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The committee, the college, and the University of Central Florida are not liable for any use of the materials presented in this study.

AUTOMATED SPACELIFT TRAINING FOR RANGE OPERATORS (ASTRO)

by

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ABSTRACT

It takes several hundred men and women to successfully launch manned vehicles from Kennedy Space Center and unmanned vehicles from Cape Canaveral Air Force Station. Both locations support commercial and Department of Defense operations, and because the ranges are owned by the military, military personnel end up supporting commercial launches. The problem is that the military personnel lack the experience that their civilian counterparts have. To combat this problem we must provide the operators with adequate training.

The purpose of this thesis is to study issues related to the development of a low-cost, off-line, high-fidelity training system. We focus in particular on two general aspects: data latency, which could later be exploited in the Satellite Control Ground Station, and second, displaying Air Traffic Control data, which could be applied in practical Air Traffic Control Systems. Respective problems have been analyzed at the specification levels and software has been designed and implemented in LabVIEW.

I would like to dedicate this thesis to my family. They are the ones who have sacrificed the most during my studies.

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LIST OF ABBREVIATIONS

ACO	Aerospace Control Officer
ADVHMS	Autonomous Spacecraft Validation/Health Monitoring System
ASTRO	Automated Spacelift Training for Range Operators
bps	bits per sec
Bps	Bytes per sec
CAB	Commander's Advisory Board
CSC	Computer Software Component
CTSC	Center Technical Services Contractor
DT&E	Development, Test and Evaluation
ER	Eastern Range
ETR	Eastern Test Range
FCO	Flight Control Officer
GUI	Graphical User Interface
ICD	Interface Control Document
IDD	Interface Design Document
IRIG	Inter-Range Instrumentation Group
MSAW	Minimum Safe Altitude Warning
OT&E	Operations, Test and Evaluation
RCO	Range Control Officer
ROC	Range Operations Commander
ROCC	Range Operations Command Canter
TBD	To Be Determined

CHAPTER 1. INTRODUCTION

This study concentrates on various aspects of software to provide adequate training for staff participating in launch operations. It takes several hundred men and women to successfully launch manned and unmanned vehicles from Cape Canaveral Air Force Station (CCAFS) and Kennedy Space Center (KSC) in Florida. Military personnel control and operate the instrumentation that supports the commercial, national interest, and Department of Defense (DOD) launches. The difficulty is that the military personnel must rotate to a new assignment approximately every three years, while their civilian counterparts may have 20 - 30 years of experience on the range. Thus, the military personnel lack the experience that their civilian counterparts have. To combat this problem we must provide the operators with the best training possible. Unfortunately, in the high tech, high priced world of rocket launching, training does not have the highest priority.

In particular, in the 45th Range Squadron, there are several military positions that need initial or recurring off-line training [3]:

- Aerospace Control Officer (ACO)
- Range Control Officer (RCO)
- Range Operations Commander (ROC)
- Flight Control Officers (FCO)

- Commander's Advisory Board (CAB)

One of the issues important when significant amounts of data are transferred during the training operation is data latency. This is particularly important if the spaceborne data collected at Cape Canaveral or KSC will be transmitted for processing by the Autonomous Spacecraft Validation/Health Monitoring System (ADVHMS), the Satellite Ground Control Station (SGCS), or Autonomous Spacecraft Data located at UCF.

The ADVHMS, whose purpose is to monitor satellite health in real-time and to automate troubleshooting, will provide the real-time signal detection, fault mode diagnostic identification, and control and system parameter correction for the Spacecraft to autonomously operate in the space environment for long periods of time without frequent telecommunications from a ground station. Therefore it has to have assurance on the quality of real-time data.

The SGCS, which is being built by the Florida Space Institute (FSI), will also accurately record the time each frame is received. The data latency needs to be calculated by comparing the time transmitted embedded in the frame to the time the data was received. For example, the ground station may need to transmit commands to move the satellite in orbit, the calculations are only good for one instance in time; therefore, the data latency can be used to offset the calculations. This will ensure the satellite thrusters fire at the exact instant required.

Another critical issue in range operations training is the need to graphically display Air Traffic Control Data. We depend on the air traffic controllers to ensure public safety. The controllers cannot afford the catastrophic results if they are unable to monitor the airspace. For this reason a lot of research has been done on distributing the processing load and receiving the data in real-time. However, in range operations training there is no good way to display this data the same way an air traffic controller would view it.

The primary objective of this thesis is to address the problems in range operations training and develop an Automated Spacelift Training for Range Operators (ASTRO). There are three main goals for this research work:

- Design and test a methodology for a proof of concept for a low-cost, off-line, high-fidelity simulator
- Design and test a methodology to accurately measure data latency for data transmitted from a satellite to a ground station
- Design and test a methodology to ingest Air Traffic Control data from a radar site and graphically display it.

In the following, we present the requirements specification in Chapter 2, the design description in Chapter 3, the implementation and testing in Chapter 4, and conclusions in Chapter 5.

CHAPTER 2. PROBLEM DESCRIPTION

In this chapter, we outline several specific problems of range operations training which need to be addressed.

2.1 Range Operator Timing Problem

A problem exists in scheduling real world range assets to provide timing for a simulation. One such system is the timing system known as the countdown display system. The L Clock is the range time and is the actually time in minutes and seconds until launch. The T Clock is the user countdown time and has the user's holds built into it. In addition, the simulator needs to display the current Zulu or Greenwich Mean Time (GMT) [3]. See Figure 2-1.

A deficiency exists in that there is no off-line simulator that will correlate and display the Operation Number, the L Clock, the T Clock, GMT, and T-Zero for all users. An algorithm will be developed in this research that will form the core of a software simulator engine and correlate and transmit the timing data to all operators

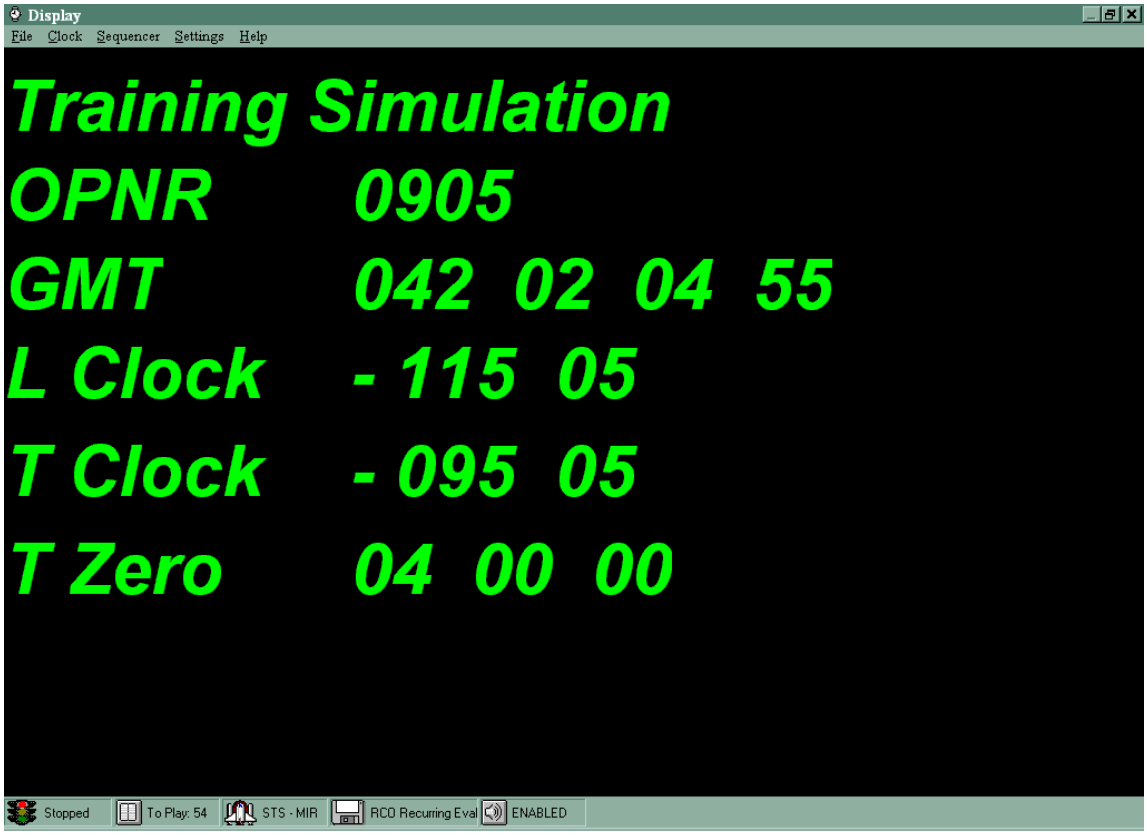


Figure 2-1 Range L Clock, T Clock, T Zero and GMT timing display

2.2 Aerospace Control Officer (ACO) Unique Problem

During launch operations the Aerospace Control Officer (ACO) is responsible for ensuring the Eastern Range (ER) restricted and warning airspaces are cleared of all aircraft. If an unidentified aircraft either intentionally or unintentionally enters the restricted airspace, the ACO must notify the RCO. It is the responsibility of the RCO to access the impact of the unidentified aircraft and the safety impact to all parties and, if necessary, hold the launch in the minus count. Once the aircraft has cleared the restricted airspace, the ACO will notify the RCO of the change in status. The RCO changes the range status from red to green and resumes the count if time permits. D-BRITE (Digital

Brite Radar Equipment) is the primary means the ACO has of monitoring airspace and aircraft over the ER [3]. See Figure 2-2.

There is a need to provide realistic off-line training for the ACOs. The developed software needs to simulate the D-BRITE Air Traffic Control Terminal to provide effective training for surveillance of aircraft entering, departing, or operating within area controlled by the Cape Canaveral Air Station.

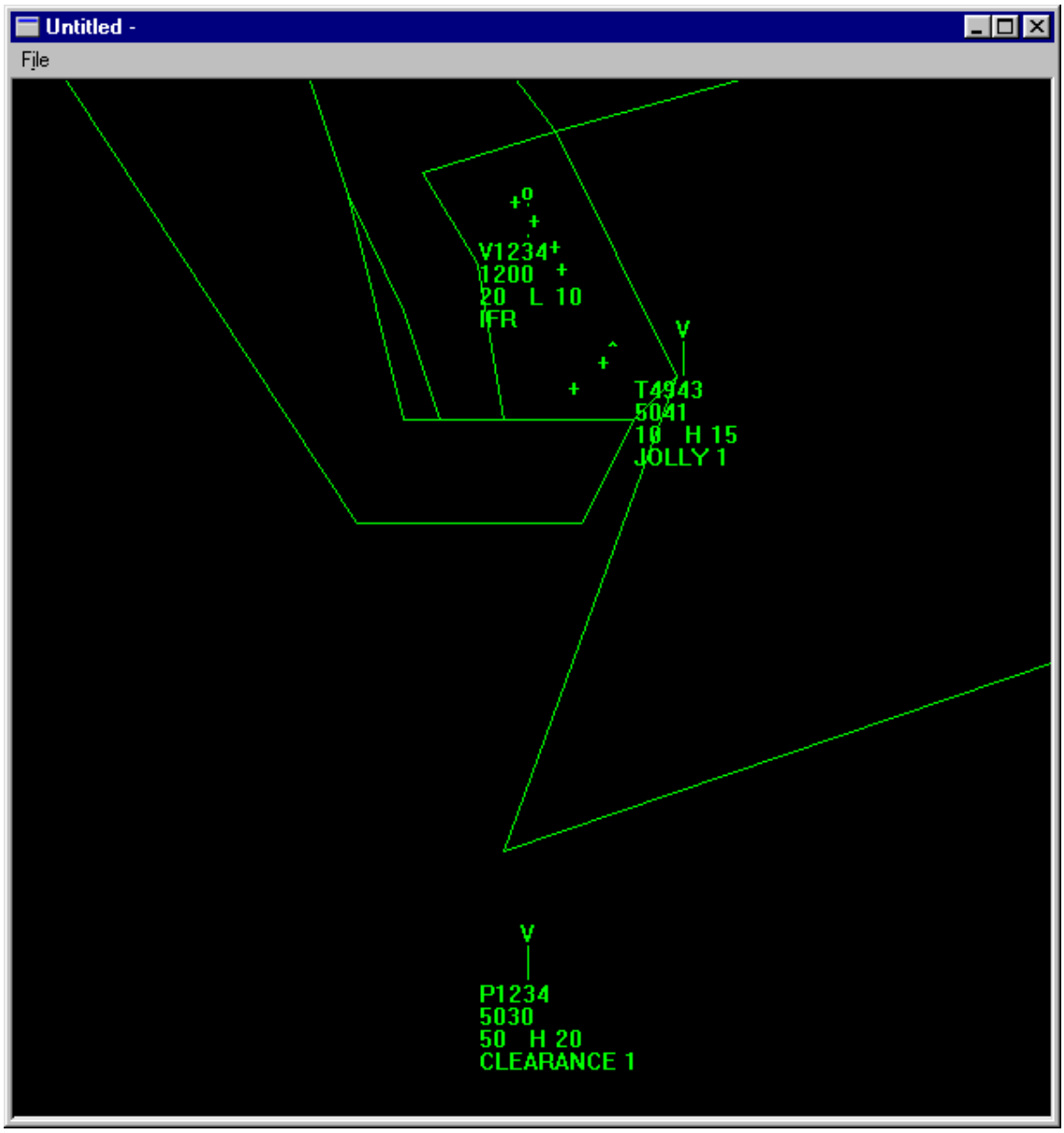


Figure 2-2 Typical ACO Airspace Display

2.3 Range Control Officer (RCO) Unique Problem

During launch operations, the RCO is responsible for ensuring the Eastern Range (ER) is capable of supporting the launch. The range consists of specialized instrumentation: radars, command destruct systems, weather systems, telemetry systems,

timing systems, optics, computers and communications. See Figure 2-3. Some of this instrumentation is deemed mandatory to ensure public safety. The RCO must determine the impact of every instrumentation outage in the minus count and, if necessary, engage the holdfire switch to stop the countdown clock. The RCO then notifies the ROC of the instrumentation outage and estimated time to return to operation (ETRO) [3].

A need exists to have an off-line simulator for holdfire. The developed software for the RCO needs a switch that is capable of stopping the countdown clock on the simulation server.

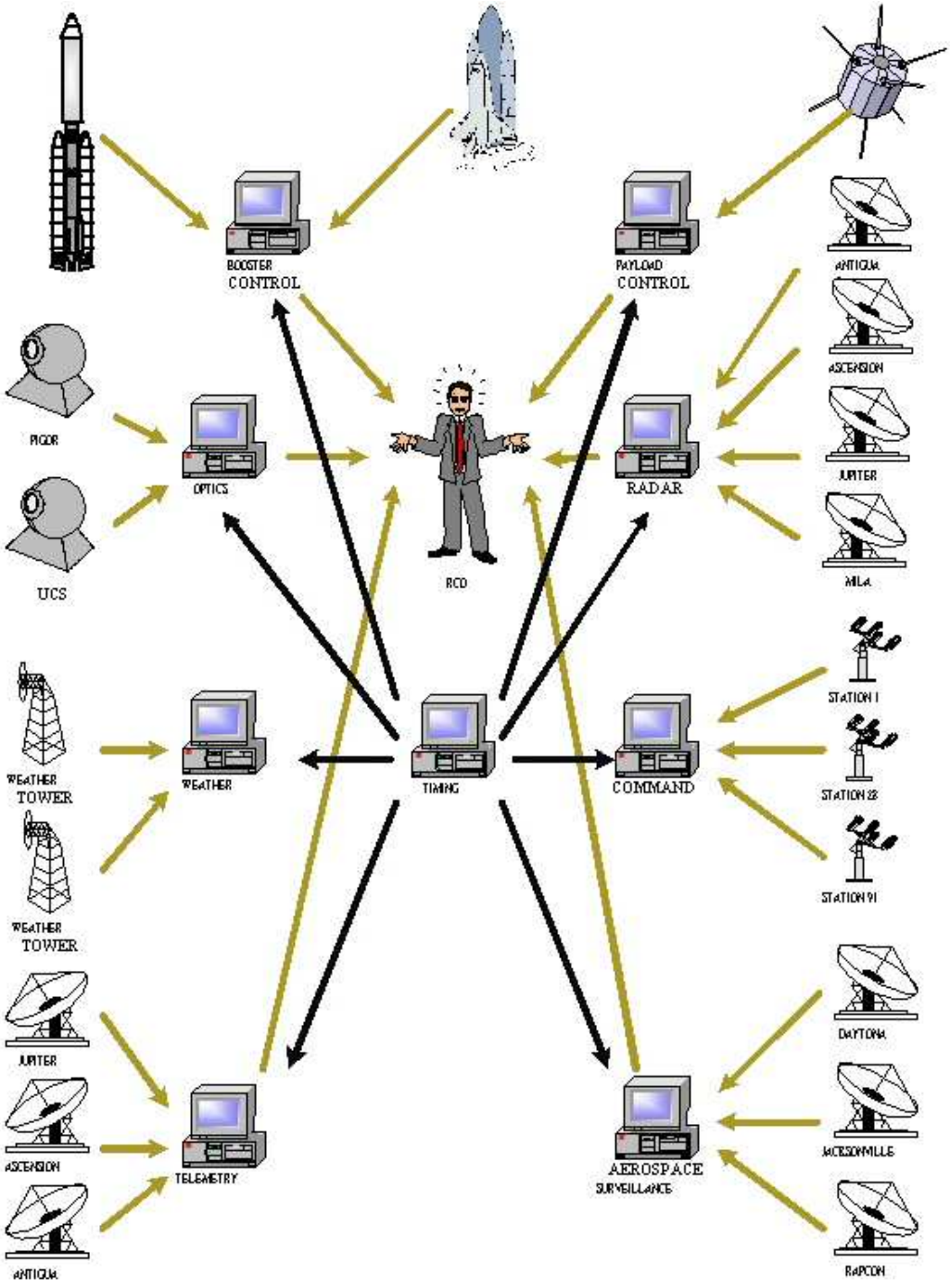


Figure 2-3 RCO's Range Instrumentation

2.4 Flight Control Officer (FCO) Unique Problem

"The ER recognizes the inherent risks associated with launch activities and provides subsystems for monitoring launch vehicle performance, and terminating the flight of an errant vehicle. Collectively these systems provide the 'Range Safety Function' which is essential to minimize the risk to people, property, and the environment [2]." During launch operations the FCO is responsible for ensuring public safety during launch operations on the Eastern Range (ER). If the vehicle veers off course and endangers civilians, the FCO transmit an encoded command destruct message. This message sets off a charge that rips open the side of the booster thus terminating its forward momentum. The FCO's job starts once the vehicle lifts off, and to accomplish the mission he needs access to a display that shows the rocket's position until it achieves orbital velocity [3]. See Figure 2-4.

As with the previously mention launch positions, the FCO also has a need for realistic off-line training. The developed software needs to simulate the FCO range safety system that graphically displays the current position of the launch vehicle.

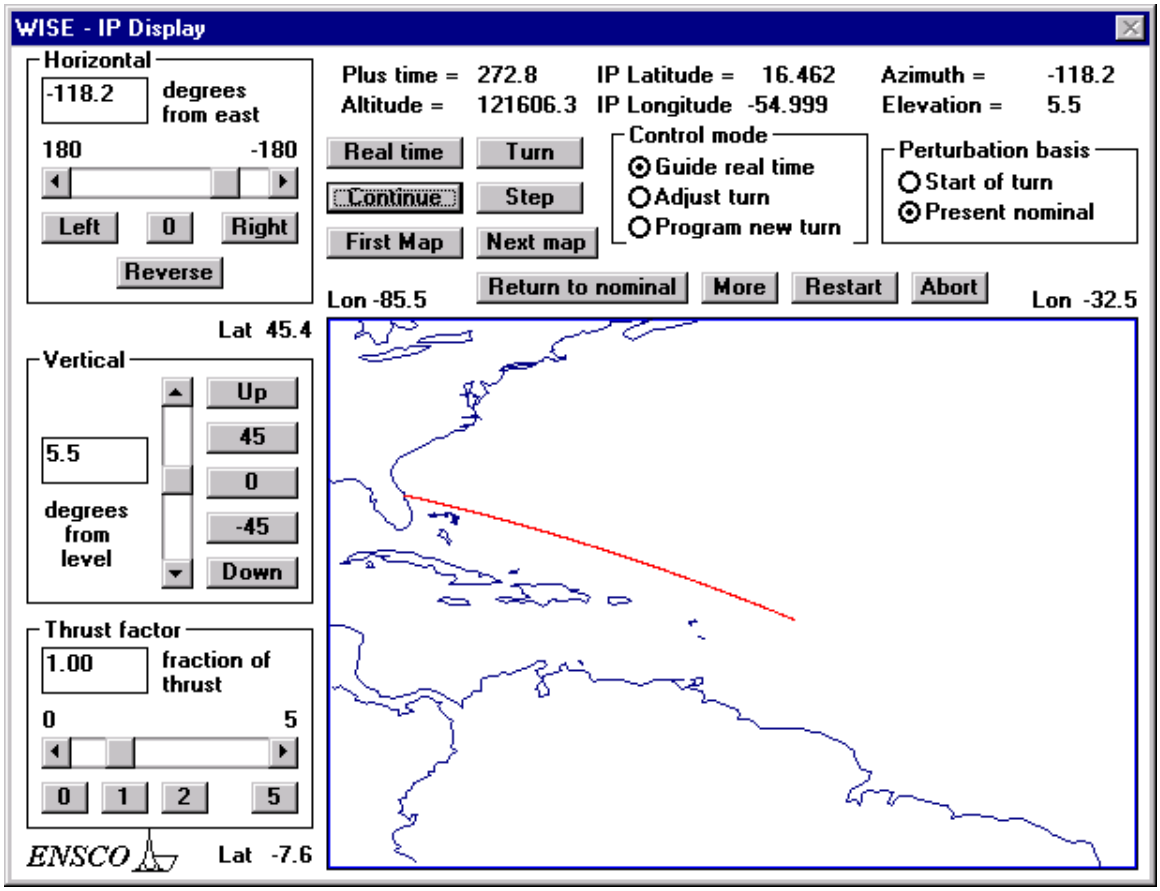


Figure 2-4 Typical FCO Range Safety Display

2.5 Range Operations Commander (ROC) Unique Problem

During launch operations the Range Operations Commander (ROC) receives range status from the ACO, FCO, and RCO. When a instrumentation outage is reported the ROC changes the status of the Launch Status Display System (LSDS). See Figure 2-5. In addition, he acts as a buffer between the Commander's Advisory Board (CAB)

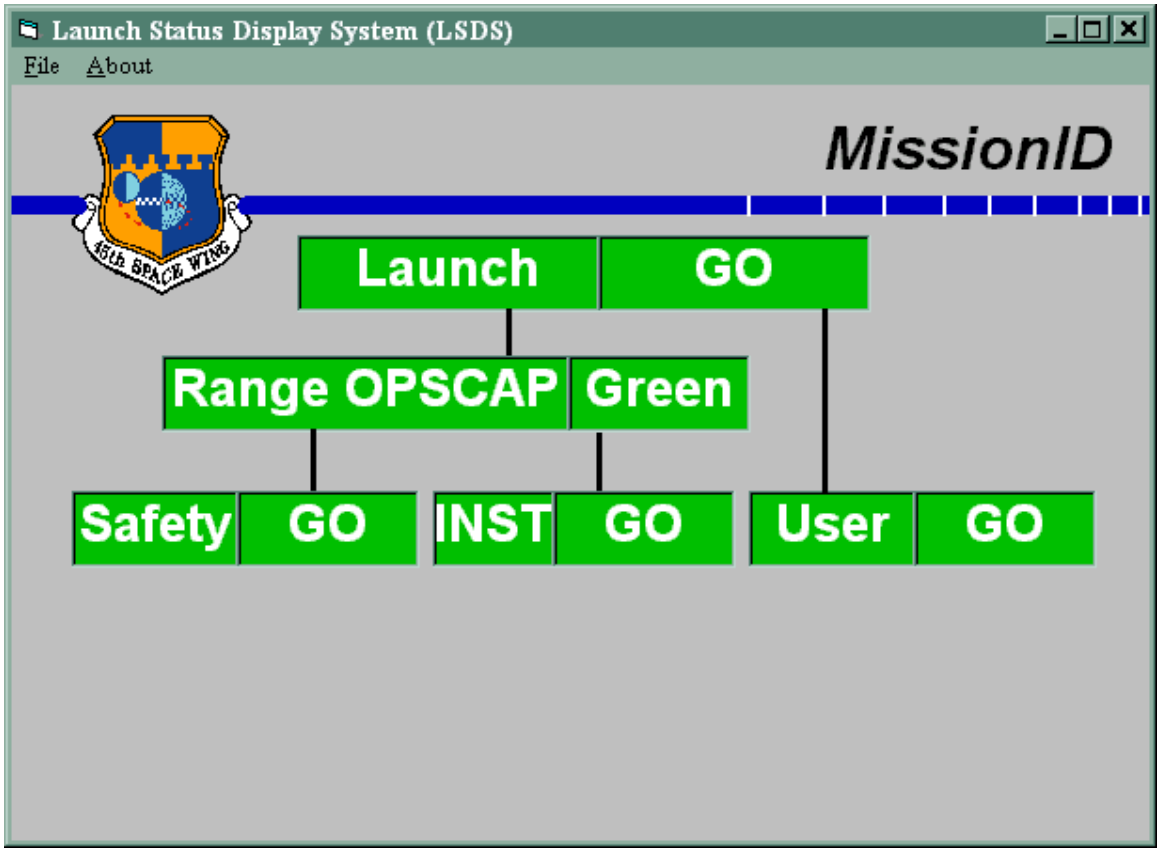


Figure 2-5 ROC Launch Status Display System (LSDS)

and his crew. This system currently uses closed circuit television (CCTV) to display the range status [3].

