the active system and either take control or become the backup CPU.

## Racks

The only detectable rack failure is bad data across the backplane. This bad data can take the form of a bad control line as well as a bad data or address line. In most cases bad data lines are detected by the data integrity checks associated with the data transfers. If these occur the PLC is faulted and control transfers to the backup unit. An indication is given that a data transfer error has occurred.

There is no single indication that a rack failure has occurred. The rack is a very reliable component in the system and rack failures are extremely rare. A rack failure (other than a catastrophic rack failure) can only be correctly diagnosed by process of elimination.

In the unlikely event that a rack failure does occur and is correctly diagnosed, the rack can be replaced with power removed from the system. When the rack is replaced and power restored to the system, the CPU will obtain synchronization with the active system and either take control or become the backup CPU.

## Central Processor Unit

If the redundancy CPU fails, the OK light on the CPU will turn off or blink. In addition, fault information will be available in the Fault Table of one or both CPUs.

If the active CPU fails, control is transferred to the backup system. CPU replacement can be accomplished by removing power from the rack and replacing the CPU. When power is returned to the system, the program can be loaded into the CPU and the CPU started. It will then obtain synchronization with the active system and either take control or become the backup CPU.

## Redundancy Communications Module and Cables

If a fault is detected in a single Redundancy Communications Module or in its terminated I/O cable, the backup RCM is used. Control does not transfer to the backup CPU. An RCM fault is logged in the PLC Fault Tables of both PLCs. *The loss of an RCM is not fatal.* If there are expansion racks within a system, and the cable fault is such that the system can no longer communicate to the expansion racks, then the fault is fatal and the PLC is halted. Control then transfers to the backup PLC.

If an RCM fault is detected, proceed as follows:

- STOP the unit with the suspected bad RCM.
- Turn power off at that rack.
- Unplug the terminated cable from the RCM and replace the module.
- Reconnect the terminated cable.
- Power-up the rack with mode switch in STOP.
- Verify that the REMOTE ACTIVE and REMOTE READY LEDs are on. *Note that the RCM LEDs only update if the board is not faulted.*
- Switch the repaired unit to RUN.

## Redundancy Communications Link Failures

There are two types of Redundancy Communications Link failures; a "Link Timeout" and a "Hard Link Failure". When a *Link Timeout* occurs, the RCM BOARD OK LED remains ON and the LOCAL READY and LOCAL ACTIVE LEDs continue to reflect the status of the Local unit. The REMOTE ACTIVE and REMOTE READY LEDs are not updated by the Remote unit until the link is reinitialized by storing a configuration or power cycling either unit. When a *Hard Link Failure* occurs, all five RCM LEDs go OFF. A power cycle of the Local unit is required to attempt to reinitialize the failed link.

## Bus Transmitter Module

A fault in the Bus Transmitter Module is treated just like a fault in the Redundancy Communications Module. It is only fatal if the fault prevents communications to any expansion racks within the system.

Failure of the Bus Transmitter Module may not easily be distinguished from a Redundancy Communications cable failure or even an RCM failure. However, most failure modes of the Bus Transmitter Module can be isolated to the BTM. When a Bus Transmitter Module fails, the system responds as described for the Redundancy Communications Module and cable failure. It only faults the PLC if the PLC has expansion racks installed.

The Bus Transmitter Module can be replaced by removing power from the rack and replacing the module. When power is restored to the CPU, the CPU obtains synchronization with the active system and either takes control or becomes the backup CPU.

## Genius Bus Controller

In a synchronized CPU Redundancy system, all GBC faults are considered fatal. Failure of a Genius Bus Controller is detected and isolated by the PLC. If a Genius Bus Controller fails in the active PLC, the active PLC goes to STOP/FAULT mode and the backup assumes control.

The Genius Bus Controller can be replaced by removing power from the rack and replacing the module. When power is restored to the CPU, the CPU obtains synchronization with the active system and either takes control or becomes the backup CPU.

## Genius Bus

For both single and dual bus Genius networks, Genius bus faults are not fatal to the PLC. However, if a bus fault exists, it exists for both units.