The ROC needs the capability during training exercises to pass this information to other operators. The developed software needs to provide the ROC with the capability to send data from the LSDS system via a means other than the ranges CCTV system.

2.6 Accurate Measurement of Data Latency Problem

Accurately determining the data latency of satellite transmissions is important to real-time calculations. The SGCS will need to accurately record the time each frame is received and calculate the data latency by comparing the time transmitted embedded in the frame to the time the data was received. See Figure 2-6. The developed software

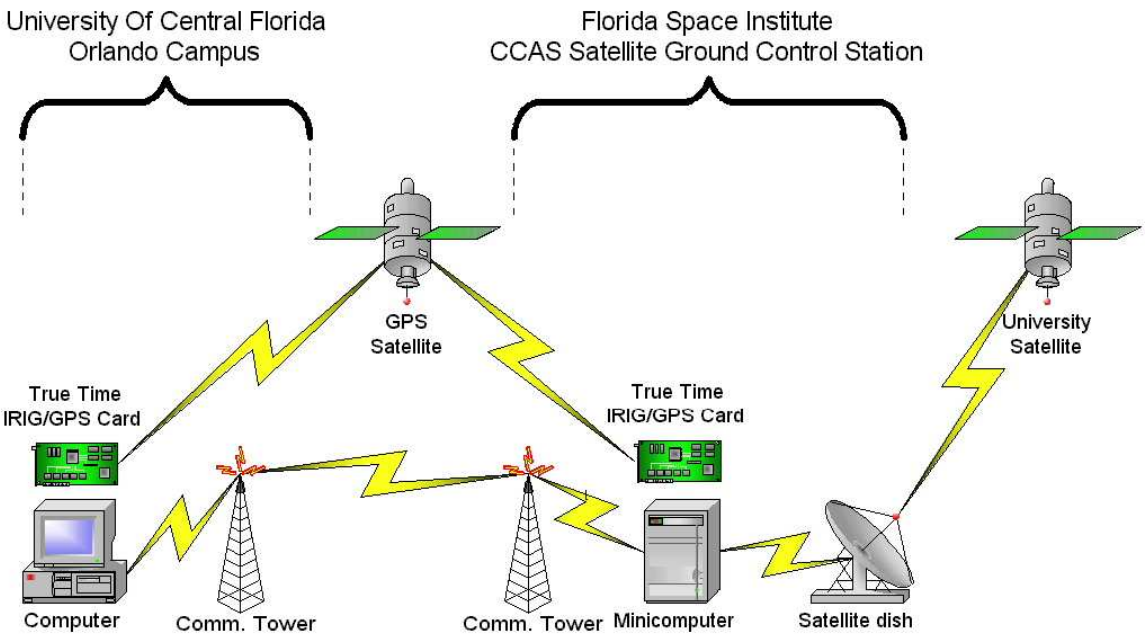


Figure 2-6 Satellite Ground Control Station

needs to stamp each frame as it is received, determine the data latency, and make this data available as an offset for other calculations.

2.7 Problem Description Summary

The primary goal is to develop a simulator system, called ASTRO, which shall consist of the computer hardware and software necessary to address the problems defined in Sections 2.1, 2.2, 2.3 and 2.6. We are focusing on the proof of concept to show that LabVIEW software can be utilized in the implementation phase to develop the entire system. The developed system will support the off-line training of the ACO and RCO operator positions. The ACO position will use simulated data from an Air Traffic Control site and graphically display the targets. The ROC, FCO and CAB operator positions will benefit from the timing displays but specific software to address their training deficiency is not developed in this project.

CHAPTER 3. REQUIREMENTS SPECIFICATION

3.1 Overall Timing Requirements

Every operator performing launch operations needs timing information to perform his/her duties. Two sequencers are necessary to provide an L Clock and a T Clock. The L Clock is the range time and is the actual time in minutes and seconds until launch. The T Clock is the user countdown time and has the user's holds built into it. In addition, the simulator needs to display the current Zulu or Greenwich Mean Time (GMT). Unfortunately, this clock is not tied into the sequencer and has to be manually synchronized.

A resolution to the timing synchronization is to calculate the L Clock, T Clock, and GMT time based on the launch T Zero. The capability to tie all these times together has never existed; however, it is necessary to provide realistic training. This approach will provide realistic training for the operators who have to execute some items on their checklist based on the user's T Clock, some items based on the range's L Clock, and others based on the Zulu or GMT time. Although it would be nice to have just one countdown clock, the fact is that there are two. An when it comes to unscheduled holds and coordinating new T Zeroes under pressure, the training needs to be as realistic as possible. The ASTRO shall provide an off-line simulator that will correlate and display

the Operation Number, the L Clock, the T Clock, GMT, and T-Zero for all users over an existing LAN using TCP/IP protocol.

3.2 Aerospace Control Officer (ACO) Unique Requirements

The purpose of this requirements specification is to simulate an existing system, therefore, it would be beneficial to understand how the existing equipment worked. During launch operations the ACO is responsible for ensuring the ER restricted and warning airspaces are cleared of all aircraft. The ACO uses D-BRITE (Digital Bright Radar Instrumentation and Tower Equipment) equipment to monitor Range Airspace. Developed for use in control towers, D-BRITE equipment only provides 60 nautical miles of coverage from Patrick RAPCON (Radar Approach). Proper configuration of the D-BRITE equipment provides you with an accurate picture of the airspace [2].

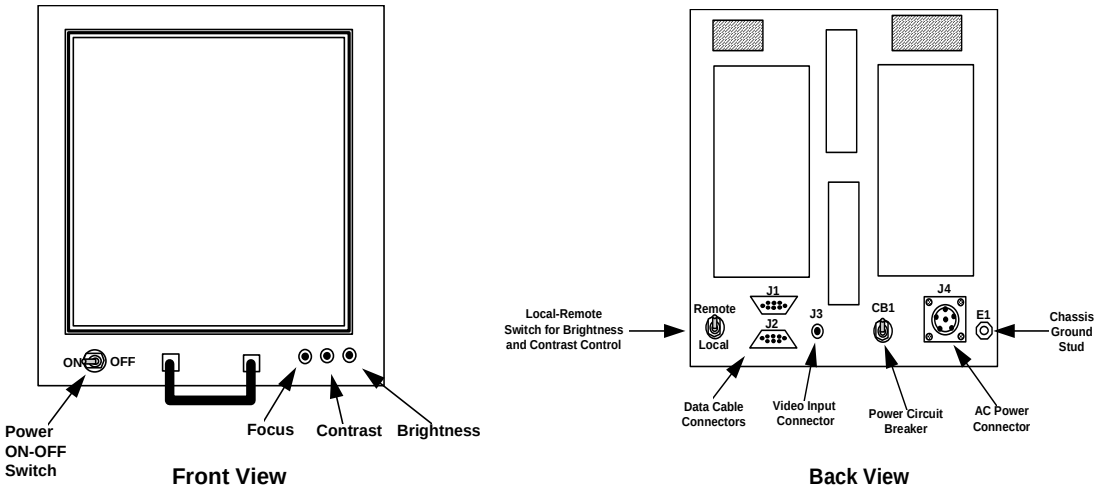


Figure 3-1 D-BRITE Monitor

PIDP/TFX-42 RCU Control Panel

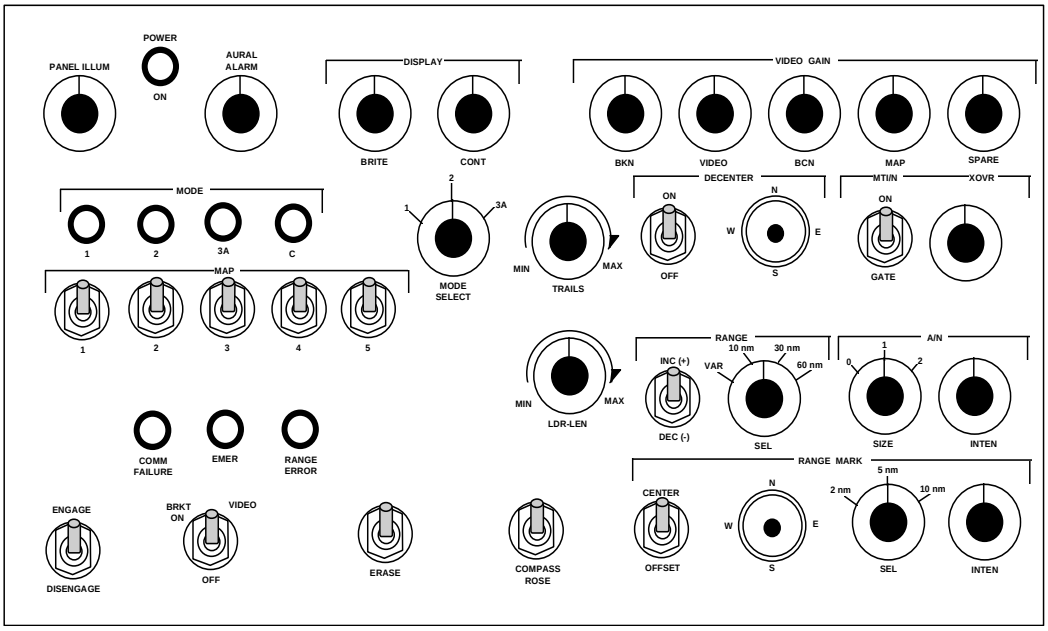


Figure 3-2 D-BRITE Remote Control Unit (RCU)

The monitor in Figure 3-1 and the Remote Control Unit (RCU) in Figure 3-2 can be configured to the operator's preference. When the equipment is in the BIT mode, a symbol will appear in the top right section of the monitor. This symbol is a circle with a dash rotating around the outside. If an error occurs, this indicator will be replace with an error code. To clear errors, continue to depress the erase switch on the RCU until the BIT indicator appears [2].

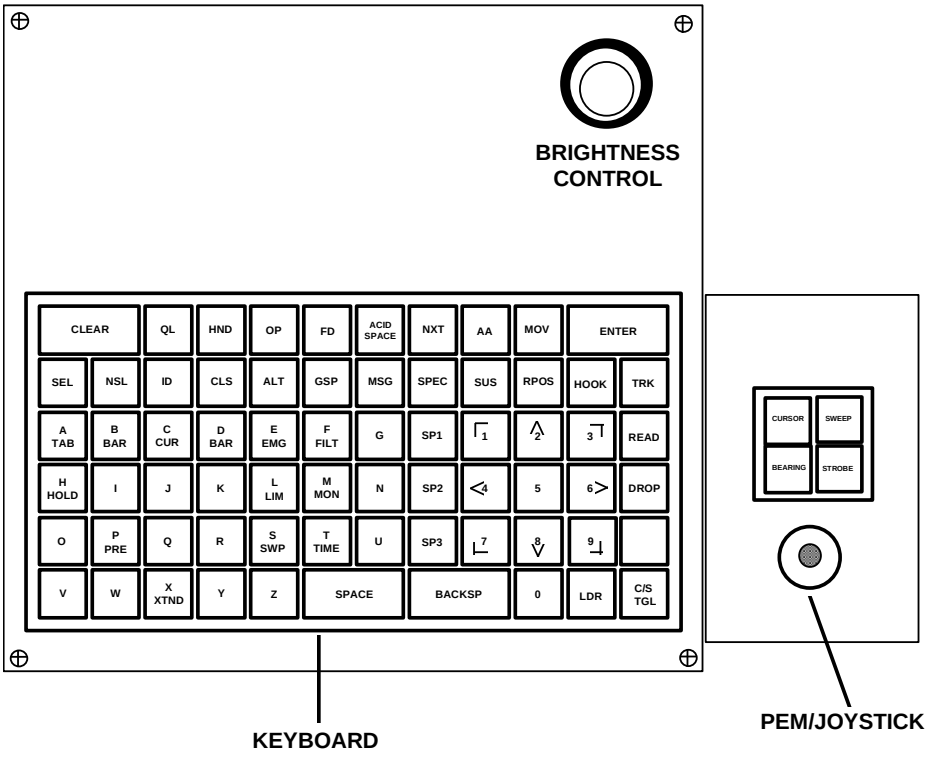


Figure 3-3 D-BRITE Keyboard

The D-BRITE uses a small keyboard in Figure 3-3 to allow the operator to enter information into the system. Also on the keyboard is a small joystick referred to as the PEM (Position Entry Module). The PEM enables you to control the cursor. Keyboard/PEM entries select presentation parameters for the display unit. Target identity/altitude filtering and display format, barometric pressure setting, transition altitude setting, low altitude alert exemption, and aural alarm shut-off are keyboard functions. The PEM is used to change cursor bearing and strobe range, and to relocate cursor origin, sweep origin, and tabular data lists on the display screen.

Each support aircraft is assigned a specific Mode III code. The Mode III is what is used to identify mission support aircraft, so it is very important the aircraft transmit the

proper code. The operator should know, prior to the mission, which aircraft are supporting and it's Mode III code [1]. See Table 3.1.

Table 3.1 Range Aircraft Callsigns and Mode III Codes in Octal

CALLSIGN	MODE III		CALLSIGN	MODE III
Search 1	5030		Patrol 1	5046
Search 2	5031		Patrol 2	5047
NASA STA	5034		King 1	5050
NASA T-38	5035		King 2	5051
Clearance 1	5036		Hawkeye 1	5052
Jolly 1	5041		King 3	5054
Jolly 2	5042		Relay 1	5057
Jolly 3	5043		Weather 1	5052
Jolly 4	5044			
Jolly 5	5045			

The D-BRITE does not operate independently; it is connected, like RAPCON, KSC, Malabar, and Patrick Tower, to a central computer or the Programmable Indicator Data Processor (PIDP). The PIDP is the central brain of the system. The D-BRITE can not function properly without the PIDP. Since the D-BRITE equipment is only one user of the PIDP, some commands may affect other users on the system.

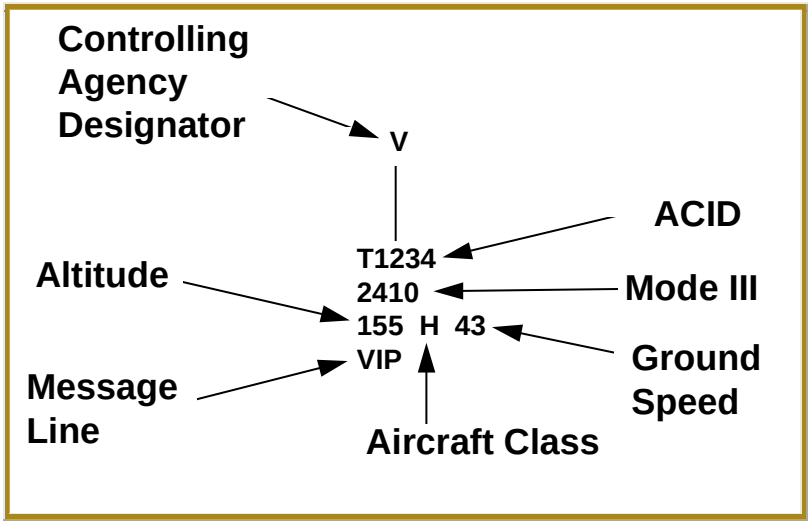


Figure 3-4 Target Track Elements

The term target refers to any trackable object displayed by the D-BRITE. Beacon targets squawking a Mode III code will be tracked, either by automatic acquisition (auto-acquire) from previously entered flight plan data or through keyboard procedures. Only the tracker owner may control the track format, modify track elements and delete the track in Figure 3-4. The first line of the track contains up to seven alphanumeric characters representing the aircraft identifier (ACID). The second line contains four digits representing the aircraft's transponder code. The third line contains the aircraft altitude in hundreds of feet, a blank space or a left caret, the aircraft class, a blank space, and the aircraft's ground speed in tens of knots. The fourth line is an optional message line of up to eight alphanumeric characters. Below are the normal letter designators that the ACO will encounter [1].

Table 3.2 Radar Letter designators

Site	Location
A-F	Patrick RAPCON Consoles A - F
J	Patrick Tower
K	Melbourne Tower
N	Other FAA facility (i.e. Jacksonville, Miami, Orlando)
U	NASA Tower
V	Cape Canaveral (D-BRITE)

The PIDP displays three classes of targets, selected, non-selected and tracked. Selected and non-selected classes are similar in that they consist of beacon code and altitude only. Tracked targets allow for the added capabilities of the PIDP.

Non-selected targets are those targets not selected by keyboard actions. The symbol for a non-selected target at a particular indicator is a small circle or the letter designator of the indicator that is tracking that particular target. A 2-line data block is attached by a leader to the non-selected target symbol.

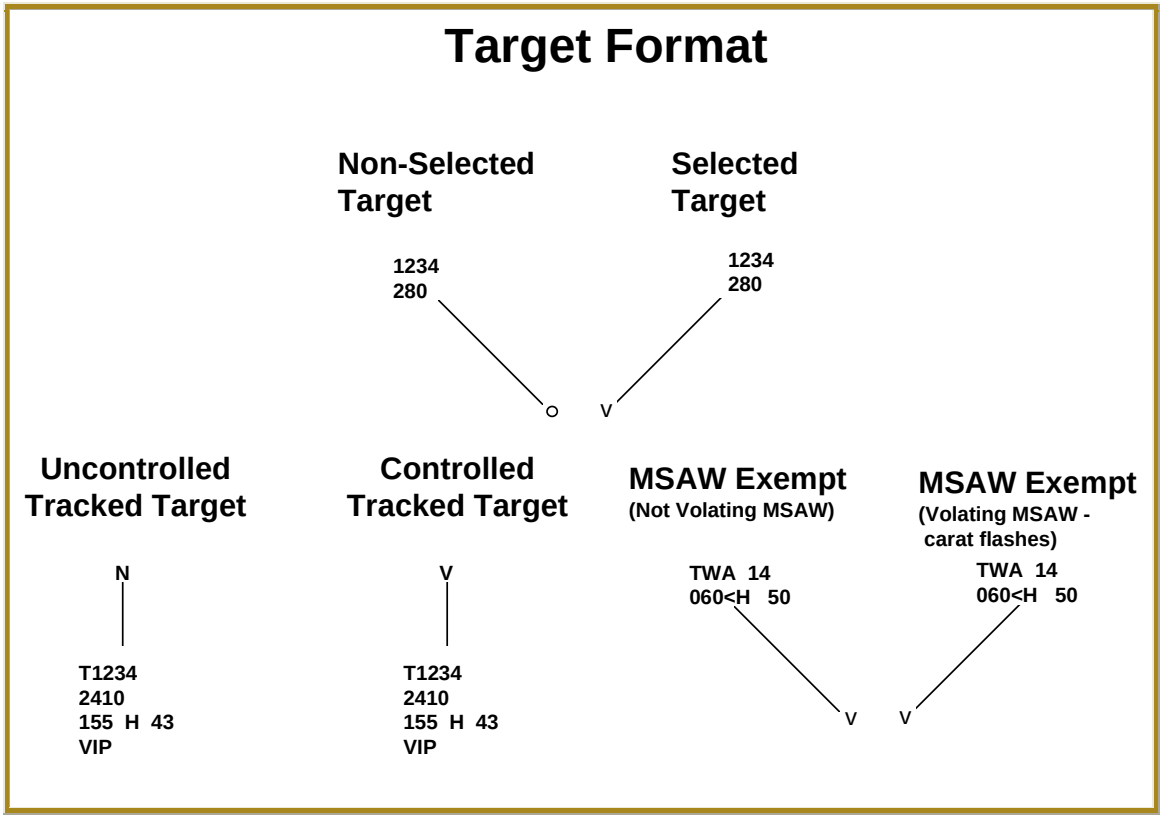


Figure 3-5 Target Display Format

Selected Targets are those targets that are code selected by a controller. You may select up to five discrete beacon codes and/or 2-digit code blocks to become selected targets. The remaining portion of the format is the same as described for the non-selected target.

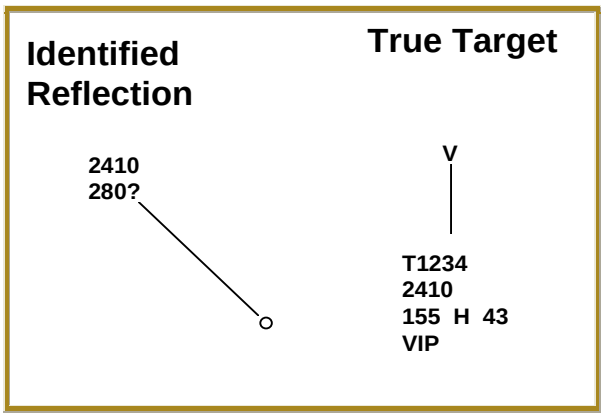


Figure 3-6 False Target Display

D-BRITE provides an accurate and reliable picture of the airspace; however, sometimes the equipment will display a false target. See Figure 3-6. False targets are not a defect of the equipment, but a problem inherent to most radar systems. This problem is called "Reflection Discrimination." At many ATC sites, reflections of beacon (secondary) targets have become a major problem with automated systems. Aircraft's Mode III reflections off these obstructions cause the PIDP to recognize the obstruction as an aircraft. These reflections cause the aircraft's transponder to squawk when the radar antenna is not pointing at the aircraft. Thus, two targets are created, one true and one false both squawking the same code. The PIDP will identify only false targets of a true target being tracked. Reflections will be displayed provided reflection data has been submitted for your facility. Those targets identified as reflections are displayed as a non-select target with a "?" after the altitude. Another sign that a target is false, is when an

aircraft appears on the monitor at a high altitude squawking the same code and traveling in the same direction.

The three procedures performed by the ACO while performing monitoring duties are: Manual Track Initiate, Altitude Assignment, and Minimum Safe Altitude Warning. The purpose of the "Manual Track Initiate" command is to allow the controller to manually identify a selected or non-selected target and change it to a tracked target. There are two ways to select an aircraft; Mode III/ACID or PEM. The most effective of the two is to enter the Mode III/ACID. The ACO should initiate track on all aircraft entering Range Airspace and maintain that track until the aircraft departs. To initiate track, type in the Mode III and press READ. This will capture the aircraft. Next, type in an ACID for the aircraft and press ENTER. The ACID will appear on the monitor momentarily. The system will continue to track the aircraft until track is dropped. To drop track, type the ACID or Mode III then press the READ followed by the DROP key.

When an aircraft is at the mission support point (MSP), you should assign the MSP altitude to that aircraft. This will enable the system to monitor all aircraft at the same time. The PIDP is capable of performing altitude monitoring by assigned altitude on controlled tracked targets. The processor will alert you when the target is 300 feet above or below an assigned altitude level. If a specific altitude is not entered, the processor will assign the current altitude to the aircraft. When the altitude entered differs from the current altitude displayed, the assigned altitude will be displayed by time sharing the class and ground speed positions of the data block every scan. Until the tracked target reaches the assigned altitude, an up-arrow or down-arrow will be displayed

with the assigned altitude indication whether the track should be climbing or descending. When the target comes within 300 feet of the assigned altitude, the time sharing will stop; and an “A” will show in the right-half of line 2 of the data block. Should the target exceed the limit in either direction, the full track format begins to flash; and the audible alarm sounds. The 3-character message “ABV” or “BLO” appears in the last three character positions. You can acknowledge the condition by <PEM> HOOK, <ACID> READ, or <MODE III> READ. Once the condition is acknowledged, the alarm is automatically silenced and the full format will stop flashing, but the message “ABV” or “BLO” will continue to flash.

A low altitude alerting function called MSAW is built into the PIDP program. Anytime a tracked target is at or below the altitude set for that sector, the full track format begins to flash and the audible alarm is sounded, except for those codes or tracks exempted. In addition, the message “MSAW” is displayed in line 4 for the data block. This works much like the above procedures. You may encounter this situation during an operation. The Jolly helicopters often operate at extremely low altitudes. You can MSAW exempt specific aircraft. To exempt an aircraft type the ACID or Mode III then press READ then “x” and ENTER. This will exempt only that specific aircraft, to exempt other aircraft follow the same procedures.

The system responds to the operator’s keyboard commands Drop, Read, and Track. For example, the operator can "Read" a non-selected target and then select "Track". The operator can also "Drop" a selected target. The following scenario uses the procedures mentioned above [1].

Table 3.3 D-BRITE Operating Procedures

	Selection	Capture	ACID/Mode	Execute	Remarks
Jolly 1 enters the Range	5041	READ	JOLLY1	ENTER	Inhibits track and assigns an ACID
Jolly 1 drops to a low altitude and the MSAW alarms.	JOLLY1	READ			Acknowledges alarms
	JOLLY1	READ	X	ENTER	MSAW exempts Jolly 1
Jolly 1 arrives at MSP	JOLLY1	READ	005A	ENTER	Assigns 500 ft altitude to Jolly 1
Jolly1 departs Range	JOLLY1	READ		DROP	Drops track on Jolly 1.

If you feel the equipment is not performing properly, the first action is to checks for error messages. Error messages will appear in the top right section of the monitor. Error messages began with “E” and are displayed in a box on the D-BRITE display. See Figure 3-7.



Figure 3-7 D-Brite Error Messages

The “E” indicates an error. “D” indicates a problem in the Display Unit, and the “010” further defines the problems as a video preamp malfunction. Below is a list of alpha characters, and the major component they represent.

Table 3.4 Major Component Designator

Code	Problem Location
R	RCU problems
I	Automation system or interface board problems
P	PS and J box, tower display, RCU, or keyboard problem
S	Synthetic board problem
D	Tower display problem
X	Circuit card assembly problem

A minimum safe altitude warning (MSAW) function shall be provided to determine, if an aircraft is flying in close proximity to any type of natural or man-made obstructions in the air space, as follows: If an aircraft is flying at an unsafe altitude, the controller shall be alerted, so that an action can be taken to avoid a possible collision.

3.3 Range Control Officer (RCO) Unique Requirements

The RCO requires a timing panel that displays the following information: operation number, Julian date, GMT time, L Clock, T Clock and T Zero. In addition, the RCO also needs a holdfire switch to suspend the launch [4].

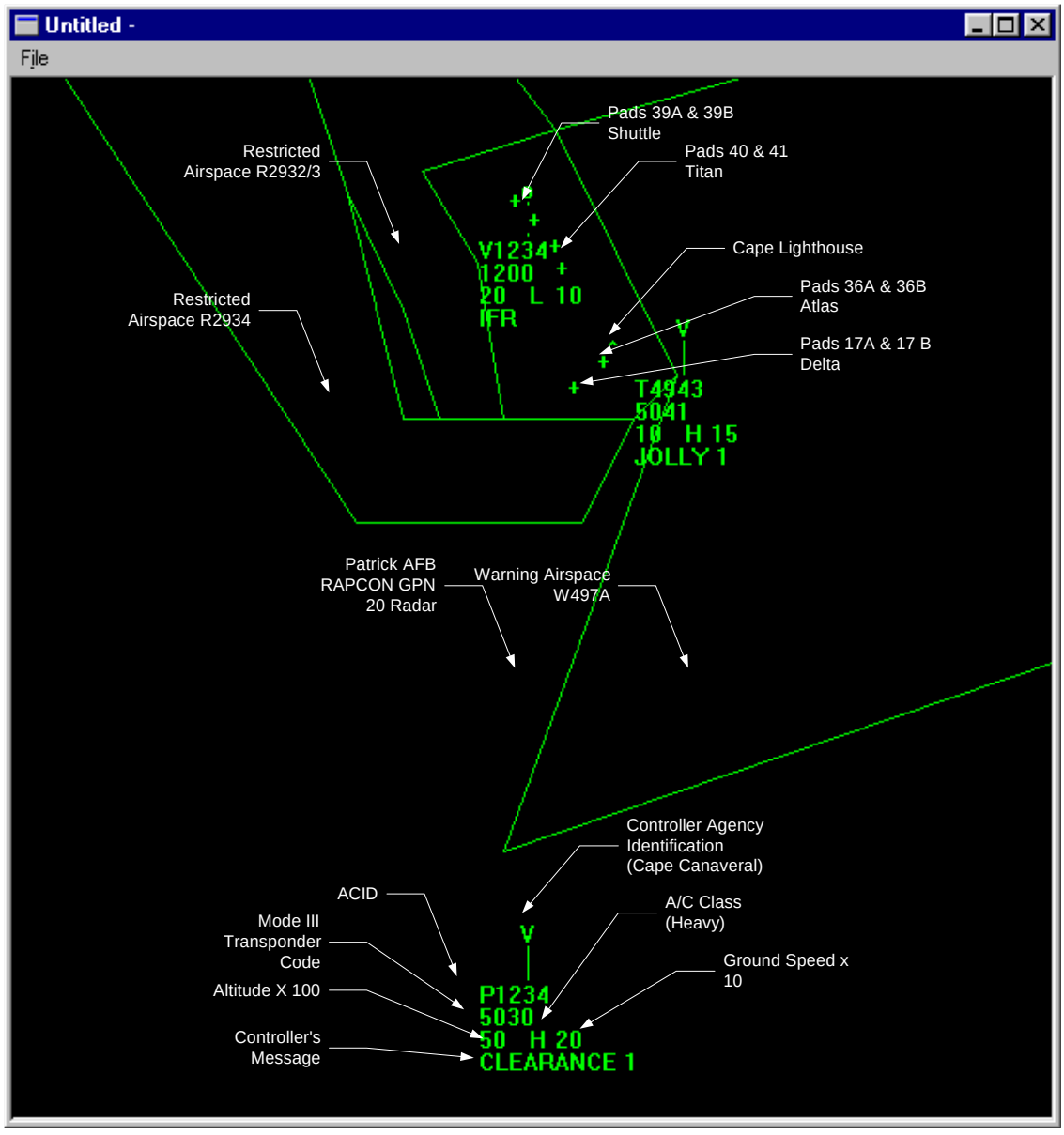


Figure 3.8 CCAS ACO Display with Key Areas Identified (white lettering)

3.4 Qualification Methods

Verification of the ASTRO functional requirements is accomplished through one or more of the following methods:

a. **DEMOSTRATION**: A verification method relying on observation of an item performing its specified function under a specific set of conditions. This does not require the use of instrumentation or special test equipment.

b. **INSPECTION**: Verification by visually examining an item, reviewing the descriptive documentation, and comparing appropriate characteristics with a predetermined or referenced standard to determine conformance to specific requirements.

c. **ANALYSIS**: Verification by technical or mathematical evaluation using mathematical equations, algorithms, or models; the use of charts, diagrams and representative data; or evaluation of previously qualified equipment.

d. **TEST**: Verification using instrumentation of an item performing its specified function. This involves the systematic exercise of the test item under all applicable conditions and measuring its specified parameters. Acceptability of the item under test is determined by evaluation of the measured data against predetermined performance requirement.

3.5 Specific Requirements

This section includes a detailed list of specific requirements to develop the software.

Table 3.5 General Requirements

Num	Requirement	Category	Tested by
1.0	General Requirements		
1.1	The ASTRO shall run on Windows 9X/NT clients on an existing network connected via a hub.	Functional	Inspection
1.2	The ASTRO shall utilize TCP/IP socket to communicate data between consoles.	Input/ Output	Demonstration
1.3	The ASTRO shall allow for a 50% increase in growth.	Functional	Inspection

Table 3.6 Overall Timing Requirements

Req	Functionality	Category	Tested by
2.0	Overall Timing Requirements		
2.1	The ASTRO system shall determine whether a True Time IRIG/GPS card is present in the server system.	Input/ Output	Demonstration
2.2	The ASTRO system shall use system time if True Time IRIG/GPS card is not present in the server system.	Input/ Output	Demonstration
2.3	The ASTRO system shall use IRIG time if a True Time IRIG/GPS card is present in the server system.	Input	Demonstration
2.4	The ASTRO system shall stamp the selected timing source's time in the transmitted data stream.	Output	Demonstration
2.5	The ASTRO system shall act as a server and transmit all the entered and calculated fields to client machines via TCP/IP.	Output	Demonstration

Table 3.7 ACO Unique Requirements

Num	Requirement	Category	Tested by
3.0	ACO Unique Requirements		
3.1	The ASTRO system shall be able to simulate and display the BIT mode of operation icon on the D-BRITE display.	Output	Demonstration
3.2	The ASTRO system shall be able to simulate and display the ERROR mode of operation box on the D-BRITE display. See Figure 3-7.	Input/ Output	Demonstration
3.3	The ASTRO system shall be able to clear errors by pressing the erase switch on the D-BRITE RCU. See Figure 3-2.	Input/ Output	Demonstration
3.4	The ASTRO system shall be able to simulate the functionality of all controls on the D-BRITE Remote Control Unit. See Figure 3-2.	Input/ Output	Demonstration
3.5	The ASTRO system shall be able to simulate the functionality of the range mark intensity control knob on the D-BRITE display and located on the RCU. It determines the intensity of the range circles. See Figure 3-2.	Input/ Output	Demonstration
3.6	The ASTRO system shall be able to simulate the functionality of the range mark selection knob on the D-BRITE display and located on the RCU. It determines the distance between range circles in nautical miles and is selectable between 2, 5 and 10 nautical miles. See Figure 3-2.	Input/ Output	Demonstration
3.7	The ASTRO system shall be able to simulate the functionality of the center/offset toggle switch on the D-BRITE display and located on the RCU. When in the center mode of operation it centers the range circles on the radar location. When the offset mode of operation is selected it enables the center/offset joystick. See Figure 3-2.	Input/ Output	Demonstration

Num	Requirement	Category	Tested by
3.8	The ASTRO system shall be able to simulate the functionality of the center/offset joystick on the D-BRITE display and located on the RCU. Is only functional when the center/offset toggle switch is in the offset position and allows the operator to have manual control of the range circles center position. See Figure 3-2.	Input/ Output	Demonstration
3.9	The ASTRO system shall be able to simulate the functionality of the range selection knob on the D-BRITE display and located on the RCU. It determines the maximum distance in nautical miles viewable from the picture center location to the edge of the picture. This is equivalent to the picture radius and is selectable between 10, 30, 60 or variable. See Figure 3-2.	Input/ Output	Demonstration
3.10	The ASTRO system shall be able to simulate the functionality of the range inc (+) dec (-) switch on the D-BRITE display and located on the RCU. It allows the operator to manually adjust the radius of the display from 2 to 60 nautical miles. This control is only accessible when the range selection knob is set to variable mode. See Figure 3-2.	Input/ Output	Demonstration
3.11	The ASTRO system shall be able to simulate the functionality of the decenter on/off toggle switch on the D-BRITE display and located on the RCU. When decenter mode of operation is in the off position it centers the display on the radar center location. When decenter mode of operation it enables the decenter joystick. See Figure 3-2.	Input/ Output	Demonstration
3.12	The ASTRO system shall be able to simulate the functionality of the decenter joystick on the D-BRITE display and located on the RCU. It is only functional when the decenter on/off toggle switch is in the on position and allows the operator to change the display's center position. See Figure 3-2.	Input/ Output	Demonstration
Num	Requirement	Category	Tested by

3.13	The ASTRO system shall be able to simulate the functionality of the map switch #1 on the D-BRITE display and located on the RCU. It toggles user specified data on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	Input/ Output	Demonstration
3.14	The ASTRO system shall be able to simulate the functionality of the map switch #2 on the D-BRITE display and located on the RCU. It toggles user specified data on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	Input/ Output	Demonstration
3.15	The ASTRO system shall be able to simulate the functionality of the map switch #3 on the D-BRITE display and located on the RCU. It toggles landmarks on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	Input/ Output	Demonstration
3.16	The ASTRO system shall be able to simulate the functionality of the map switch #4 on the D-BRITE display and located on the RCU. It toggles user specified data on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	Input/ Output	Demonstration
3.17	The ASTRO system shall be able to simulate the functionality of the map switch #5 on the D-BRITE display and located on the RCU. It toggles the maps on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	Input/ Output	Demonstration
3.18	The ASTRO system shall be able to simulate the functionality of all the keys on the D-BRITE Keyboard. See Figure 2-1.	Input/ Output	Demonstration
Num	Requirement	Category	Tested by

3.19	The ASTRO system shall be able to simulate the functionality of the PEM/Joystick on the D-BRITE Keyboard. See Figure 2-1.	Input/ Output	Demonstration
3.20	The ASTRO system shall be able to acquire simulated radar data and convert them into a format the controller can use. See Figure 3-5.	Input/ Output	Demonstration
3.21	The ASTRO system shall be able to handle new radar track information within 1 second of the sweep that occurs at 10 RPM or one update every 6 seconds.	Input	Demonstration/ Inspection
3.22	The ASTRO system shall allow the controller to manipulate ident display data. For example, the user should be able to change the message line in the ident display. See Figure 3-4.	Input/ Output	Demonstration
3.23	The ASTRO system shall be able to allow the simulation operator to add/delete/modify flight targets.	Input/ Output	Demonstration
3.24	The ASTRO system shall be able to allow the PEM to change the cursor bearing and strobe range, and to relocate cursor origin, sweep origin, and tabular data lists on the D-BRITE display.	Input/ Output	Demonstration
3.25	The ASTRO system shall be able to receive and display the Mode III code of each aircraft and display them on the D-BRITE display. See Figure 3-4.	Input/ Output	Demonstration
3.26	The ASTRO system shall be able to simulate the functionality of the Programmable Indicator Data Processor (PIDP). For example, the ability to hook a target and display it's ground speed. See Figure 3-4.	Input/ Output	Demonstration
3.27	The ASTRO system shall be able to receive and display targets on the D-BRITE display either through automatic acquisition from flight plan data or through keyboard procedures. See Figure 3-4.	Input/ Output	Demonstration
Num	Requirement	Category	Tested by

3.28	The ASTRO system shall be able to receive and display the Controlling Agency Designator (CAD). See Figure 3-4 and Table 3.2.	Input/ Output	Demonstration
3.29	The ASTRO system shall be able to receive and display up to seven alphanumeric characters on line 1 that represent the aircraft identification (ACID). See Figure 3-4.	Input/ Output	Demonstration
3.30	The ASTRO system shall be able to receive and display up to four digits on line 2 that represent the aircraft's transponder code. See Figure 3-4.	Input/ Output	Demonstration
3.31	The ASTRO system shall be able to receive and display on line 3 of the alphanumeric display the transponder code, aircraft altitude, a blank space or caret, the aircraft class, a blank space, and the aircraft's ground speed in tens of knots. See Figure 3-4	Input/ Output	Demonstration
3.32	The ASTRO system shall be able to receive and display on line 4 of the alphanumeric display an optional message that can contain up to eight alphanumeric characters for the a user defined operator message. See Figure 3-4	Input/ Output	Demonstration
3.33	The ASTRO system shall be able to receive and display on D-BRITE selected and non-selected targets. See Figure 3-5.	Input/ Output	Demonstration
3.34	The ASTRO system shall be able to receive and display on D-BRITE tracked targets utilizing the functionality of the PIDP. See Figure 3-3 and Figure 3-5.	Input/ Output	Demonstration
3.35	The ASTRO system shall be able to process and display up to five operator request to track targets utilizing the functionality of the PIDP. See Figure 3-6.	Input/ Output	Demonstration
Num	Requirement	Category	Tested by
3.36	The ASTRO system shall be able to receive	Input/	Demonstration

	and process false targets (reflection discrimination) for training purposes. See Figure 3-6.	Output	
3.37	The ASTRO system shall be able to allow the operator to initiate a manual track on a selected or non-selected target.	Input/ Output	Demonstration
3.38	The ASTRO system shall be able to allow the operator to assign an altitude to an aircraft.	Input/ Output	Demonstration
3.39	The ASTRO system shall be able to monitor aircraft with operator assigned altitudes and initiate an audible alarm alert when the aircraft is above or below 300 feet of its assigned altitude.	Input/ Output	Demonstration
3.40	The ASTRO system shall be able to monitor aircraft with operator assigned altitudes and flash the track information when the aircraft is above or below 300 feet of its assigned altitude. “ABV” or “BLO” is also added to the track display also adds	Output	Demonstration
3.41	The ASTRO system will allow the operator to respond to the keyboard commands Drop, Read, and Track. For example, the operator can "Read" a non-selected target and then select "Track". The operator can also "Drop" a selected target. See Figure 3-3.	Input/ Output	Demonstration
3.42	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the center and sector boundaries.	Input/ Output	Demonstration
3.43	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the Track data and current aircraft positions.	Input/ Output	Demonstration
3.44	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the map overlays.	Input/ Output	Demonstration
Num	Requirement	Category	Tested by
3.45	The ASTRO system shall be able to handle a	Input/	Demonstration

	graphical representation on D-BRITE to display the aircraft data (i.e. aircraft ID, reported altitude, assigned altitude, and ground speed). See Figure 3-4.	Output	
3.46	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the weather information (barometric pressure).	Input/ Output	Demonstration
3.47	The ASTRO system shall be able to provide a log file that will provide data recording of any data sent or received between processes and/or operators.	Input/ Output	Demonstration
3.48	The ASTRO system shall communicate with other terminals using existing network protocols (i.e. TCP/IP Socket Services)	Input/ Output	Demonstration
3.49	The ASTRO system shall be able to display the range and bearing between two points at the top center of the D-Brite Screen based on user inputs.	Input/ Output	Demonstration
3.50	The ASTRO system shall provide alert and advisory functions to ensure safe separation of aircraft in the Center's airspace. The specific functions shall be as follows: • track prediction function • conflict probe and alert function • resolution advisory function	Output	Demonstration
3.51	The ASTRO system shall provide an alert to the controller, if two or more aircraft are too close in proximity to each other. The normal separation distances over US air space are: • 5 miles horizontally • 1,000 to 2,000 feet vertically	Output	Demonstration
3.52	The ASTRO system shall provide a track prediction function of a given aircraft. This can be used to determine if any of the aircraft currently under control in the Center's airspace will be in conflict with each other in the immediate future.	Input/ Output	Demonstration

Table 3.8 RCO Unique Requirements

Num	Requirement	Category	Tested by
4.0	RCO Unique Requirements		
4.1	The ASTRO system shall allow the RCO operator to be able to engage a holdfire from their display for the simulation.	Functional	Inspection
4.2	The ASTRO system shall be able to receive and display the operation number, the Julian date, the GMT time, the L Clock, the T Clock and the T Zero via a TCP/IP socket.	Input/ Output	Demonstration
4.3	The ASTRO system shall determine whether a True Time IRIG/GPS card is present in the client system.	Input/ Output	Demonstration
4.4	The ASTRO system shall use system time if True Time IRIG/GPS card is not present in the client system.	Input/ Output	Demonstration
4.5	The ASTRO system shall use IRIG time if a True Time IRIG/GPS card is present in the client system.	Input	Demonstration
4.6	The ASTRO system shall wrap the received string with the selected timing source's time in the received data stream.	Input/ Output	Demonstration
4.7	The ASTRO system shall act as a client and receive all data sent by the server via TCP/IP.	Input	Demonstration

Table 3.9 Overall Simulation Server Requirements

Req	Functionality	Category	Tested by
5.0	Simulation Server Requirements		
5.1	The ASTRO system shall allow the simulation operator to enter the operation number.	Input	Inspection
5.2	The ASTRO system shall allow the simulation operator to enter up to four scheduled holds in at the Clock minutes they occur and their duration.	Input	Demonstration
5.3	The ASTRO system shall allow the simulation operator to enter the T Zero for the launch.	Input/ Output	Demonstration
5.4	The ASTRO system shall allow the simulation operator to enter when the scheduled holds occur in relation to the L Clock and the duration of each hold.	Input	Demonstration
5.5	The ASTRO system shall display the actual day of the year.	Output	Demonstration
5.6	The ASTRO system shall synchronize all the display times by calculating the L Clock, T Clock, and GMT time based on the launch T Zero and scheduled hold times and durations.	Input/ Output	Demonstration
5.7	The ASTRO system shall act as a server and transmit all the entered and calculated fields to client machines via TCP/IP.	Output	Demonstration
5.8	The ASTRO system shall allow the simulation operator to be able to suspend the simulation.	Input/ Output	Demonstration
5.9	The ASTRO system shall allow the simulation operator to be able to engage a holdfire from their display for the simulation.	Input/ Output	Demonstration

CHAPTER 4. DESIGN AND IMPLEMENTATION

4.1 Overall Design

The system architecture is centered on a computer acting as a Simulation Server on an existing network or across the Internet. As an implementation tool we chose LabVIEW which allows communication over the Internet in addition to traditional data acquisition of control functions. This server can be any computer on a network connected via TCP/IP running either Windows 9X or NT. The LabVIEW code could also be easily ported to the UNIX operating system. The complete ASTRO system is comprised of three software components, the Simulation Server, the ACO Client, and the RCO Client (Figure 4-1). Other clients can be added at a later date to complete the simulator: FCO Client, CAB Client, and ROC Client. (Figure 4-2).