### Single Bus Networks Bus faults

For single bus Genius networks, there may be situations where Genius bus faults are not fatal to the PLC. However, if a bus fault exists, it exists for both systems. There may be situations where one controller can communicate to more blocks than the other controller can. The blocks will choose which controller to respond to, if either can be heard.

The Genius bus can be repaired without disturbing power to either system and thus without disturbing whichever PLC is in control of the process. Replacement of a bus can be done on line but is not recommended because all devices on that bus will be lost until the bus is repaired.

---

## Dual Bus Networks

For dual bus Genius networks, a single trunk cable failure will result in the blocks downstream from the failure switching to the other Genius bus. Since both busses are attached to the same Genius blocks no loss of inputs or outputs will result.

Failures in bus stubs (the portion from a BSM to its associated blocks) result in the loss of the blocks on that bus stub that are downstream from the failure. These blocks will be lost for both the active and the backup unit.

The failed Genius bus can be repaired without disturbing power to either system and thus without disturbing which PLC is in control of the process. To repair a failed trunk cable, first disconnect the failed bus from both GBCs which will cause any remaining blocks on that bus to switch to the other bus; the failed bus can then be replaced. Failure of a Genius bus stub can be done online but will result in the loss of any remaining blocks on that stub until the bus is repaired.

## Genius Blocks

The failure of a single block is not fatal when the PLCs are synchronized.

If the fault action of LOSS OF OR MISSING I/O MODULE is configured to be Fatal, the failure of a single block will be fatal when the PLCs are not synchronized.

## IC690CBL714A Multi-drop Cable

### Purpose

To interconnect Series 90-70 Redundant PLCs in a multi-drop serial communications arrangement.

### Specifications

- Connector A: DB15F, 15-pin female connector with M3 latchblocks
- Connectors B and C: DB15M, 15-pin right angle, male connector with spring clips
- Wire: Cable consists of three individually shielded pairs of 22-gauge stranded conductors, equivalent to Belden #8777.
- Jumpers: All jumpers are made of #22 AWG (UL1061) type individual wires.
- Length: The length from back of Connector A to entry into Connector B is 6 inches (+/- 0.5 inch). The length from back of Connector C to entry into Connector B is 40 inches (+/- 1.0 inch).