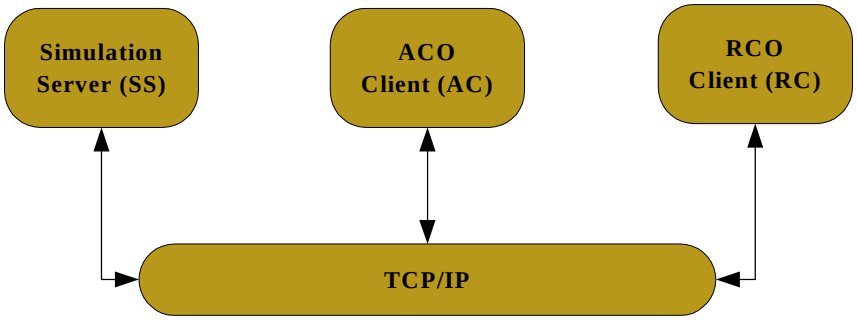


Figure 4-1 Component Connectivity

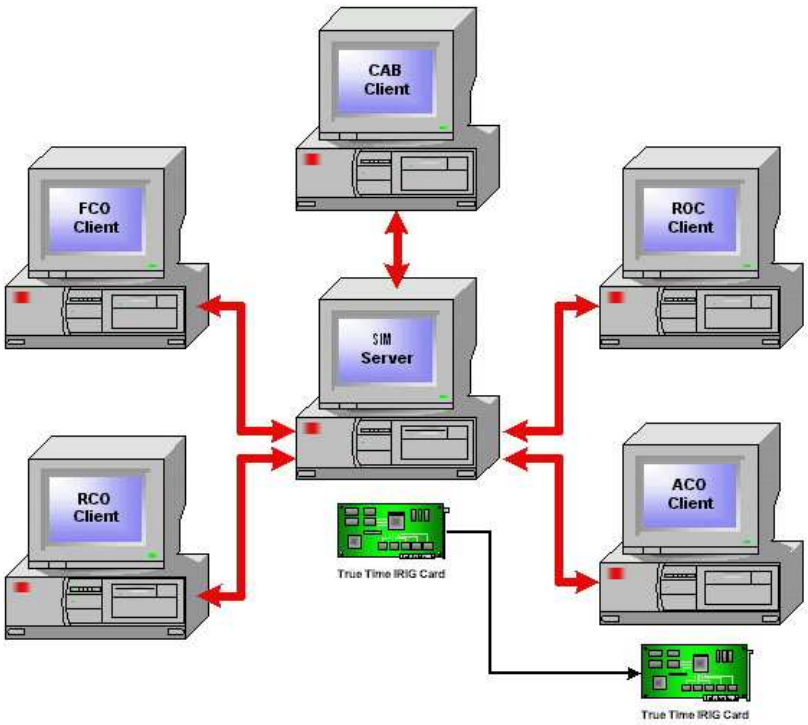


Figure 4-2 Overall Simulator Connectivity

The Simulation Server, the ACO Client, and the RCO Client work together to give the user end-to-end control of a launch training simulation. The Simulation Server computer is equipped with a True Time IRIG card to stamp data packets as they leave the computer via a TCP/IP socket. The only other computer equipped with a True Time IRIG card is the RCO client computer. This computer receives data packets from the Simulation Server and wraps the packet with a time stamp. The time stamp wrapped around the package is then compared to the time stamp embedded in the data stream to determine data latency. This measurand represents the data latency between two points is displayed and recorded to a file. The RCO client computer receives and displays the

current operation number, GMT time, L Clock, T Clock, and T Zero. In addition, this client has a switch capable of stopping the range count on the server.

The ACO client computer receives and displays radar targets along with the current operation number, GMT time, L Clock, T Clock, and T Zero. The ACO client computer is not equipped with a True Time IRIG card. One can also use a GPS daughter card, which, although not as accurate as the IRIG card, allows the flexibility to run the software from any location over the Internet without a coax connection and still provide timing accuracy in the milliseconds.

The Simulation Server is heart of the system and receives numerous inputs from the operator. The inputs and outputs of the Simulation Server are shown in Figure 4-3. The operator has control over all of the timing variables, such as the System/IRIG time, the Operation Number, The L Clock, and the Z Zero. Several variables are derived from these values such as the GMT Time and the T Clock. The current Julian Date is concatenated with the GMT. This data is embedded and transmitted as a TCP/IP string known as the Timing Message.

The operator also has the ability to generate up to 200 radar targets. The operator can alter the target heading, target range, target Mode C or altitude, target Mode 3 or identification, and the target ground speed. This data is embedded and transmitted as a TCP/IP string known as the Radar Message. The format of this message has been specified according to current FAA practice.

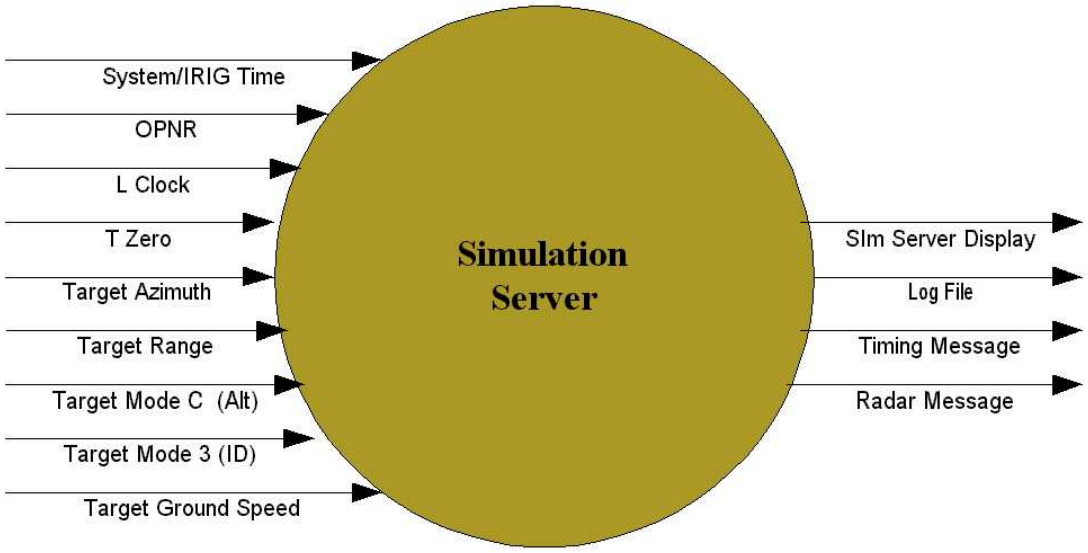


Figure 4-3 Simulation Server Context Diagram

The ACO Client receives numerous inputs from the operator via the RCU Control Panel. These controls allow the ACO to alter the display and graphical appearance of his display. The ACO Client also receives two TCP/IP messages: the Radar Message and the Timing Message. The format and content of these messages is discussed in more detail later in this document. The inputs and outputs of the ACO Client are shown in Figure 4-4.

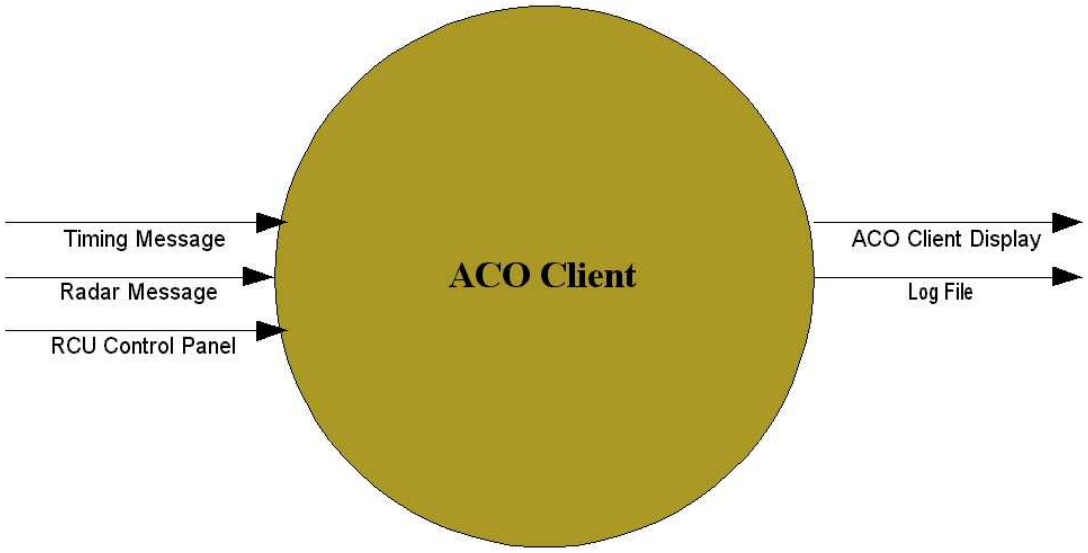


Figure 4-4 ACO Client Context Diagram

The RCO Client has only one input from the operator, the holdfire switch. The RCO Client also receives one TCP/IP messages: the Timing Message. The format and content of these messages is discussed in more detail later in this document. The inputs and outputs of the ACO Client are shown in Figure 4-5.

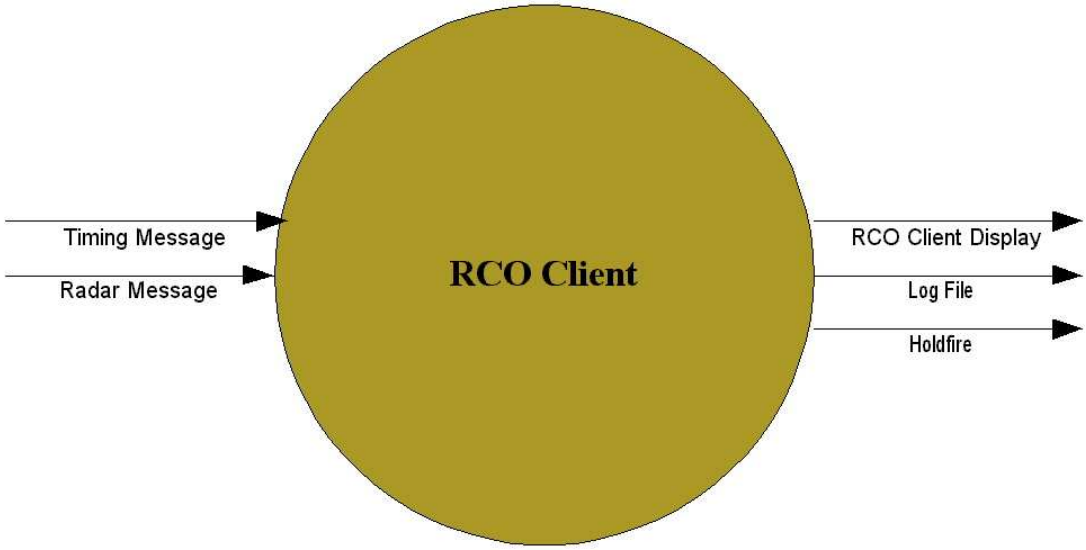


Figure 4-5 RCO Client Context Diagram

There are two messages passed from Sim Server: the radar message and the timing message. The ACO client receives and processes both of these messages while the RCO Client only receives the timing message. The format for the timing message is shown in Table 4.1. The first 4 bytes determine the size of the message. The message type field is not currently used but would allow the flexibility to alter the message contents based on the users future needs. The operation number, Julian date, GMT, L Clock, T Clock, and T Zero are also embedded in the stream. The user hold field functions the same as the RCO Client holdfire switch. The L and T Clocks stop and the GMT time continues. The pause switches pauses the entire simulation, the L Clock, T Clock, and GMT time all stop. The next field is the system time which is read from the IRIG card if it is present. If the card is not found the software will read and embed the current system time from the computer clock. The final field is the checksum and is used

to determine whether the packet was corrupted and needs to be resent during transmission. This field, although available, is not currently used since the data is transmitted every second. This datagram approach nullifies the need for the retransmittal of packets (Table 4.1).

Table 4.1 Time Message Format

TCP/IP Header for Time Display							
Msg Size (4)	Msg Type (1)	OPNR (8)	Julian Date (4)	Sim GMT (8)	L Clock (8)	T Clock (8)	T Zero (4)
User Hold (1)	Sim Pause (1)	System Time (32)			Checksum (1)	N/A	

The other TCP/IP message is the radar message and is received by the ACO client. The format for the radar message is shown in Table 4.2. The first 4 bytes determine the size of the message. Each target requires 33 bytes in the message. Additional targets concatenate themselves to the end of the message. The message size is basically the number of targets multiplied by 33 bytes plus the four bytes reserved for the size. The format starts with the target azimuth (in radians), range (in nautical miles), mode C (actual altitude in feet), and Mode 3A (aircraft 4 digit octal beacon code). The following fields are available in the string but are not currently used: Run length of radar echo, beacon value, alt value byte, radar beacon byte, time in storage before transmission, Id, and St.

Table 4.2 Radar Message Format

TCP/IP Header for ACO Data					
Msg Size Int (4)	Azimuth (radians) Double (8)	Range (Naut. Miles) Double (8)	Mode C (Alt in Feet) Short Int (2)	Mode 3A (4 digit Octal) Short Int (2)	Run Length Short Int (2)
Beacon Byte (2)	Altitude Byte (1)	Radar Beacon Byte (1)	Time Byte (1)	Id Boolean (1)	St Boolean (1)
Padding Double (4)	N/A				

4.2 ACO Client.vi

ACO Client is one of three high level software components of the simulator. It connects to and receives data from Sim Server. It receives a timing and radar message stream from two TCP/IP sockets. See Figure 4-6 for the ACO Client Hierarchy VI Diagram. The modules used by ACO Client are described in more detail in the following Sections. Figure 4-7 shows the display for the ACO Client. See Figure A-1 and Figure A-2 for the LabVIEW code.

Inputs:

Timing data stream (Table 4.1)

Radar data stream (Table 4.2)

Outputs:

Graphical display (Figure 4-7)

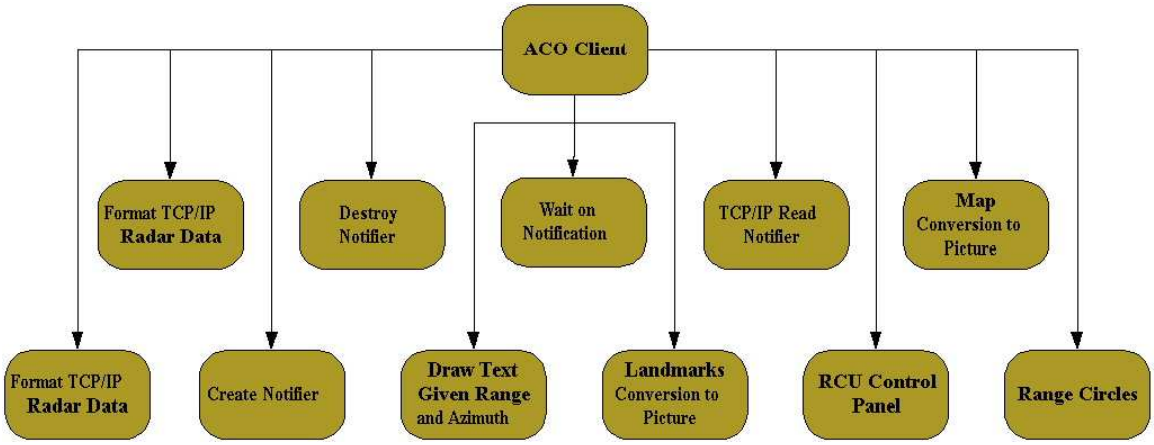


Figure 4-6 ACO Client Hierarchy VI Diagram

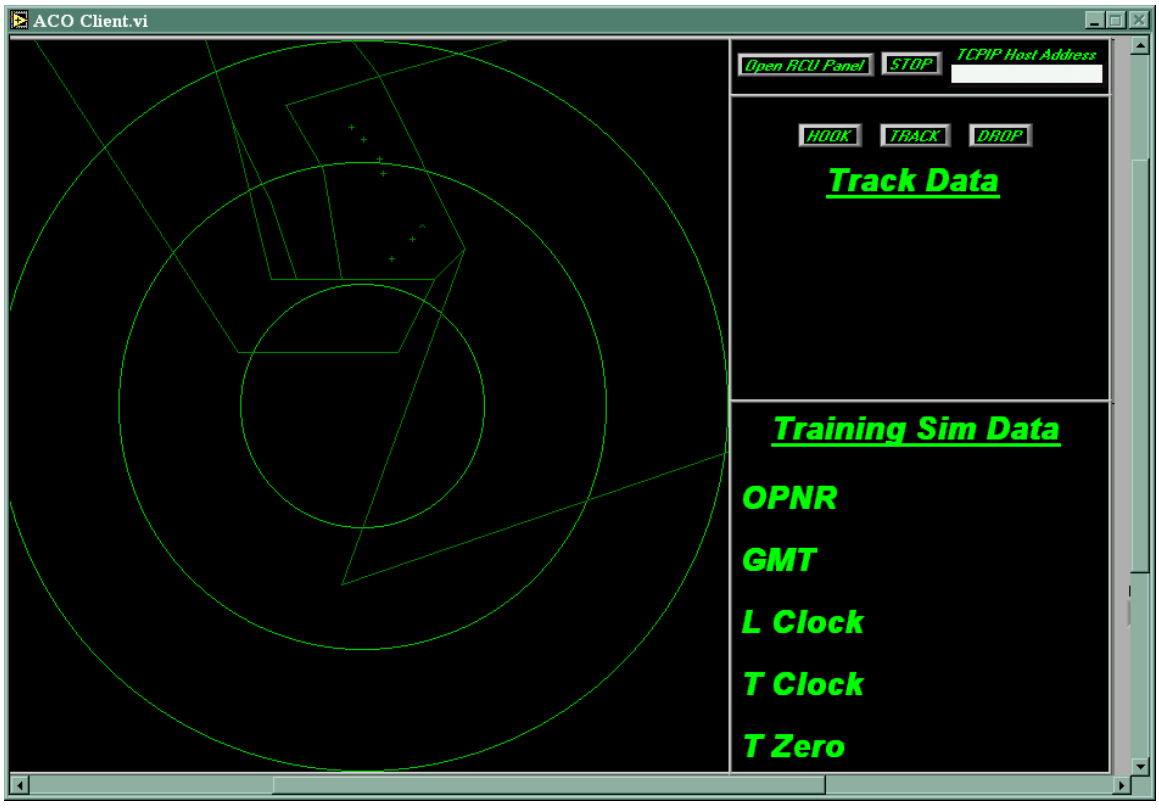


Figure 4-7 ACO Client Display

4.2.1 Create Notifier.vi

Looks up an existing notifier or creates a new notifier and returns a refnum that you can use when calling other Notification VIs. If name is specified, the VI first searches for an existing notifier with the same name and will return its refnum if it exists. If a named notifier with the same name does not already exist and the return existing input is FALSE, the VI will create a new notifier and return its refnum. The created new output returns TRUE if the VI creates a new notifier. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Name - contains the name of the notifier that you are looking up or creating. The default value is an empty string to create an unnamed notifier. LabVIEW does not automatically release named notifiers.

Return Existing - specifies whether you want to create a new notifier if one with that name does not exist. The default value is FALSE, specifying that a notifier should be created if it does not exist.

Error In - describes error conditions that occur before this VI runs. The default input of this cluster is no error. If an error already occurred, this VI returns the value of error in in error out. The VI runs normally only if no incoming error exists. Otherwise, the VI passes the error in value to error out.

Outputs:

Notifier - is a reference to an existing or newly created notifier.

Created New - returns TRUE if a new notifier was created.

Error Out - contains error information. If error in indicates an error, error out contains the same error information. Otherwise, it describes the error status that this VI produces.

4.2.2 Destroy Notifier.vi

Destroys the specified notifier and returns the last notification that was sent. All Wait on Notification VIs that are currently waiting on this notifier will time out immediately and return an error. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Notifier - is a reference associated with a notifier.

Error In - describes error conditions that occur before this VI runs. The default input of this cluster is no error. If an error already occurred, this VI returns the value of "Error In" in "Error Out". The VI runs normally only if no incoming error exists. Otherwise, the VI passes the error in value to error out.

Outputs:

Notifier - name contains the name of the notifier that you are looking up or creating.

Last Notification - contains the last notification sent to the notifier.

Error Out - contains error information. If error in indicates an error, error out contains the same error information. Otherwise, it describes the error status that this VI produces.

4.2.3 Draw Arc.vi

Draws an arc in a picture. A rectangle specifies the size of an oval that contains the arc. Thus, the arc may not fill the whole rectangle. LabVIEW specifies the angles that

describe the arc in degrees. It can range from -360° to 360°, with positive angles appearing clockwise, and negative angles appearing counterclockwise. Zero degrees is straight up. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Arc Size - specifies the length of the arc.

Start Angle - is where the arc begins.

Picture - is the picture to which you want to add the arc. It defaults to an empty picture if you do not wire it.

Rect - is a cluster containing four numerics that describe the left, top, right, and bottom coordinates of the outer edges of the rectangle. Left is the horizontal coordinate of the left edge of the rectangle. Top is the vertical coordinate of the top edge of the rectangle. Right is the horizontal coordinate of the right edge of the rectangle. Bottom is the vertical coordinate of the bottom edge of the rectangle.

Fill - specifies whether to fill the rectangle. If FALSE (default), the VI draws only the arc component (it does not draw interior bounds of the wedge).

Color - is a color numeric that specifies the color of the arc. If the arc is filled, the VI uses this color for the interior. The default is black.

Black in B/W - specifies whether the arc should be black or white if you display it on a black-and-white monitor. The default is black (TRUE).

Outputs:

New Picture - is the modified picture.

4.2.4 Draw Circle by Radius.vi

Draws a circle based on a specified radius and center point. The VI uses this information and calls the Draw Oval VI. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Arc Size - determines the degree value of the circle you want to draw. For example, a value of 360 creates a complete circle, and a value of 180 creates a semicircle. *Start Angle* - is where the arc begins.

Picture - determines what picture, if any, to concatenate this drawing to. If this input is unwired, it defaults to empty picture.

Radius - determines the size of the circle, in pixels. If, for example, this value is 40, the radius of the resulting circle is 40 pixels.

Pixel Center - is a cluster containing the upper-left and lower-right coordinates that describe a rectangle bounding the text. The text will be clipped to this rectangle. All coordinates are absolute.

Horizontal - determines where the pixel center of the circle is from the left side of the picture control.

Vertical - determines where the pixel center of the circle is from the top of the picture control.

Fill - specifies whether to fill the oval. It defaults to drawing only the frame (FALSE).

Color - specifies the color of the oval. This sets the pen's color. If no color is specified, the last color specified as the pen's color will be used.

Black in B/W - specifies whether the oval appears as black or white if you choose to display in black and white. The default is black (TRUE). This value is ignored if no color is specified as the RGB Color.

Outputs:

New Picture - is the indicator that holds the new picture created using this VI.

4.2.5 Draw Multiple Lines.vi

Draws multiple connected lines into a picture. You can also use it to draw color-filled polygons by passing TRUE to the fill input. All points are absolute coordinates. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Picture - is the picture to which you want to add lines. It defaults to an empty picture.

Line - endpoints is an array of points describing the lines to draw. The lines are drawn in the specified color, connecting the points in order. All coordinates are absolute. X is the horizontal coordinate that increases to the right and y is the vertical coordinate that increases to the bottom.

Fill - specifies whether to fill the interior. It defaults to drawing only the lines (FALSE).

Color - is a color numeric that specifies the color of the lines. If the interior is filled, the VI uses this color for the interior. The default is black.

Black in B/W - specifies whether the lines appear as black or as white if you display it on a black-and-white monitor. The default is black (TRUE).

Outputs:

New Picture - is the modified picture.

4.2.6 Draw Text Given Range and Azimuth.vi

Overlays text onto the original picture based on range and azimuth data. See Figure A-4 for the LabVIEW code.

Inputs:

Original picture

Text

Range and Azimuth Data

Outputs:

New Picture

Map Intensity

4.2.7 Draw Text in Rect.vi

Draws a rectangle, optionally filling the interior. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Picture - is the picture to which you want to add the rectangle. It defaults to an empty picture.

Rect - is a cluster containing four numerics that describe the left, top, right, and bottom coordinates of the outer edges of the rectangle.

Left - is the horizontal coordinate of the left edge of the rectangle.

Top - is the vertical coordinate of the top edge of the rectangle.

Right - is the horizontal coordinate of the right edge of the rectangle.

Bottom - is the vertical coordinate of the bottom edge of the rectangle.

Fill - specifies whether to fill the rectangle. It defaults to drawing only the frame (FALSE).

Color - is a color numeric that specifies the color of the rectangle border. If the rectangle is filled, the VI also uses this color for the interior. The default is black.

Black in B/W - specifies whether the rectangle should be black or white if you display it on a black-and-white monitor. The default is black (TRUE).

Outputs:
New Picture - is the modified picture.

4.2.8 Format TCP/IP Radar Data.vi

Converts the notifier string into an array of clustered radar data suitable for displaying on the ACO client screen. This program performs the inverse of Radar data array to string conversion.vi. See Figure A-6 for the LabVIEW code.