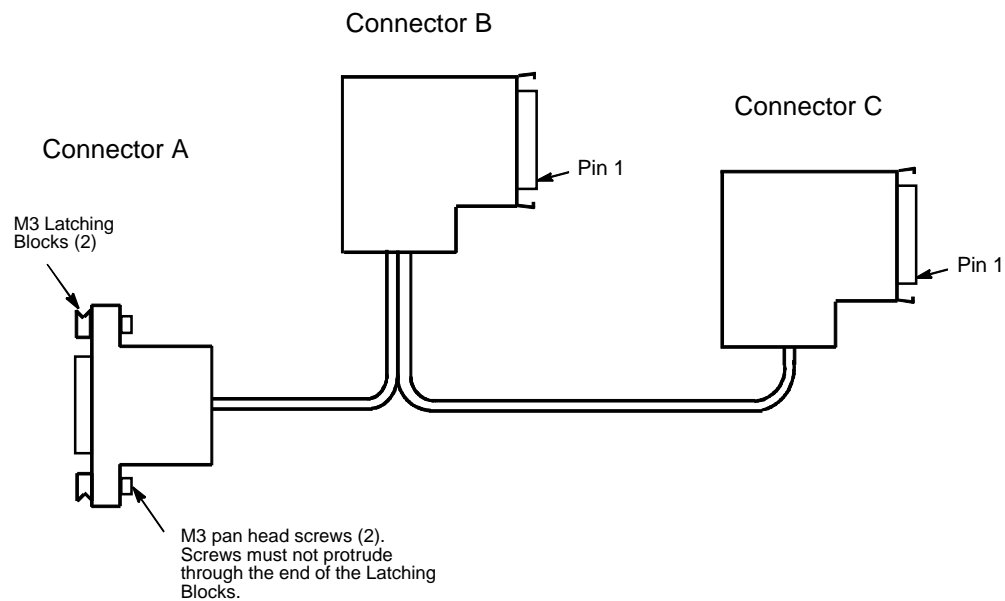


Figure A-1. Multi-Drop Cable Connection Diagram



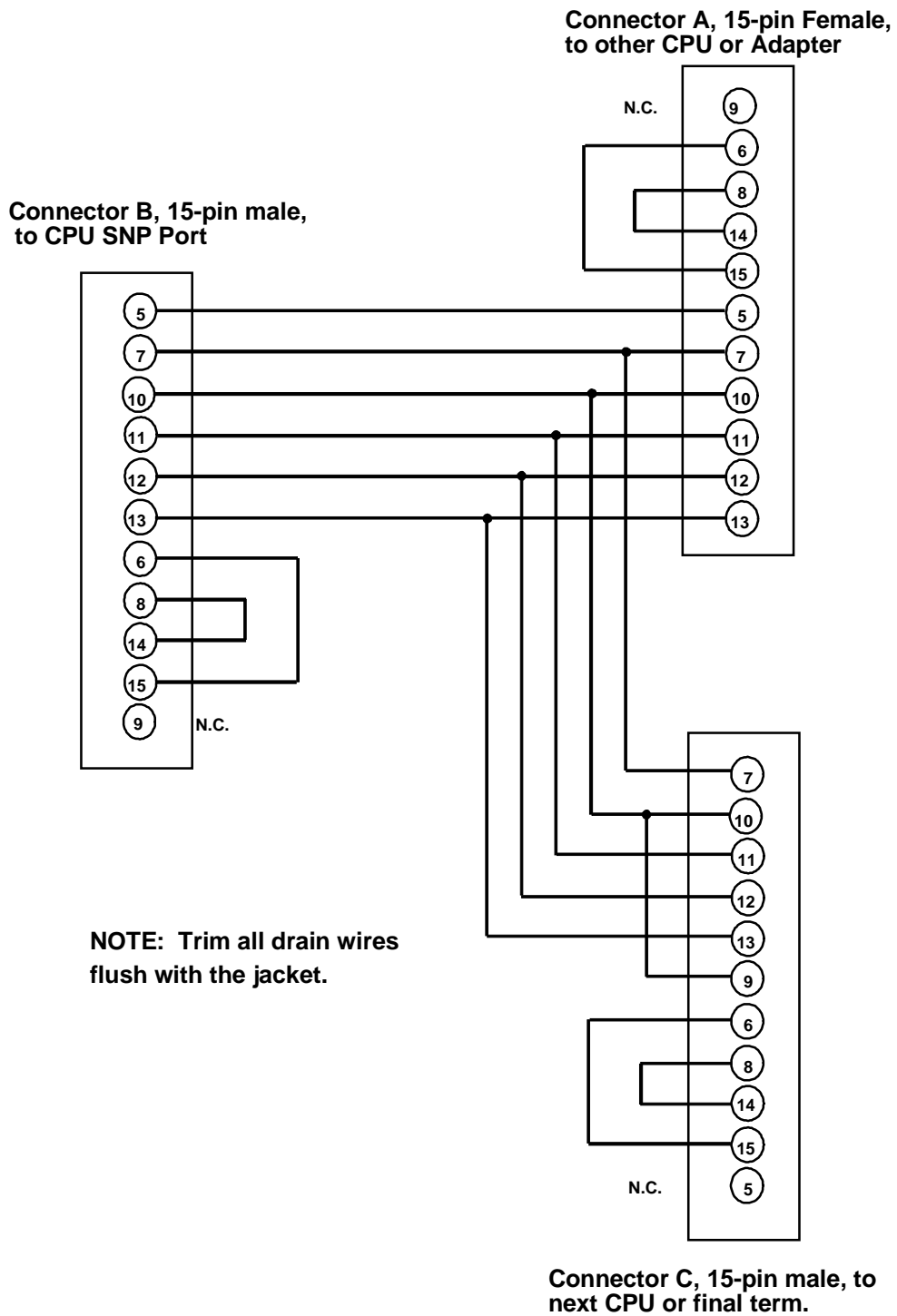


Figure A-2. Multi-Drop Cable Wiring Diagram

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