Inputs:

Notifier

Outputs:

Radar Message (Table 4.2)

4.2.9 Get Text Rect.vi

Returns the bounding rectangle of a string. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

User-specified Font - is a cluster containing the specific font characteristics for the text you draw. The VI uses this input only if you set the desired font input to zero (user-specified font).

Font Name - selects the font to use for the string.

Font Size - selects the size of the font in points.

Strikeout - If true, text appears in strikeout.

Italic - If true, text appears in italic.

Underline - If true, text appears underlined.

Outline - If true, text appears in outline.

Shadow - If true, text appears in shadow.

Bold - If true, text appears in bold.

Desired Font - specifies the font for the text you draw

Alignment - specifies the location of the text relative to the specified origin.

Horizontal - is an enumeration that you use to specify the horizontal position of the text with respect to the origin.

Vertical - is an enumeration that you use to specify the vertical position of the text with respect to the origin.

Origin - is the coordinate of the starting point of the text.

Text - specifies the string of text to be drawn.

Outputs:

Rect - is a cluster containing four numerics that describe the left, top, right, and bottom coordinates of the outer edges of the rectangle.

4.2.10 Landmarks Conversion to Picture.vi

Overlays text onto the original picture based on latitude, longitude, and a display icon contained in the landmarks.txt file. Landmark.txt contains various points of interest for the area surrounding the radar. The landmark file for the cape can be found in appendix A.3. The user can replace this with the latitude and longitude of landmarks for their radar area of operation. This program accurately scales and repositions the landmarks on the display based on switch positions located on the ACO's D-BRITE Control panel. This was accomplished using an algorithm to calculate the distance between two points on the Earth. Since the shape of the Earth is spherical, calculating the exact distance between two points requires spherical geometry and trigonometric math functions. The math can be simplified using an approximation algorithm [5]. For example:

Approximate distance in miles = sqrt (x * x + y * y)

where x = 69.1 * (lat2 – lat1)

and y = 53 * (lon2 – lon1)

The accuracy can be improved by adding the cosine math function:

Approximate distance in miles = sqrt (x * x + y * y)

where x = 69.1 * (lat2 – lat1)

and y = 69.1 * (lon2 – lon1) * cos (lat1/57.3)

See Figure A-8 and Figure A-9 for the LabView Code.

Inputs:

RCU Control Panel Controls
Original picture

New Center

Lat/Lon

Pixels/NM

Switch 3

Default Picture Center (Pixels)

Map Intensity

Landmarks.txt

Outputs:

New Picture

4.2.11 Map Conversion to Picture.vi

Overlays lines onto the original picture based on latitude and longitude contained in the maps.txt file. Maps.txt contains various corner points of the restricted airspace for the area surrounding the radar. The landmark file for the cape can be found in appendix A.4. This module uses the same mathematical algorithm to accurately convert latitude and longitude to pixel location as the Landmark Conversion to Picture module [5]. See Figure A-10 for the LabVIEW code. This program accurately scales and repositions the maps on the display based on the following switch positions that are located on the ACO's D-BRITE Control panel.

Inputs:
RCU Control Panel Controls
Original picture

New Center

Lat/Lon

Pixels/NM

Switch 5

Default Picture Center (Pixels)

Map Intensity

Maps.txt

Outputs:

New Picture

4.2.12 Mouse Global.vi

Contains global variables used by Draw Text Given Range and Azimuth.vi, Landmark Conversion to Picture.vi, Map Conversion to Picture.vi, Range Circles.vi, RCU Panel.vi, ACO Client.vi, and Sim Server.vi. The use of these global variables allows RCU Panel.vi to modify various scaling and display aspects of the data displayed by ACO Client.vi.

Inputs:

Circle intensity

Map intensity

Actual Range

Circle Radius

Switch 3

Switch 5

Pixels/NM

Center Offset (Pixels)

Picture Bounds

New Picture Center (Pixels)

Default Picture Center (Pixels)

Default Center lat/lon

New Center lat/lon

Radar Message

Ground Speed

XY Center Dist NM

Outputs:

Same as the inputs listed above.

4.2.13 Picture Position Adjuster.vi

Allows objects that require a 4 parameter rect specification for drawing (like text boxes) to be repositioned with the specification of an x and y position. See Figure A-13 for the LabVIEW VI diagram.

Inputs:

Original Rect,

New X and Y

Outputs:

New Picture

Adjusted Rect

4.2.14 Range Circles.vi

Accurately scales, positions, and chooses the correct number of range circles and overlays them on the display based on switch positions located on the ACO's D-BRITE Control panel. See Figure A-15 for the LabView Code.

Inputs:
RCU Control Panel Controls
Original picture

New Center

Lat/Lon

Pixels/NM

Default Picture Center (Pixels)

Map Intensity

Outputs:

New Picture

4.2.15 RCU Control Panel.vi

The RCU Control Panel is the operator's control for the ACO Client display. See Figure 4-8 for a RCU Control Panel. See the following figures for the VI code: Figure A-20, Figure A-21, and Figure A-22. The operator can adjust the following controls:
Video Gain Map Control Knob - Determines the intensity of the maps and landmark icons.
Range Selection Knob - Determines the maximum distance in nautical miles viewable from the picture center location to the edge of the picture. This is equivalent to the picture radius. It is selectable between 10, 30, 60 or variable.

Range Inc (+) Dec (-) Switch - Allows the operator to manually adjust the radius of the display from 2 to 60 nautical miles. This control is only accessible when the Range Selection Knob is set to variable mode.

Decenter On/Off Toggle Switch - When decenter mode of operation is in the off position it centers the display on the radar center location. When decenter mode of operation it enables the decenter joystick.

Decenter Joystick - Is only functional when the decenter On/Off toggle switch is in the On position. Allows the operator to change the display's center position.

Map Switch 3 - Toggles the landmarks on and off on the display.

Map Switch 5 - Toggles the maps on and off on the display.

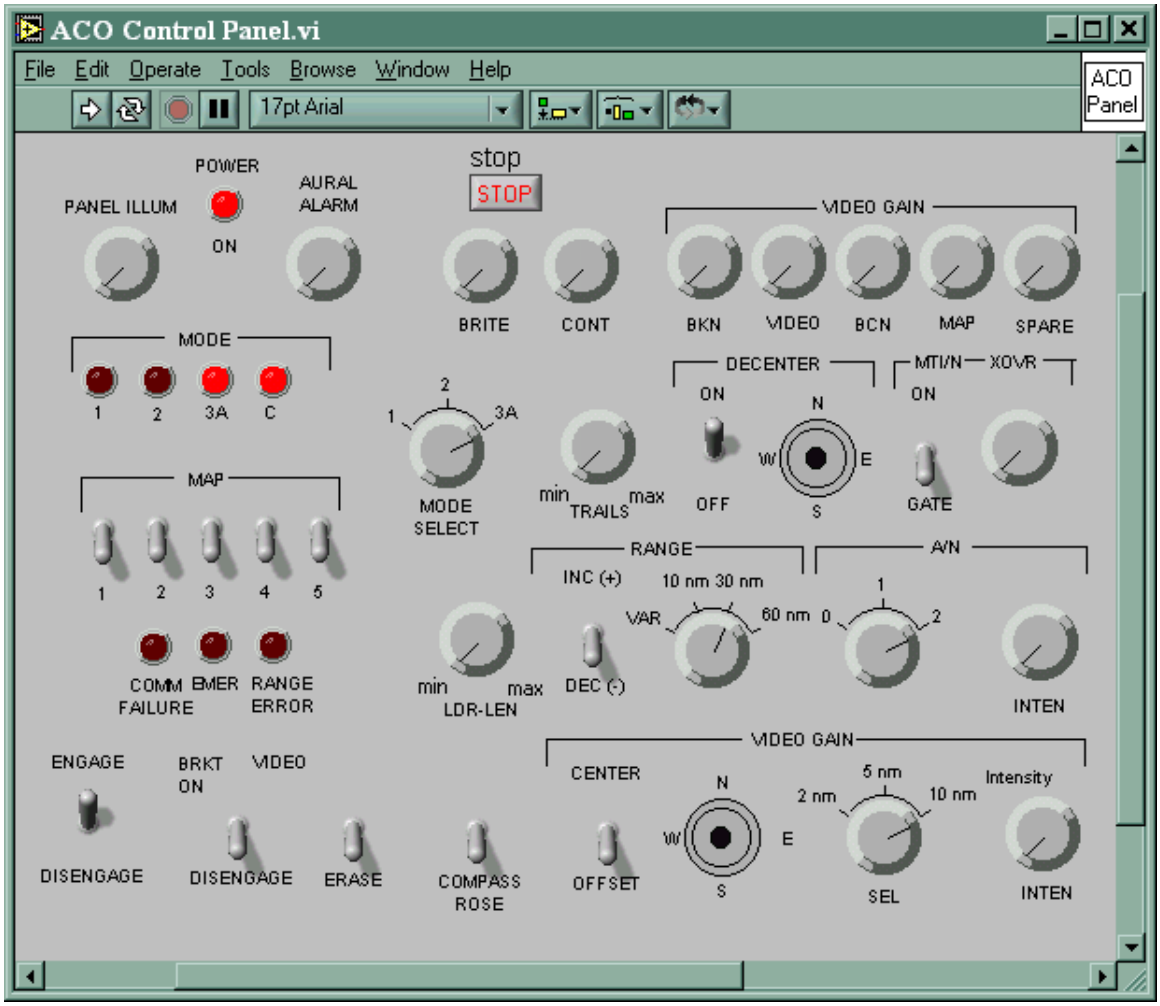


Figure 4-8 RCU Control Panel VI Diagram

4.2.16 Read From Spreadsheet File.vi

Reads a specified number of lines or rows from a numeric text file beginning at a specified character offset and converts the data to a 2D, single-precision array of numbers. You can optionally transpose the array. The VI opens the file before reading from it and closes it afterwards. You can use this VI to read a spreadsheet file saved in text format. This VI calls the Spreadsheet String to Array function to convert the data.

This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Format - specifies how to convert the numbers to characters. If the format string is %.3f (default), the VI creates a string long enough to contain the number, with three digits to the right of the decimal point. If the format is %d, the VI converts the data to integer form using as many characters as necessary to contain the entire number.

File Path - is the path name of the file. If file path is empty (default value) or is Not A Path, the VI displays a file dialog box from which you can select a file. Error 43 occurs if you select Cancel from the dialog box.

Number Of Rows - is the maximum number of rows or lines the VI reads. For this VI, a row is a character string ending with a carriage return, line feed, or a carriage return followed by a line feed; a string ending at the end of file; or a string that has the maximum line length specified by the max characters per row input. If number of rows is < 0, the VI reads the entire file. The default value is -1.

Start Of Read - offset is the position in the file, measured in characters (or bytes), at which the VI begins reading.

Max Characters/Row - is the maximum number of characters the VI reads before ending the search for the end of a row or line. The default is 0, which means that there is no limit to the number of characters the VI reads.

Transpose - is set TRUE to transpose the data after converting it from a string. The default value is FALSE.

Delimiter - contains an input string, which you can use to specify a character or a string of characters as a delimiter, such as tabs, commas, and so on, to use in your spreadsheet.

Outputs:

New File Path - is the path of the file from which the VI reads data. You can use this output to determine the path of a file that you open using a file dialog box.

new file path returns Not A Path if you select Cancel from the dialog box.

All Rows - is the data read from the file in the form of a 2D array of single-precision numbers.

First Row - is the first row of the all rows array in the form of a 1D array of single-precision numbers. You can use this output when you want to read one row into a 1D array.

Mark After Read - is the location of the file mark after the read; it points to the character (byte) in the file following the last character read.

EOF - is TRUE if you attempt to read past the end of file.

4.2.17 Read Lines From File.vi

Reads a specified number of lines from a byte stream file beginning at a specified character offset. The VI opens the file before reading from it and closes it afterwards. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Convert EOL - determines whether the function converts the end of line markers it reads into LabVIEW end of line markers. The system-specific end of line marker is a carriage

return followed by a line feed on Windows, a carriage return on Macintosh, and a line feed on UNIX. The LabVIEW end of line marker is a line feed. If convert eol is TRUE, the function converts all end of line markers it encounters into line feeds. If convert eol is FALSE, the function does not convert the end of line markers it reads. convert eol defaults to FALSE.

File Path - is the path name of the file. If file path is empty (default value) or is Not A Path, the VI displays a file dialog box from which you can select a file. Error 43 occurs if you select Cancel from the dialog box.

Number Of Lines - is the maximum number of characters the VI reads. The VI reads fewer characters if it reaches the end of file first. If number of lines is < 0, the VI reads the entire file. The default value is -1.

Start Of Read - offset is the position in the file, measured in characters (or bytes), at which the VI begins reading.

Max Characters Per Line - is the maximum number of characters the VI reads before ending the search for the end of a line. The default is 0, which means that there is no limit to the number of characters the VI reads.

Outputs:

New File Path - is the path of the file from which the VI reads data. You can use this output to determine the path of a file that you open using a file dialog box. new file path returns Not A Path if you select Cancel from the dialog box.

Line String - is the data read from the file.

Mark After Read - is the location of the file mark after the read; it points to the character (byte) in the file following the last character read.

EOF - is TRUE if you attempt to read past the end of file.

4.2.18 Send Notification.vi

Sends notification to the specified notifier. All Wait On Notification VIs that are currently waiting on this notifier stop waiting and return the specified notification. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Notifier - is a reference associated with a notifier.

Notification - is a string sent to the Wait on Notifier function waiting on the notifier.

Error In - describes error conditions that occur before this VI runs. The default input of this cluster is no error. If an error already occurred, this VI returns the value of error in in error out. The VI runs normally only if no incoming error exists. Otherwise, the VI passes the error in value to error out.

Outputs:

Notifier Out - has the same value as notifier.

Error Out - contains error information. If error in indicates an error, error out contains the same error information. Otherwise, it describes the error status that this VI produces.

4.2.19 TCP/IP Read Notifier

Reads a string over TCPIP given an address and port number and sends the data out via a notifier. Reads data from a TCPIP connection given a port and host address. Reports the connection ID via TCPIP Status Global.vi.

Inputs:

Notifier

Address

Remote Port

Outputs:

6340 – Timing Data to RCO Client

6341 – Timing Data ACO Client

6342 – Radar Data to ACO Client

4.2.20 TCP/IP Status Global.vi

Contains global variables used by TCPIPListenGlobalStatus.vi, TCPIPReadNotifier.vi, and TCPIPWriteNotifierGlobalStatus.vi. Globals are necessary since status is required while the TCPIP programs are in while loops. Without globals, data could not be passed out of these routines until they were finished waiting for TCPIP connections.

Inputs:

N/A

Outputs:

6340 TCPIP Status (global),

6340 Blinking (global), 6340 Status String (global), 6340 Read Connection ID (global), 6340 Write Connection ID (global),

6341 TCPIP Status (global), 6341 Blinking (global), 6341 Status String (global), 6341 Read Connection ID (global), 6341 Write Connection ID (global)

6342 TCPIP Status (global), 6342 Blinking (global), 6342 Status String (global), 6342 Read Connection ID (global), 6342 Write Connection ID (global).

4.2.21 Wait on Notification.vi

Waits for the Send Notification VI to send notification to the specified notifier. If ignore previous is FALSE and a notification was sent since the last time this VI was called, the VI returns immediately with the value of the old notification and with timed out as FALSE. If the ignore previous input is TRUE, the VI will wait timeout milliseconds (default -1, or forever) before timing out. If a notification is sent, timed out will return FALSE. If a notification is not sent or if notifier is not valid, timed out will return TRUE. This module was supplied by National Instruments Incorporated and was used without modification [6].

Inputs:

Notifier - is a reference associated with a notifier.

Ignore Previous - specifies whether notifications sent to the notifier since the last time this function was called should be ignored. The default value is TRUE.

MS Timeout - specifies how many milliseconds the function waits for a notification to arrive. The default value is -1, indicating never to time out.

Error In - describes error conditions that occur before this VI runs. The default input of this cluster is no error. If an error already occurred, this VI returns the value of error in in error out. The VI runs normally only if no incoming error exists. Otherwise, the VI passes the error in value to error out.

Outputs:

Notifier Out - has the same value as notifier.

Notification - contains the last notification sent to the notifier.

Timed Out - returns TRUE if no notification arrived before the function timed out or if an error occurred.

Error Out - contains error information. If error in indicates an error, error out contains the same error information. Otherwise, it describes the error status that this VI produces.

4.3 RCO Client.vi

RCO Client.vi is a top level program and displays training simulation data sent by Sim Server.vi over a TCPIP connection. RCO Client also reads the current time (either from an IRIG card if present, or system time if not) and compares it to the time sent from Sim Server.vi to measure TCPIP data latency. If an IRIG Card is present, this program initializes the card in slave mode so the IRIG card is in sync with the card present in the computer running the Sim Server.vi program. . It receives a timing message stream from a TCP/IP sockets. See Figure 4-9 for the RCO Client Hierarchy VI Diagram. The modules used by RCO Client are described in more detail in the following sections. Figure 4-10 shows the display for the RCO Client. See Figure A-17, Figure A-18, and Figure A-19 for the LabVIEW code.

Inputs:

Timing data stream (Table 4.1)

Outputs:

Graphical display (Figure 4-10)

Holdfire

Stop

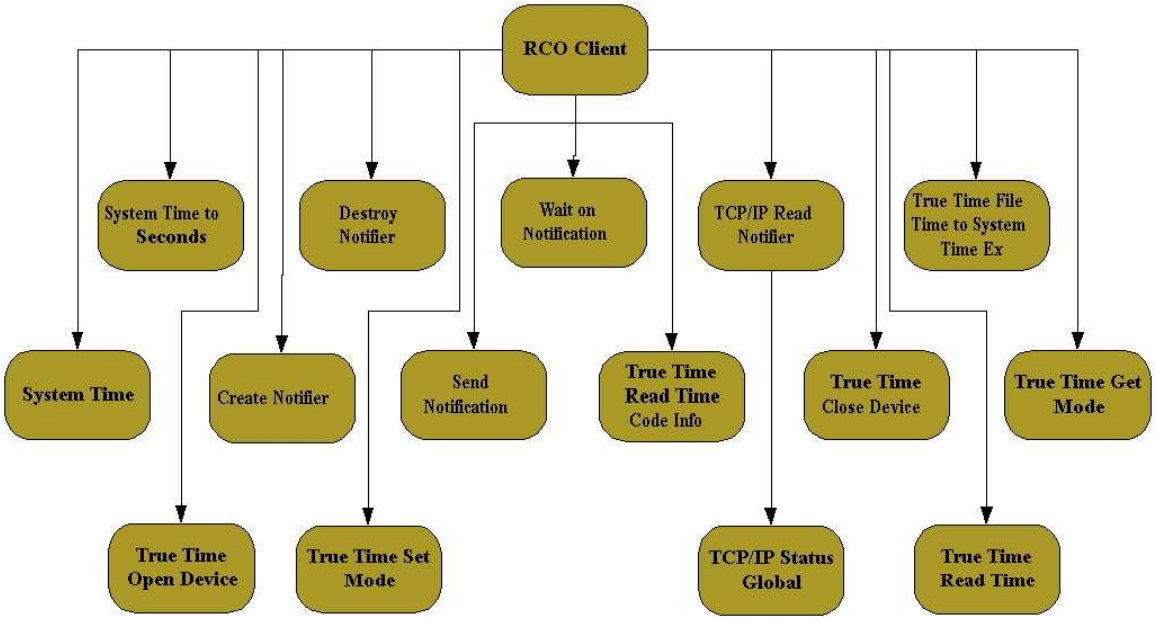


Figure 4-9 RCO Client Hierarchy VI Diagram

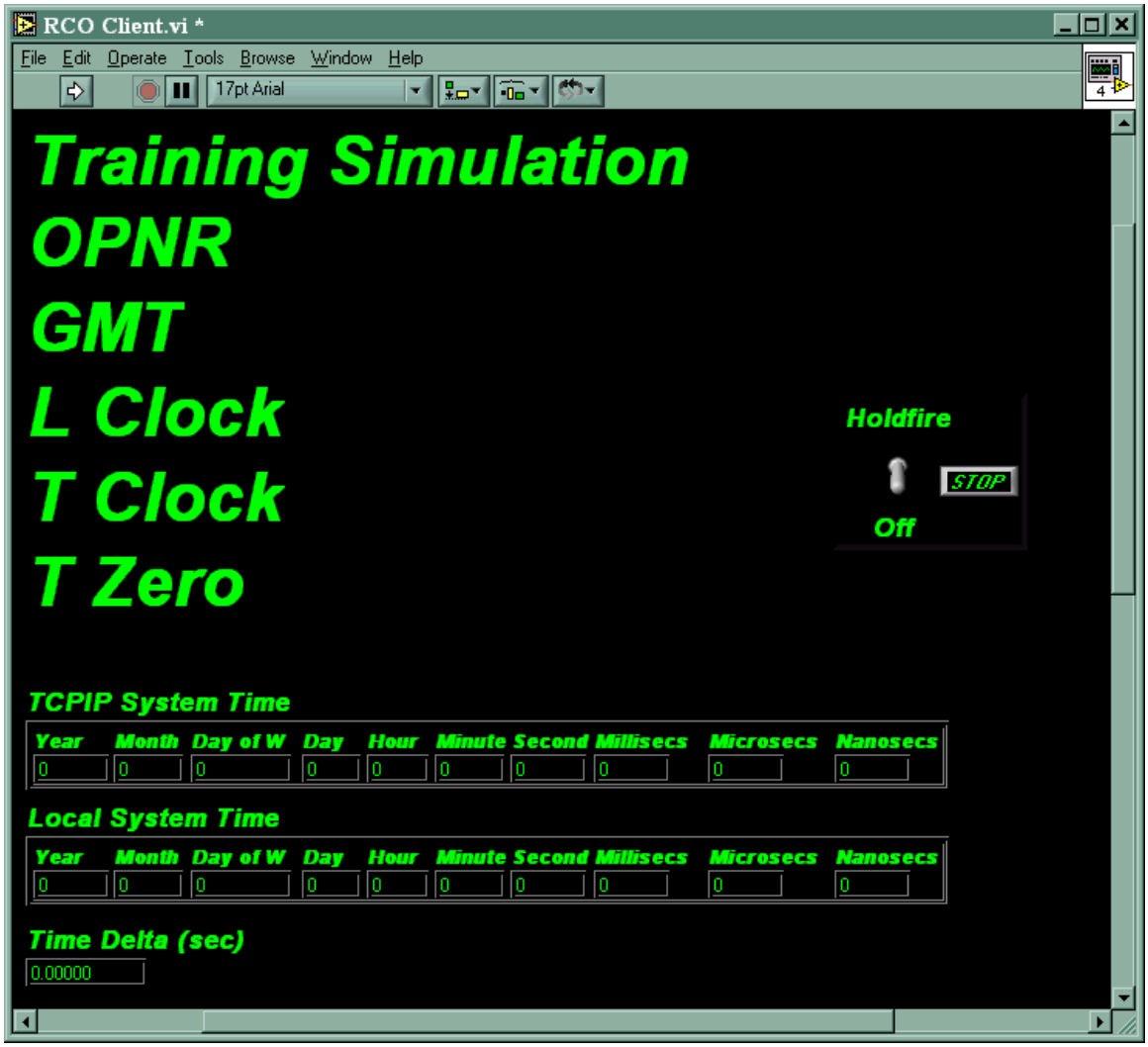


Figure 4-10 RCO Client Display

4.3.1 Create Notifier.vi

See Section 4.2.1.

4.3.2 Destroy Notifier.vi

See Section 4.2.2.

4.3.3 Send Notification.vi

See Section 4.2.18.

4.3.4 System Time.vi

Calls the windows .dll to get the system time and modifies it to conform to the Truetime IRIG time format. See Figure A-7 for the LabVIEW code.

Inputs:

N/A

Outputs:

Output Cluster

4.3.5 System Time to Seconds.vi

Does math to convert system time to total seconds. Converts the cluster of individual time elements to total seconds so that data latency can be calculated in seconds.

Inputs:

Cluster

Outputs:

Delta Seconds

4.3.6 TCP/IP Read Notifier

See Section 4.2.19.

4.3.7 TCP/IP Status Global.vi

See Section 4.2.20.

4.3.8 True Time Close Device.vi

Detaches the calling application from the specified TrueTime device. This function should be called by every application using the TrueTime SDK, prior to termination. It performs resource de-allocation and other cleanup operations. This module was supplied by True Time Incorporated and was used without modification [8]. See Figure A-39.

Inputs:

Reference Handle

Error Status

Outputs:

Error Status

4.3.9 True Time File Time to System Time.vi

This function converts a 64-bit file time to system time format. It only works with FILETIME values that are less than 0x8000000000000000. Converts from file time that is in two 32 bit pieces representing total seconds since 1904 to a cluster of time elements (Year, Month, Day of Week, Day, Hour, Minutes, Seconds, Milliseconds, Microseconds, Nanoseconds) referred to as system time. This module was supplied by True Time Incorporated and was used without modification [8]. See Figure A-41, Figure A-42, and Figure A-43 for the LabVIEW diagrams.

Inputs:

File Time

Error In

Outputs:

System Time

Error Out

4.3.10 True Time Get Mode.vi

This function gets the current operating mode, which is maintained by the hardware in non-volatile memory. Since the hardware is pre-configured by the factory, it is not necessary for any application to call this function. However, it is available for situations where the factory settings must be known. This function requires FILE_SHARE_READ access. This module was supplied by True Time Incorporated and was used without modification (Figure A-48) [8].

4.3.11 True Time Open Device.vi

Attaches the calling application to the specified TrueTime device. This function must be called by every application using the TrueTime SDK. The parameter *dwDeviceID* is the zero-based ID of the desired board. Board ID's start with the value zero, and increment for each available board. An application can determine the number of boards available by incrementing *dwDeviceID* until the error TT_STATUS_INVALID_ID is returned. Multiple device support is only available on Windows NT. This function performs resource allocation and other initialization

operations. Only one application can open a device with GENERIC_WRITE access. This module was supplied by True Time Incorporated and was used without modification [8].

Inputs:

N/A

Outputs:

Error Status

4.3.12 True Time Read Time.vi

This function retrieves the current time value from the device, converting it as specified by *bLocalTime*. In GPS mode, time is always maintained in UTC. In other modes, time is application specific. This function requires FILE_SHARE_READ access. This module was supplied by True Time Incorporated and was used without modification. This module was supplied by True Time Incorporated and was used without modification (Figure A-54) [8].

4.3.13 True Time Read Time Code Info.vi

This function reads the Locked/Valid status for the TimeCode Input. This function requires FILE_SHARE_READ access and is only available in TimeCode mode. This module was supplied by True Time Incorporated and was used without modification (Figure A-55) [8].

Inputs:

N/A

Outputs:

TT_Status

4.3.14 True Time Set Mode.vi

This function sets the current operating mode, which is maintained by the hardware in non-volatile memory. Since the hardware is pre-configured by the factory, it is not necessary for any application to call this function. However, it is available for situations where the factory settings must be changed. This module was supplied by True Time Incorporated and was used without modification (Figure A-58) [8].

Inputs:

N/A

Outputs:

TT_Status

4.3.15 Wait on Notification.vi

See Section 4.2.21.

4.4 Sim Server.vi

Sim Server is one of three high level software components of the simulator. It connects to and transmits receives data from ACO Client and RCO Client. It transmits a timing and radar message stream from two TCP/IP sockets. See Figure 4-11 for the Sim Server Client Hierarchy VI Diagram. The modules used by Sim Server are described in more detail in the following sections. Figure 4-12 shows the display for the Sim Server.

See the following figures for the LabVIEW code: Figure A-23, Figure A-24, Figure A-25, Figure A-26, and Figure A-27.

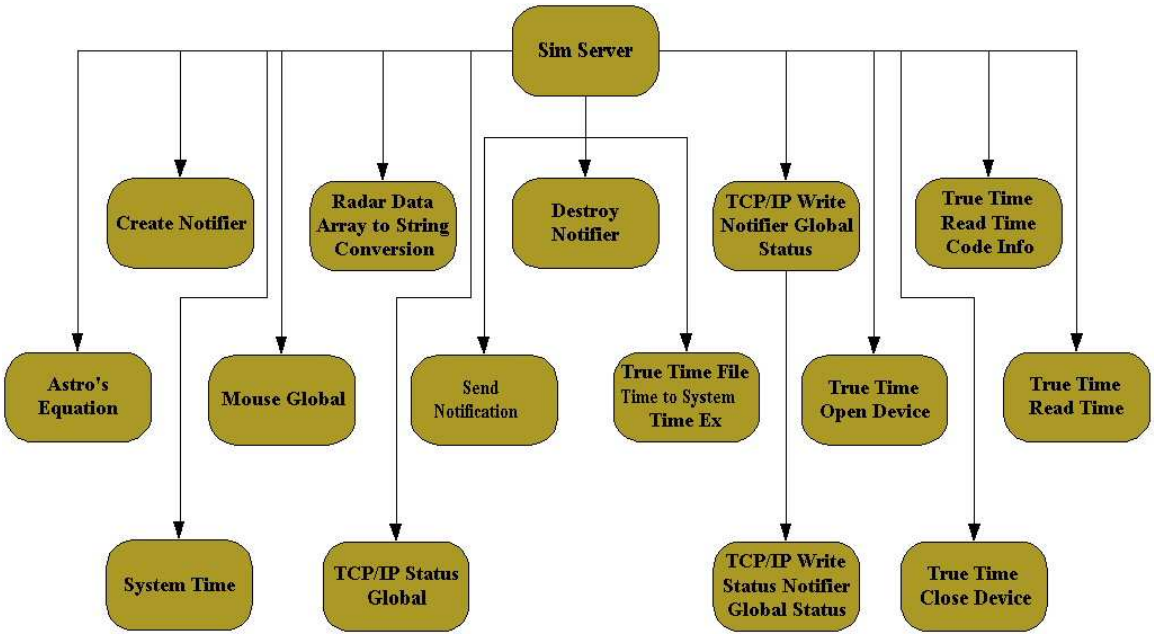


Figure 4-11 Sim Server Display Hierarchy VI Diagram

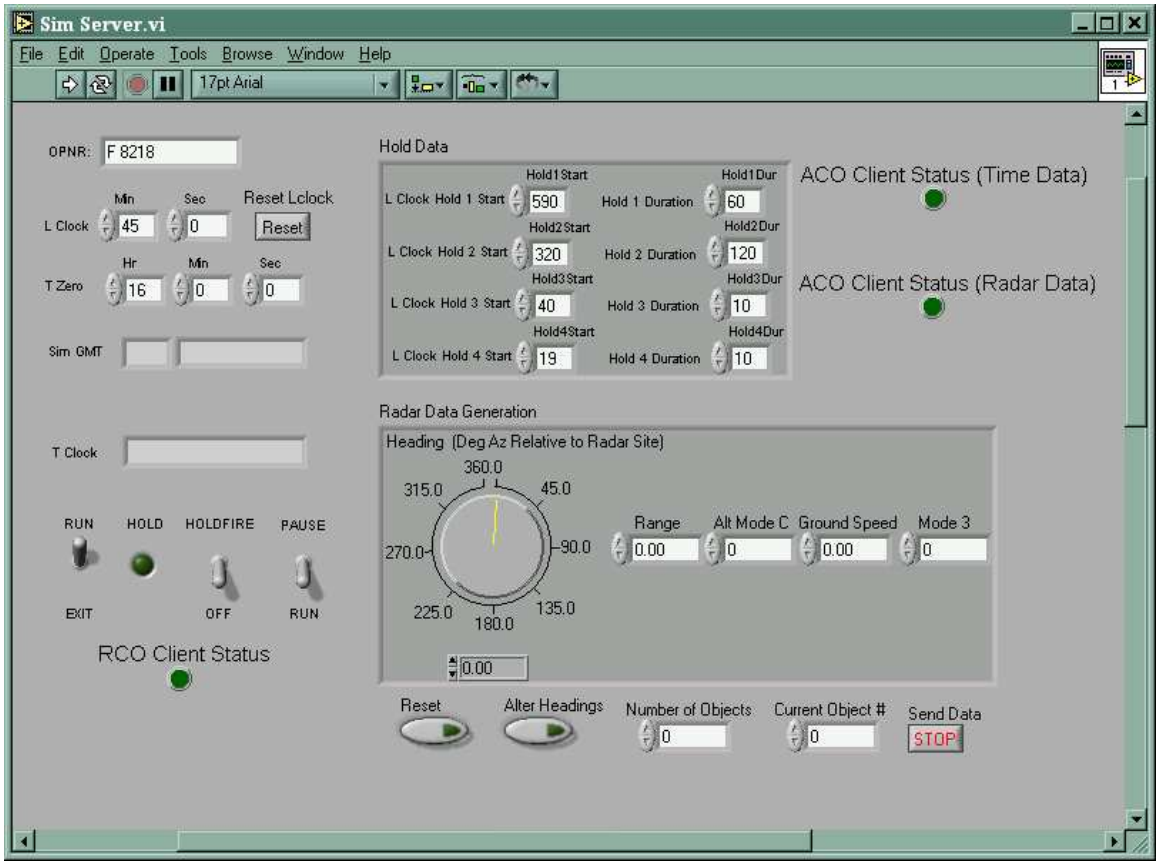


Figure 4-12 Sim Server Display

4.4.1 Astro's Equation.vi

This module provides the basis for range timing. This algorithm calculates times instead of reading it from a system clock. This allows the flexibility to tie the Sim GMT time, the L Clock, the T Clock with its scheduled holds, and the Launch T Zero together just as they are on a real launch. It also ties in the functionality of the holdfire switch. This module is dependant on an external timer firing it every 1000 milliseconds. The pseudo code for this algorithm is listed below. Refer to Figure A-3 for the LabVIEW code.

```
Initialize variables
Calculate SimGMT Total Seconds
if Hold is off
    if TZeroTotSec >= LClkTotSec
        SimGMTTotSec = TZeroTotSec - LClkTotSec
    else
        SimGMTTotSec = 86400 - LClkTotSec + TZeroTotSec
if Hold is on
        SimGMTTotSec = SimGMTTotSec + 1

Check for Sim GMT day clock rollover
if SimGMTTotSec = 0
         DayofYear = DayofYear + 1

Calculate Sim GMT Hours, Minutes and Seconds
SimGMTSec = SimGMTTotSec mod 60
SimGMTMin = SimGMTTotSec - SimGMTSec) / 60) mod 60
SimGMTHr = (((SimGMTTotSec - SimGMTSec) / 60) - SimGMTMin) / 60
Check for Sim GMT clock rollover
if SimGMTHr >= 24
    SimGMTHr = SimGMTHr – 24

Calculate L Clock Minutes and Seconds
LClkSec = LClkTotSec mod 60
LClkMin = (LClkTotSec - LClkSec) / 60

Calculate Total Hold Time
TotalHold = 0;
if (LClkTotSec >= (Hold1Start - Hold1Dur) * 60)
      TotalHold = Hold1Dur + Hold2Dur + Hold3Dur + Hold4Dur
else if ((LClkTotSec >= (Hold2Start - Hold2Dur) * 60))
      TotalHold = Hold2Dur + Hold3Dur + Hold4Dur
else if (LClkTotSec >= (Hold3Start - Hold3Dur) * 60)
      TotalHold = Hold3Dur + Hold4Dur
else if (LClkTotSec >= (Hold4Start - Hold4Dur) * 60)
      TotalHold = Hold4Dur
else
      TotalHold = 0

Calculate T Clock Minutes
if LClkTotSec < Hold1Start * 60 and LClkTotSec >= Hold1Start - Hold1Dur * 60
         TClkMin = Hold1Start - TotalHold
else if LClkTotSec < Hold2Start * 60 and LClkTotSec >= Hold2Start - Hold2Dur * 60
         TClkMin = Hold2Start - TotalHold;
```

*else if LClkTotSec < Hold3Start * 60 and LClkTotSec >= Hold3Start - Hold3Dur * 60*
TClkMin = Hold3Start - TotalHold;
*else if LClkTotSec < Hold4Start * 60 and LClkTotSec >= Hold4Start - Hold4Dur * 60*
TClkMin = Hold4Start - TotalHold
else
*TClkTotSec = LClkTotSec - (TotalHold * 60)*
TClkSec = TClkTotSec mod 60
TClkMin =abs((TClkTotSec - TClkSec) / 60)

Inputs:

Hold1Start – The start time of the first scheduled hold base on the L Clock minutes.

Hold1Dur – The duration of the first scheduled hold entered in minutes.

Hold2Start – The start time of the second scheduled hold base on the L Clock minutes.

Hold2Dur – The duration of the second scheduled hold entered in minutes.

Hold3Start – The start time of the third scheduled hold base on the L Clock minutes.

Hold3Dur – The duration of the third scheduled hold entered in minutes.

Hold4Start – The start time of the fourth scheduled hold base on the L Clock minutes.

Hold4Dur – The duration of the fourth scheduled hold entered in minutes.

TzeroHr – The T Zero start time hours.

TzeroMin – The T Zero start time minutes.

TzeroSec – The T Zero start time seconds.

LclkMin – The L Clock start time minutes.

LclkSec – The L Clock start time seconds.

Holdfire – A true / false condition that determines whether a holdfire has occurred.

Pause – A true / false condition that determines whether a pause has occurred.

Outputs:

SimGMT– A string that has the current Julian day and the calculated GMT time.

L Clock – A string that has the current L Clock time in minutes and seconds.

T Clock – A string that has the current T Clock time in minutes and seconds.

4.4.2 Create Notifier

See Section 4.2.1.

4.4.3 Destroy Notifier

See Section 4.2.2.

4.4.4 Mouse Global.vi

See Section 4.2.12.

4.4.5 Radar Data Array to String Conversion.vi

Unbundles the clustered data array from the input and converts is to a string suitable for sending over a TCPIP connection. This program performs the inverse of Format TCPIP Radar Data.vi.

Inputs:

Radar Message

Outputs:

Output String

4.4.6 Send Notification.vi

See Section 4.2.18.

4.4.7 System Time.vi

See Section 4.3.4.

4.4.8 TCP/IP Listen Global Status.vi

Waits for a TCPIP connection on ports 6340 through 6342 and reports the status of the connection process via global variables. Is a subroutine of TCPIPWriteNotifierGlobalStatus.vi

Inputs:

Port

Outputs:

6340 - TCPIP Status (global)

6340 - Blinking (global)

6340 - Status String (global)

6341 - TCPIP Status (global)

6341 Blinking (global)

6341 Status String (global)

6342 TCPIP Status (global)

6342 Blinking (global)

6342 Status String (global)

Connection ID

4.4.9 TCP/IP Status Global.vi

See Section 4.2.20.

4.4.10 TCP/IP Write Notifier Global Status.vi

Writes data out over TCPIP connection and returns status to the calling program using the global variables in TCPIP Status Global.vi

Inputs:

Notifier, port, 6340 TCPIP Status (global), 6341 TCPIP Status (global), 6342 TCPIP Status (global), Connection ID

Outputs:

6340 Write Connection ID (global), 6341 Write Connection ID (global), 6342 Write Connection ID (global), 6340 TCPIP Status (global), 6340 Blinking (global), 6341 TCPIP Status (global), 6341 Blinking (global), 6342 TCPIP Status (global), 6342 Blinking (global)

4.4.11 True Time Close Device.vi

See Section 4.3.8.

4.4.12 True Time File Time to System Time.vi

See Section 4.3.9.

4.4.13 True Time Open Device.vi

See Section 4.3.11.

4.4.14 True Time Read Time.vi

See Section 4.3.12.

4.4.15 True Time Read Time Code Info.vi

See Section 4.3.13.

4.4.16 Wait on Notification.vi

See Section 4.2.21.

4.5 Requirements Traceability

In this section, we trace the designed modules traced back to their requirement addressed in Section 3.5.

Table 4.3 General Requirements

Num	Requirement	Modules
1.0	General Requirements	
1.1	The ASTRO shall run on Windows 9X/NT clients on an existing network connected via a hub.	ACO Client, RCO Client, & Sim Server
1.2	The ASTRO shall utilize TCP/IP socket to communicate data between consoles.	TCP/IP Listen Global Status, TCP/IP Status Global, TCP/IP Read Notifier, & TCP/IP Write Notifier Global Status
1.3	The ASTRO shall allow for a 50% increase in growth.	ACO Client, RCO Client, & Sim Server

Table 4.4 Overall Timing Requirements

Req	Functionality	Modules
2.0	Overall Timing Requirements	
2.1	The ASTRO system shall determine whether a True Time IRIG/GPS card is present in the server system.	Sim Server, True Time Open Device
2.2	The ASTRO system shall use system time if	Sim Server, System Time

	True Time IRIG/GPS card is not present in the server system.	
2.3	The ASTRO system shall use IRIG time if a True Time IRIG/GPS card is present in the server system.	Sim Server, True Time Open Device, True Time Read Time, True Time Read Time Code Info, True Time File Time to System Time
2.4	The ASTRO system shall stamp the selected timing source's time in the transmitted data stream.	Sim Server
2.5	The ASTRO system shall act as a server and transmit all the entered and calculated fields to client machines via TCP/IP.	Sim Server, Send Notification, TCP/IP Write Notifier Global Status

Table 4.5 ACO Unique Requirements

Num	Requirement	Modules
3.0	ACO Unique Requirements	
3.1	The ASTRO system shall be able to simulate and display the BIT mode of operation icon on the D-BRITE display.	Not Implemented in Proof of Concept
3.2	The ASTRO system shall be able to simulate and display the ERROR mode of operation box on the D-BRITE display. See Figure 3-7.	Not Implemented in Proof of Concept
3.3	The ASTRO system shall be able to clear errors by pressing the erase switch on the D-BRITE RCU. See Figure 3-2.	Not Implemented in Proof of Concept
3.4	The ASTRO system shall be able to simulate the functionality of all controls on the D-BRITE Remote Control Unit. See Figure 3-2.	ACO Client, RCU Control Panel, Mouse Global
3.5	The ASTRO system shall be able to simulate the functionality of the range mark intensity control knob on the D-BRITE display and located on the RCU. It determines the intensity of the range circles. See Figure 3-2.	ACO Client, RCU Control Panel, Range Circles, Draw Circles by Radius, Mouse Global
3.6	The ASTRO system shall be able to simulate the functionality of the range mark selection knob on the D-BRITE display and located on the RCU. It determines the distance between range circles in nautical miles and is selectable between 2, 5 and 10 nautical miles. See Figure 3-2.	ACO Client, RCU Control Panel, Range Circles, Draw Circles by Radius, Mouse Global
3.7	The ASTRO system shall be able to simulate the functionality of the center/offset toggle switch on the D-BRITE display and located on the RCU. When in the center mode of operation it centers the range circles on the radar location. When the offset mode of operation is selected it enables the center/offset joystick. See Figure 3-2.	RCU Control Panel

Num	Requirement	Modules
3.8	The ASTRO system shall be able to simulate the functionality of the center/offset joystick on the D-BRITE display and located on the RCU. Is only functional when the center/offset toggle switch is in the offset position and allows the operator to have manual control of the range circles center position. See Figure 3-2.	ACO Client, RCU Control Panel, Range Circles, Mouse Global
3.9	The ASTRO system shall be able to simulate the functionality of the range selection knob on the D-BRITE display and located on the RCU. It determines the maximum distance in nautical miles viewable from the picture center location to the edge of the picture. This is equivalent to the picture radius and is selectable between 10, 30, 60 or variable. See Figure 3-2.	ACO Client, RCU Control Panel, Landmark Conversion to Picture, Map Conversion to Picture, Range Circles, Mouse Global
3.10	The ASTRO system shall be able to simulate the functionality of the range inc (+) dec (-) switch on the D-BRITE display and located on the RCU. It allows the operator to manually adjust the radius of the display from 2 to 60 nautical miles. This control is only accessible when the range selection knob is set to variable mode. See Figure 3-2.	ACO Client, RCU Control Panel, Landmark Conversion to Picture, Map Conversion to Picture, Range Circles, Mouse Global
3.11	The ASTRO system shall be able to simulate the functionality of the decenter on/off toggle switch on the D-BRITE display and located on the RCU. When decenter mode of operation is in the off position it centers the display on the radar center location. When decenter mode of operation it enables the decenter joystick. See Figure 3-2.	RCU Control Panel
3.12	The ASTRO system shall be able to simulate the functionality of the decenter joystick on the D-BRITE display and located on the RCU. It is only functional when the decenter on/off toggle switch is in the on position and allows the operator to change the display's center position. See Figure 3-2.	ACO Client, RCU Control Panel, Landmark Conversion to Picture, Map Conversion to Picture, Range Circles, Mouse Global

Num	Requirement	Modules
3.13	The ASTRO system shall be able to simulate the functionality of the map switch #1 on the D-BRITE display and located on the RCU. It toggles user specified data on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	Not Implemented in Proof of Concept
3.14	The ASTRO system shall be able to simulate the functionality of the map switch #2 on the D-BRITE display and located on the RCU. It toggles user specified data on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	Not Implemented in Proof of Concept
3.15	The ASTRO system shall be able to simulate the functionality of the map switch #3 on the D-BRITE display and located on the RCU. It toggles landmarks on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	ACO Client, RCU Control Panel, Landmark Conversion to Picture, Mouse Global
3.16	The ASTRO system shall be able to simulate the functionality of the map switch #4 on the D-BRITE display and located on the RCU. It toggles user specified data on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	Not Implemented in Proof of Concept
3.17	The ASTRO system shall be able to simulate the functionality of the map switch #5 on the D-BRITE display and located on the RCU. It toggles the maps on and off on the display for the area of operation of the radar by reading the latitude and longitude coordinates in from a file. See Figure 3-2.	ACO Client, RCU Control Panel, Map Conversion to Picture, Mouse Global
3.18	The ASTRO system shall be able to simulate the functionality of all the keys on the D-BRITE Keyboard. See Figure 2-1.	Not Implemented in Proof of Concept

Num	Requirement	Modules
3.19	The ASTRO system shall be able to simulate the functionality of the PEM/Joystick on the D-BRITE Keyboard. See Figure 2-1.	Not Implemented in Proof of Concept
3.20	The ASTRO system shall be able to acquire simulated radar data and convert them into a format the controller can use. See Figure 3-5.	ACO Client, TCP/IP Read Notifier, Format TCP/IP Radar Data, Wait on Notification
3.21	The ASTRO system shall be able to handle new radar track information within 1 second of the sweep that occurs at 10 RPM or one update every 6 seconds.	ACO Client
3.22	The ASTRO system shall allow the controller to manipulate ident display data. For example, the user should be able to change the message line in the ident display. See Figure 3-4.	Not Implemented in Proof of Concept
3.23	The ASTRO system shall be able to allow the simulation operator to add/delete/modify flight targets.	Sim Server, Radar Data Array to String Conversion
3.24	The ASTRO system shall be able to allow the PEM to change the cursor bearing and strobe range, and to relocate cursor origin, sweep origin, and tabular data lists on the D-BRITE display.	Not Implemented in Proof of Concept
3.25	The ASTRO system shall be able to receive and display the Mode III code of each aircraft and display them on the D-BRITE display. See Figure 3-4.	ACO Client, Format TCP/Ip Radar Data, Draw Text Given Range and Azimuth
3.26	The ASTRO system shall be able to simulate the functionality of the Programmable Indicator Data Processor (PIDP). For example, the ability to hook a target and display it's ground speed. See Figure 3-4.	Not Implemented in Proof of Concept
3.27	The ASTRO system shall be able to receive and display targets on the D-BRITE display either through automatic acquisition from flight plan data or through keyboard procedures. See Figure 3-4.	ACO Client, Format TCP/IP Radar Data, Draw Text Given Range and Azimuth

Num	Requirement	Modules
3.28	The ASTRO system shall be able to receive and display the Controlling Agency Designator (CAD). See Figure 3-4 and Table 3.2.	Not Implemented in Proof of Concept
3.29	The ASTRO system shall be able to receive and display up to seven alphanumeric characters on line 1 that represent the aircraft identification (ACID). See Figure 3-4.	Not Implemented in Proof of Concept
3.30	The ASTRO system shall be able to receive and display up to four digits on line 2 that represent the aircraft's transponder code. See Figure 3-4.	ACO Client, Format TCP/IP Radar Data, Draw Text Given Range and Azimuth
3.31	The ASTRO system shall be able to receive and display on line 3 of the alphanumeric display the transponder code, aircraft altitude, a blank space or caret, the aircraft class, a blank space, and the aircraft's ground speed in tens of knots. See Figure 3-4	Not Implemented in Proof of Concept
3.32	The ASTRO system shall be able to receive and display on line 4 of the alphanumeric display an optional message that can contain up to eight alphanumeric characters for the a user defined operator message. See Figure 3-4	Not Implemented in Proof of Concept
3.33	The ASTRO system shall be able to receive and display on D-BRITE selected and non-selected targets. See Figure 3-5.	ACO Client, Format TCP/IP Radar Data, Draw Text Given Range and Azimuth
3.34	The ASTRO system shall be able to receive and display on D-BRITE tracked targets utilizing the functionality of the PIDP. See Figure 3-3 and Figure 3-5.	Not Implemented in Proof of Concept
3.35	The ASTRO system shall be able to process and display up to five operator request to track targets utilizing the functionality of the PIDP. See Figure 3-6.	Not Implemented in Proof of Concept

Num	Requirement	Modules
3.36	The ASTRO system shall be able to receive and process false targets (reflection discrimination) for training purposes. See Figure 3-6.	Not Implemented in Proof of Concept
3.37	The ASTRO system shall be able to allow the operator to initiate a manual track on a selected or non-selected target.	Not Implemented in Proof of Concept
3.38	The ASTRO system shall be able to allow the operator to assign an altitude to an aircraft.	Not Implemented in Proof of Concept
3.39	The ASTRO system shall be able to monitor aircraft with operator assigned altitudes and initiate an audible alarm alert when the aircraft is above or below 300 feet of its assigned altitude.	Not Implemented in Proof of Concept
3.40	The ASTRO system shall be able to monitor aircraft with operator assigned altitudes and flash the track information when the aircraft is above or below 300 feet of its assigned altitude. “ABV” or “BLO” is also added to the track display also adds	Not Implemented in Proof of Concept
3.41	The ASTRO system will allow the operator to respond to the keyboard commands Drop, Read, and Track. For example, the operator can "Read" a non-selected target and then select "Track". The operator can also "Drop" a selected target. See Figure 3-3.	Not Implemented in Proof of Concept
3.42	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the center and sector boundaries.	ACO Client, RCU Control Panel, Map Conversion to Picture, Mouse Global
3.43	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the Track data and current aircraft positions.	ACO Client
3.44	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the map overlays.	ACO Client, RCU Control Panel, Map Conversion to Picture, Mouse Global

Num	Requirement	Modules
3.45	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the aircraft data (i.e. aircraft ID, reported altitude, assigned altitude, and ground speed). See Figure 3-4.	ACO Client
3.46	The ASTRO system shall be able to handle a graphical representation on D-BRITE to display the weather information (barometric pressure).	Not Implemented in Proof of Concept
3.47	The ASTRO system shall be able to provide a log file that will provide data recording of any data sent or received between processes and/or operators.	Not Implemented in Proof of Concept
3.48	The ASTRO system shall communicate with other terminals using existing network protocols (i.e. TCP/IP Socket Services)	TCP/IP Read Notifier, & TCP/IP Write Notifier Global Status
3.49	The ASTRO system shall be able to display the range and bearing between two points at the top center of the D-Brite Screen based on user inputs.	Not Implemented in Proof of Concept
3.50	The ASTRO system shall provide alert and advisory functions to ensure safe separation of aircraft in the Center's airspace. The specific functions shall be as follows: • track prediction function • conflict probe and alert function • resolution advisory function	Not Implemented in Proof of Concept
3.51	The ASTRO system shall provide an alert to the controller, if two or more aircraft are too close in proximity to each other. The normal separation distances over US air space are: • 5 miles horizontally • 1,000 to 2,000 feet vertically	Not Implemented in Proof of Concept

3.52	The ASTRO system shall provide a track prediction function of a given aircraft. This can be used to determine if any of the aircraft currently under control in the Center's airspace will be in conflict with each other in the immediate future.	Not Implemented in Proof of Concept

Table 4.6 RCO Unique Requirements

Num	Requirement	Modules
4.0	RCO Unique Requirements	
4.1	The ASTRO system shall allow the RCO operator to be able to engage a holdfire from their display for the simulation.	RCO Client
4.2	The ASTRO system shall be able to receive and display the operation number, the Julian date, the GMT time, the L Clock, the T Clock and the T Zero via a TCP/IP socket.	RCO Client,
4.3	The ASTRO system shall determine whether a True Time IRIG/GPS card is present in the client system.	RCO Client, True Time Open Device
4.4	The ASTRO system shall use system time if True Time IRIG/GPS card is not present in the client system.	RCO Client, System Time
4.5	The ASTRO system shall use IRIG time if a True Time IRIG/GPS card is present in the client system.	RCO Client, True Time Open Device, True Time Read Time, True Time Read Time Code Info, True Time File Time to System Time
4.6	The ASTRO system shall wrap the received string with the selected timing source's time in the received data stream.	RCO Client, System Time to Seconds
4.7	The ASTRO system shall act as a client and receive all data sent by the server via TCP/IP.	Sim Server, Send Notification, TCP/IP Write Notifier Global Status

Table 4.7 Overall Simulation Server Requirements

Req	Functionality	Modules
5.0	Simulation Server Requirements	
5.1	The ASTRO system shall allow the simulation operator to enter the operation number.	Sim Server
5.2	The ASTRO system shall allow the simulation operator to enter up to four scheduled holds in at the Clock minutes they occur and their duration.	Sim Server
5.3	The ASTRO system shall allow the simulation operator to enter the T Zero for the launch.	Sim Server
5.4	The ASTRO system shall allow the simulation operator to enter when the scheduled holds occur in relation to the L Clock and the duration of each hold.	Sim Server
5.5	The ASTRO system shall display the actual day of the year.	Sim Server
5.6	The ASTRO system shall synchronize all the display times by calculating the L Clock, T Clock, and GMT time based on the launch T Zero and scheduled hold times and durations.	Sim Server, Astro's Equations
5.7	The ASTRO system shall act as a server and transmit all the entered and calculated fields to client machines via TCP/IP.	Sim Server, Send Notification, TCP/IP Write Notifier Global Status
5.8	The ASTRO system shall allow the simulation operator to be able to suspend the simulation.	Sim Server
5.9	The ASTRO system shall allow the simulation operator to be able to engage a holdfire from their display for the simulation.	Sim Server

CHAPTER 5. TESTING EXPERIMENTS

5.1 Setup Description

A controlled environment has been set up to measure the data latency across the network. Three FieldWorks portable computers configured with True Time IRIG cards were used for the test.

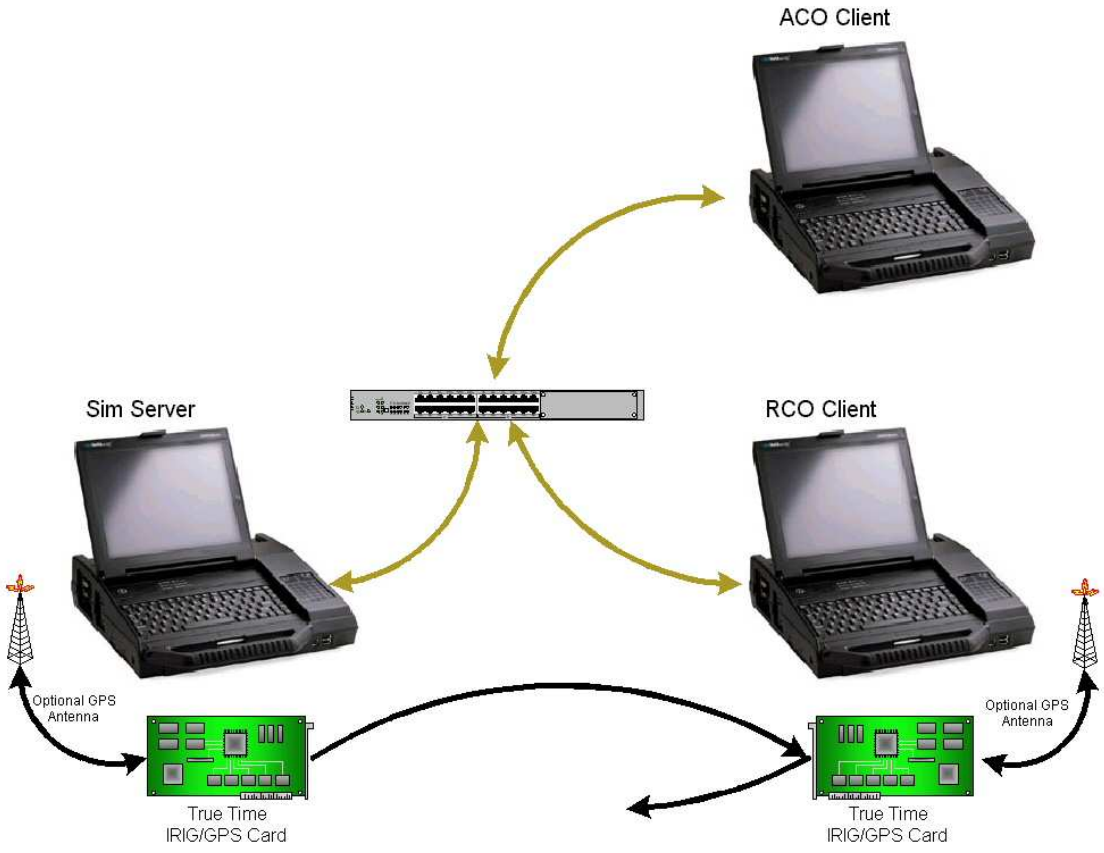


Figure 5-1 Demonstration Configuration utilizing FieldWorks Portable Computers

There is a principal difference with this study as compared to others conducted in the past. A True Time IRIG card is used to measure timing across the TCP/IP network. Previous studies typically either write or buy software that runs in the background to measure data latency by utilizing the built-in Windows timer. However, the Windows timer and Windows system time cannot be trusted for real-time operation.

The Windows timer is not very accurate. Consider the following example. For SetTimer(1,500, NULL), the Windows will actually receive a WM_TIMER message about once every 550 ms because the hardware timer on which Windows timers are based ticks once every 54.9 ms, and give or take a few microseconds, on most systems (particularly Intel-based systems). Windows rounds the value passed to SetTimer up to the next multiple of 55 ms. So, the statement SetTimer(1,1,NULL) is equal to SetTimer(1,50,NULL) because it programs a timer to send a message roughly every 55 ms. If you change it to (1,60,NULL), messages will arrive, on average, every 110 ms [7]. Therefore, it is desirable to have an external timer. The True Time IRIG card is not impacted by the Windows operating system servicing an interrupt, therefore it will provide accurate timing in the microseconds range.

The Windows system time is also not very accurate, nor is there an accurate means of synchronizing the clocks between two computers. The True Time IRIG card ensures accurate timing between two or more computers. However, IRIG timing must be connected via coax and isn't practical for long distance timing applications. The GPS daughter card resolves this issue but is not as accurate as the IRIG card.

5.2 Timing and Data Latency Testing

In conducting data latency testing several issues were identified. First, the True Time card would not run under the Windows 9X operating system, despite separate DLLs for NT and 9X. True Time Inc. confirmed they have had problems with Windows 9X and were addressing them. Therefore, the Windows NT operating system was used but a second problem was identified. There are ping pong registers located on the IRIG card designed to prevent reading a time from the register while it is being written to. Unfortunately, there is a small window measured in the nanoseconds when one can receive a corrupted time from the registers. Test runs occasionally had values spike to 1 second or so when the average was only 20 ms. Further consultation with True Time and their independent testing confirmed the problem. True Time agreed to implement a work around in there DLL to counter this problem. It is important to note that this is only a workaround and that True Time said that this was really a hardware problem and would be fixed on their new version of the GPS/IRIG card.

Several test runs were conducted to ensure the True Time cards were functioning properly. The test configuration shown in Figure 5-1 proved the accuracy of these cards. The average data latency in the test configuration was 20 ms (Figure 5-2). If a 100 MBps hub were available for the test setup the data latency would have been lower. The range of values recorded over 1 minute was between 15 and 40 milliseconds.

It is easy to see the practical application for these cards. For example, one test was run with the server running in Orlando and the client running in Cocoa Beach. If these computers were equipped with GPS cards then the exact data latency across the

Internet could have been determined. This data could then be used in future calculations where knowing the data latency is critical.

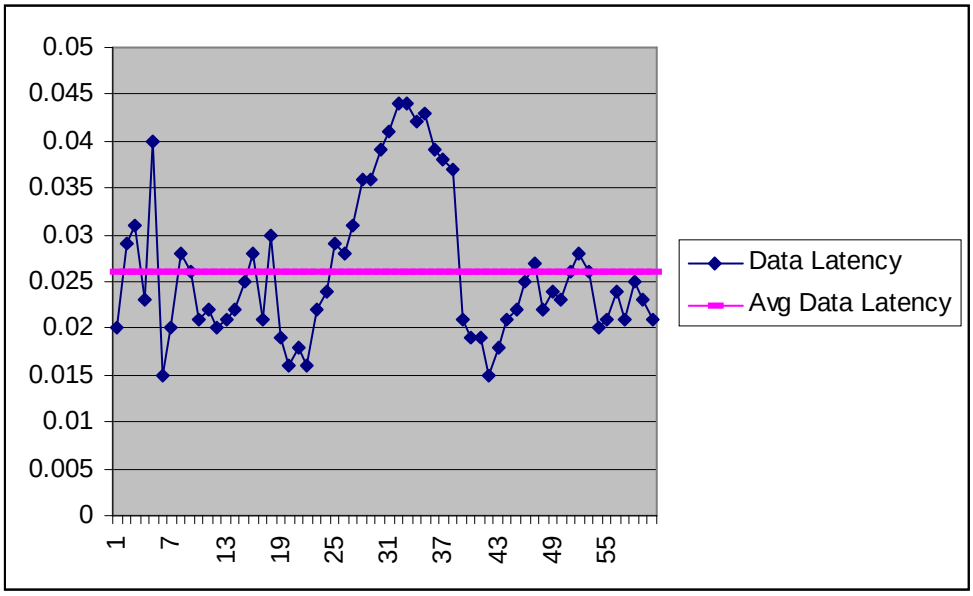


Figure 5-2 Data Latency [sec.] measured with IRIG True Time Cards over 60 sec.

5.3 ATC Graphical Display Testing

The ATC display was tested utilizing the Sim Server application to generate targets. 50 targets were entered via Sim Server into an array and transmitted across a network and displayed on the ACO Client application utilizing TCP/IP sockets (Figure 5-3). This test was also run across the Internet with identical results. Ideally, the ACO Client is capable of receiving data from a live FAA radar feed; unfortunately, this isn't practical at this time and arrangements would have to be made with the FAA to receive either live or recorded data. The FAA did provide the format for the data and the system was designed with the packet contents identical to the real format so that this is a possibility in the future. The Sim Server is capable of generating up to 200 targets and

ACO Client is capable of receiving them. The only issue is that larger display screens are necessary to spread the targets out over more screen real estate to view this many targets. Sim Server also altered the bearing and ground speed of several targets and the ACO Client displayed them accurately.

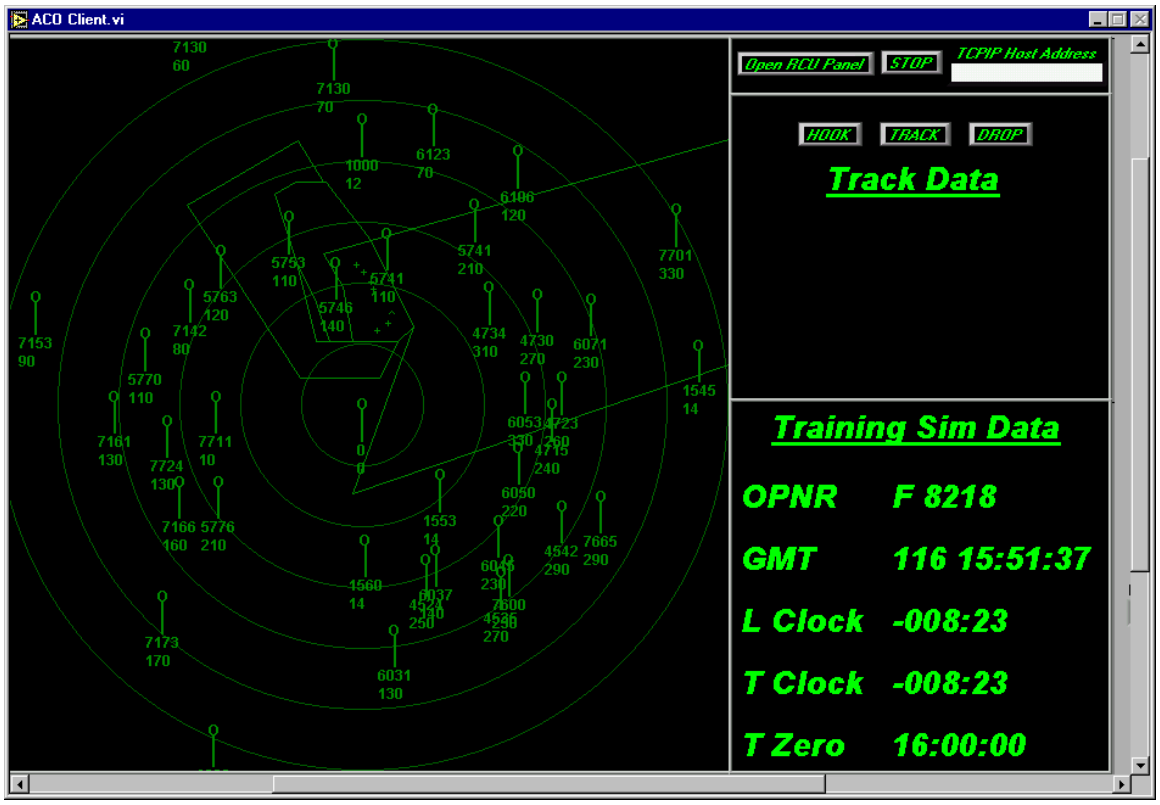


Figure 5-3 ACO Client displaying 50 targets being generated by Sim Server

CHAPTER 6. CONCLUSION

The purpose of this thesis was to study issues related to the development of a low-cost, off-line, high-fidelity training system for military range operators. We focused on TCP/IP data latency in transmitting large data sets, and the graphical display of air traffic control data received via TCP/IP. A requirements specification was developed for the transmission, reception, and calculation of timing information. A requirements specification was also developed for the graphical display of the air traffic control terminal or DBRITE display. The software system was designed and implemented in LabVIEW.

The primary objective of this thesis was met by designing a hardware and software solution to address the problems in range operations training and develop an Automated Spacelift Training for Range Operators (ASTRO). The three specific goals for this research work were also met:

- Design and test a methodology for a proof of concept for a low-cost, off-line, high-fidelity simulator
- Design and test a methodology to accurately measure data latency for data transmitted from a satellite to a ground station
- Design and test a methodology to ingest Air Traffic Control data from a radar site and graphically display it.

A proof of concept shows how LabVIEW can be utilized to develop the entire system. The developed system supports the off-line training of the ACO and RCO operator positions. The ACO position uses simulated data from an Air Traffic Control site and graphically display the targets. The ROC, FCO and CAB operator positions can also benefit from the timing displays

Data latency measurements were developed with LabVIEW code that interfaces with the True Time IRIG card. The methodology and application code are general and can be used in other projects, for example, the Satellite Ground Station being developed by Florida Space Institue (FSI). In addition, this card can be integrated with the Global Positioning Satellite (GPS) system. This hardware and software will allow for a large array of possible experiments.

An Air Traffic Control display was successfully developed for the ACO using LabView. This code can be used in other projects, especially ones using Air Traffic Control scenario to demonstrate distributed processing. The display is capable of receiving data from a live radar feed or from a simulator.

This research proved that a system could be developed quickly and efficiently with LabView. Future studies could include:

- Building the same system using JAVA for comparison against LabVIEW.
- Passing data via a CORBA connection for a graphical representation of targets in a distributed processing environment.
- Target Selection for track processing on the Air Traffic Control Display.

APPENDIX A.

A.1 LabVIEW Diagrams

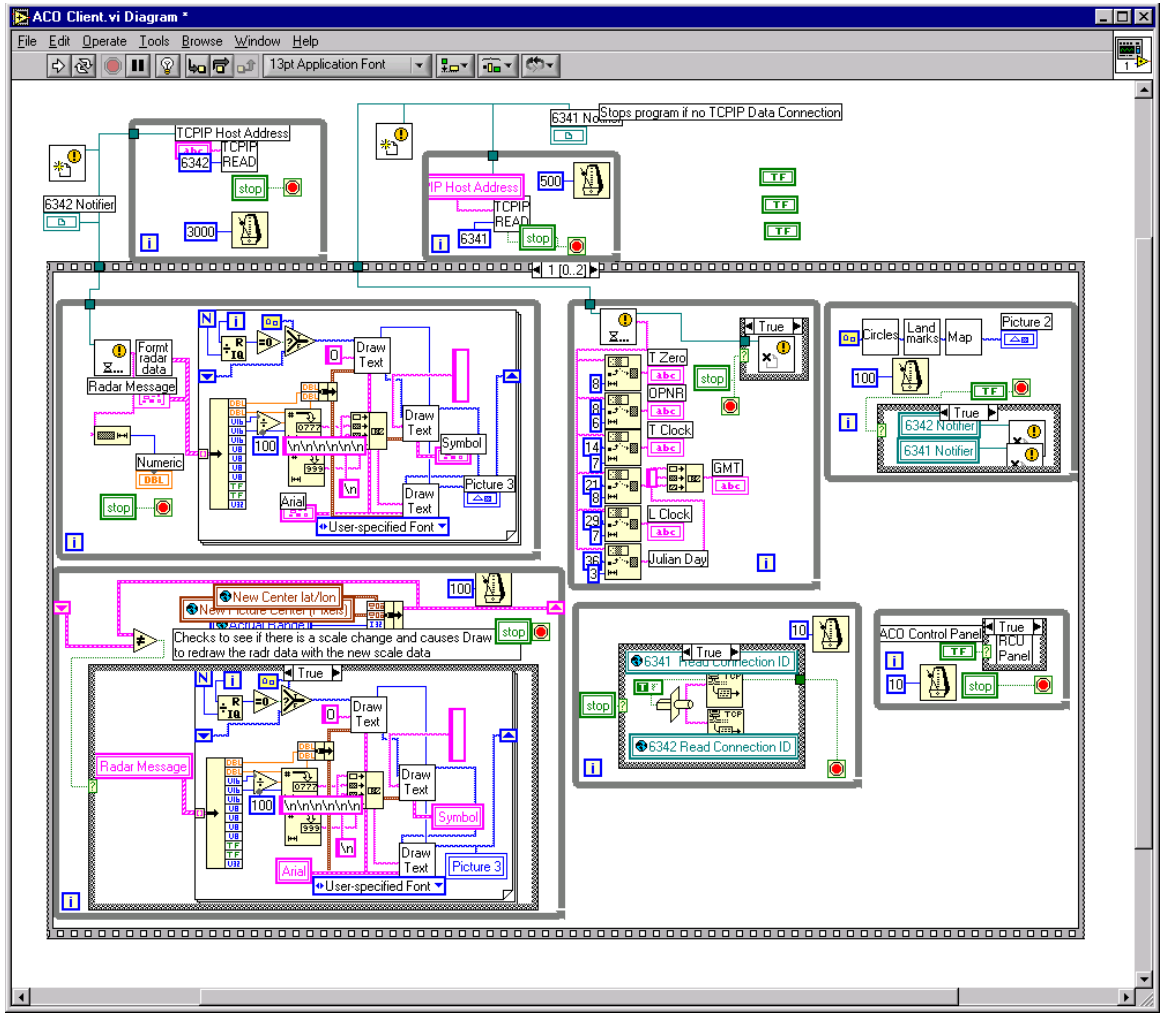


Figure A-1 ACO Client VI Diagram (True)

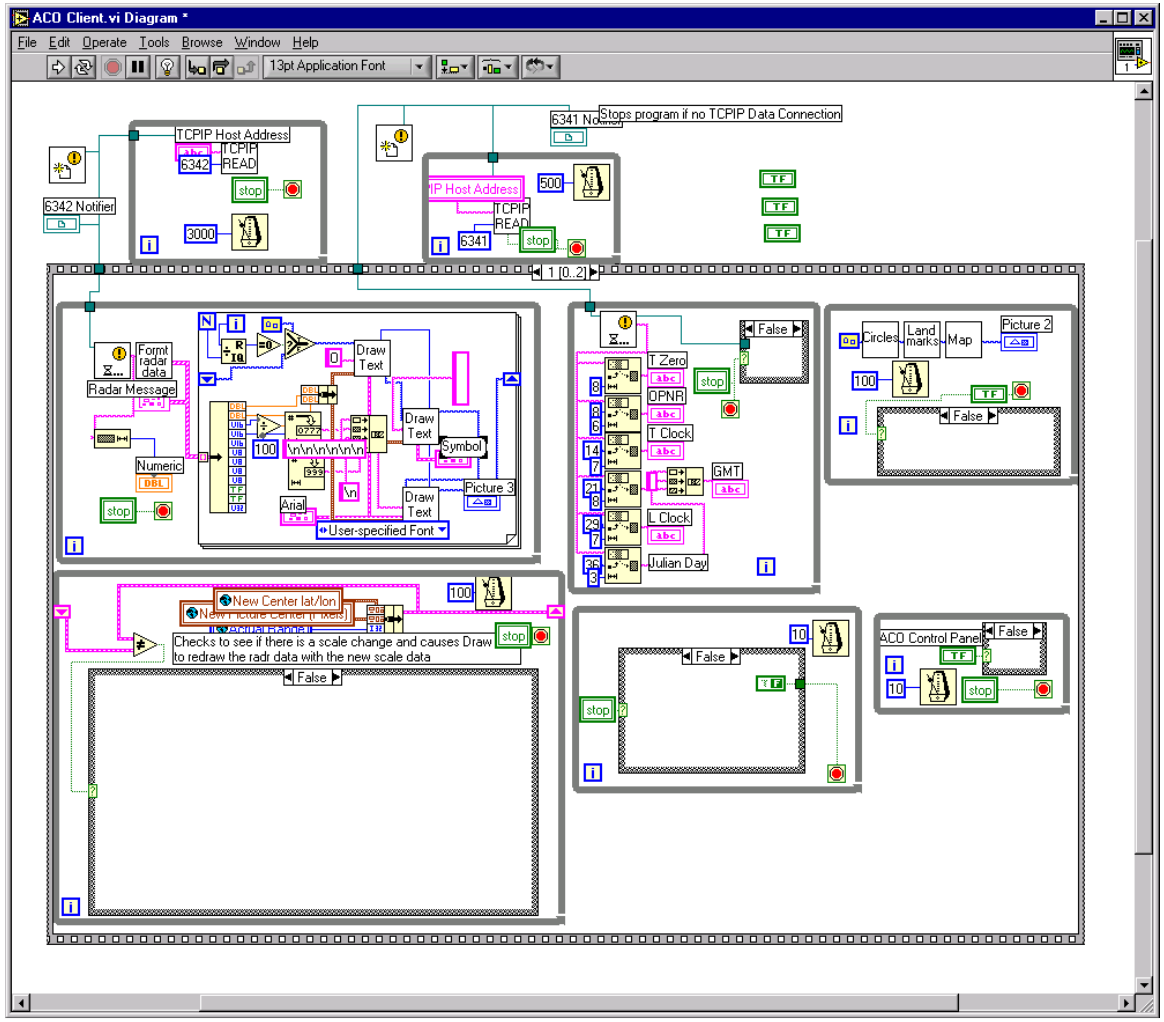


Figure A-2 ACO Client VI Diagram (False)

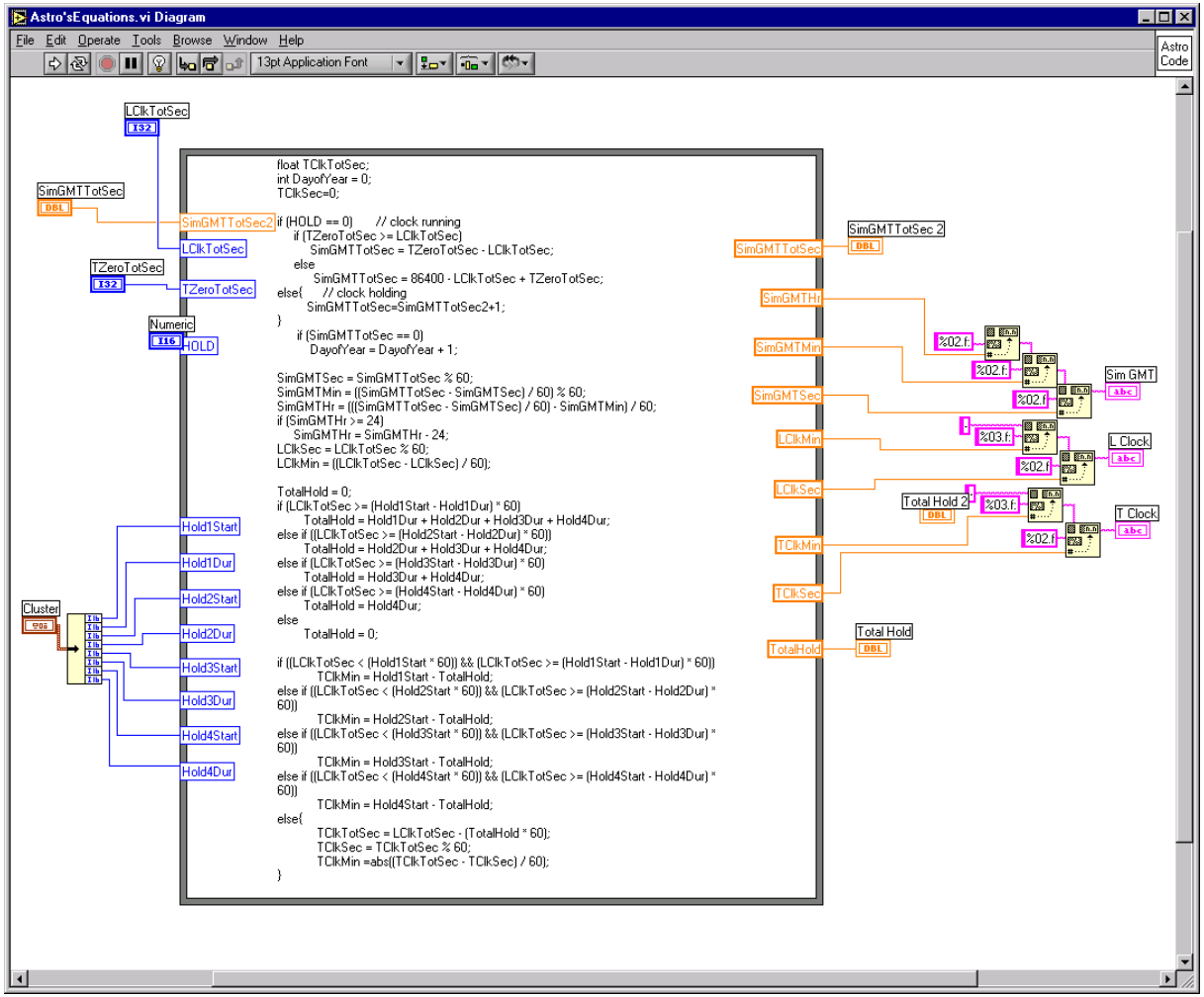


Figure A-3 Astro's Equation VI Diagram

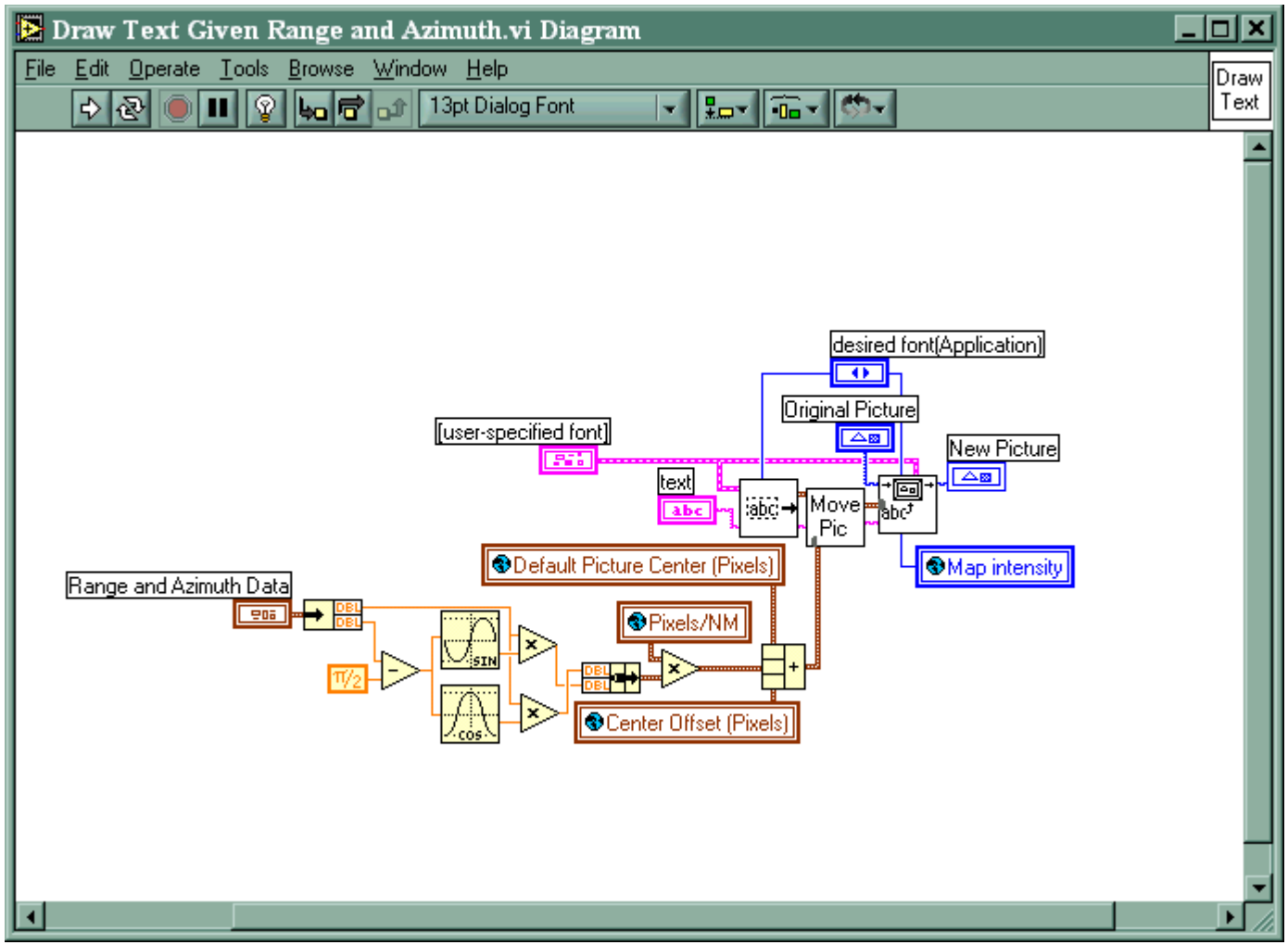


Figure A-4 Draw Text Given Range and Azimuth VI Diagram

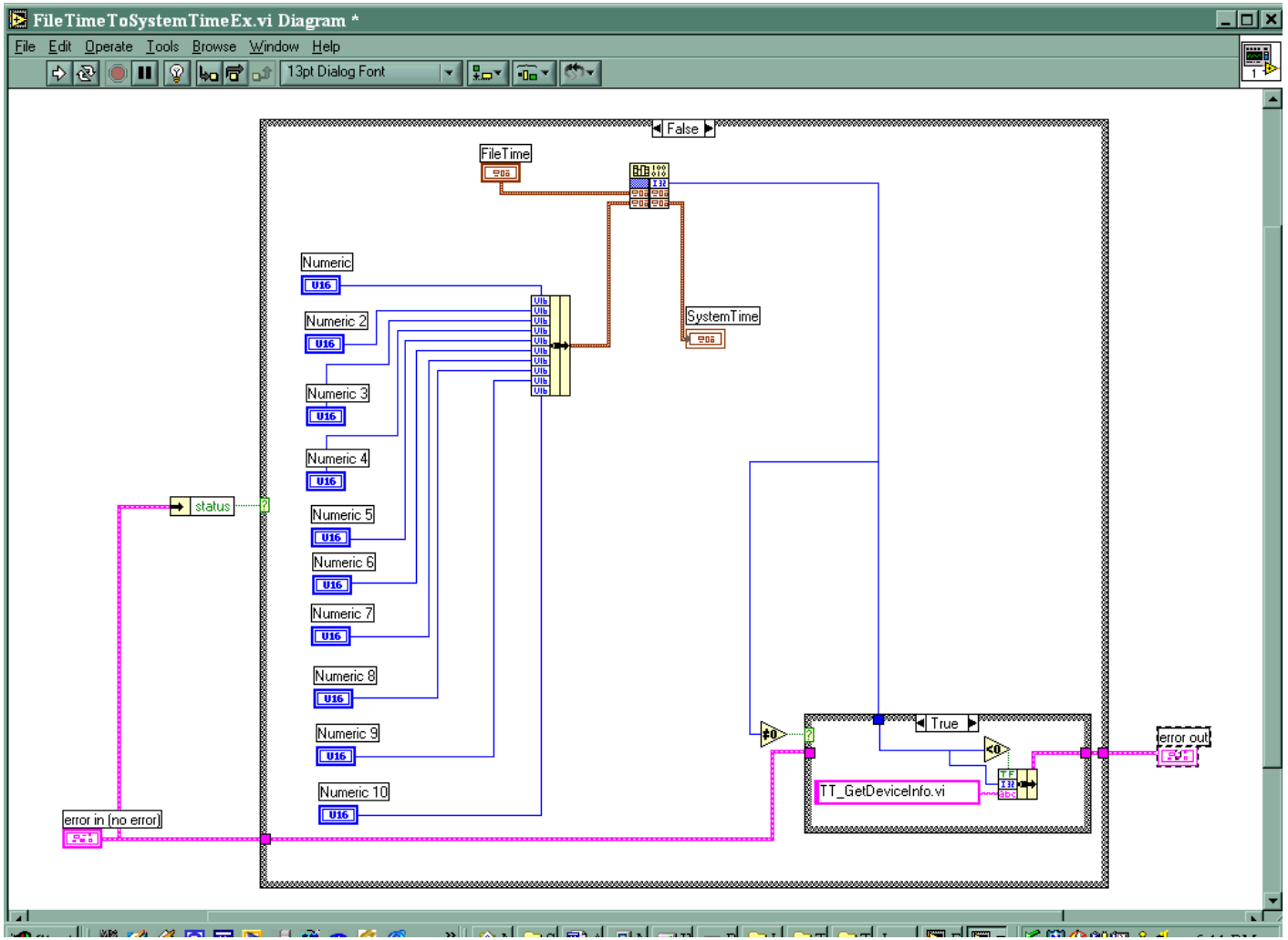


Figure A-5 File Time to System Time Ex VI Diagram (True)

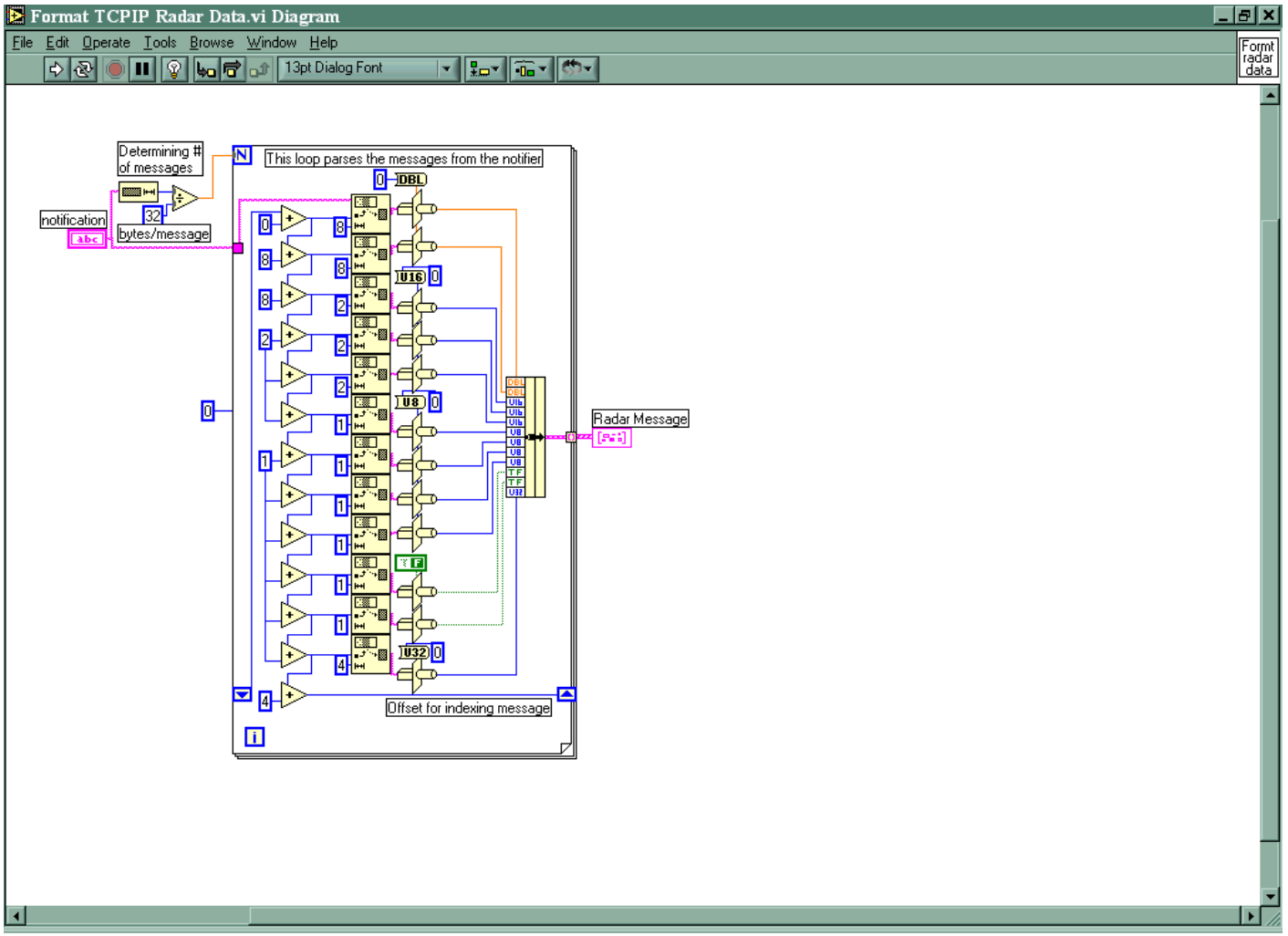


Figure A-6 Format TCPIP Radar Data VI Diagram

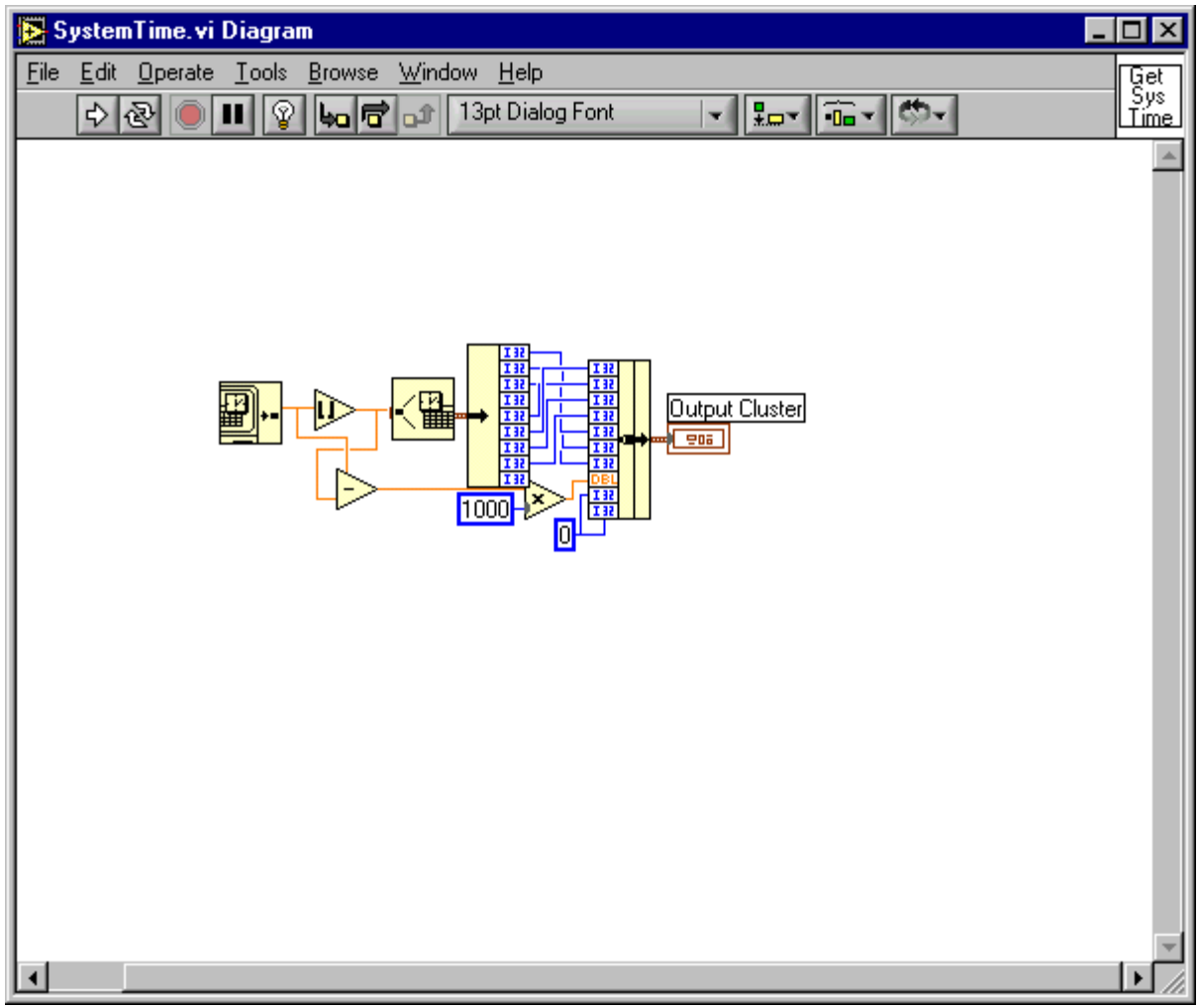


Figure A-7 Get System Time VI Diagram (True)

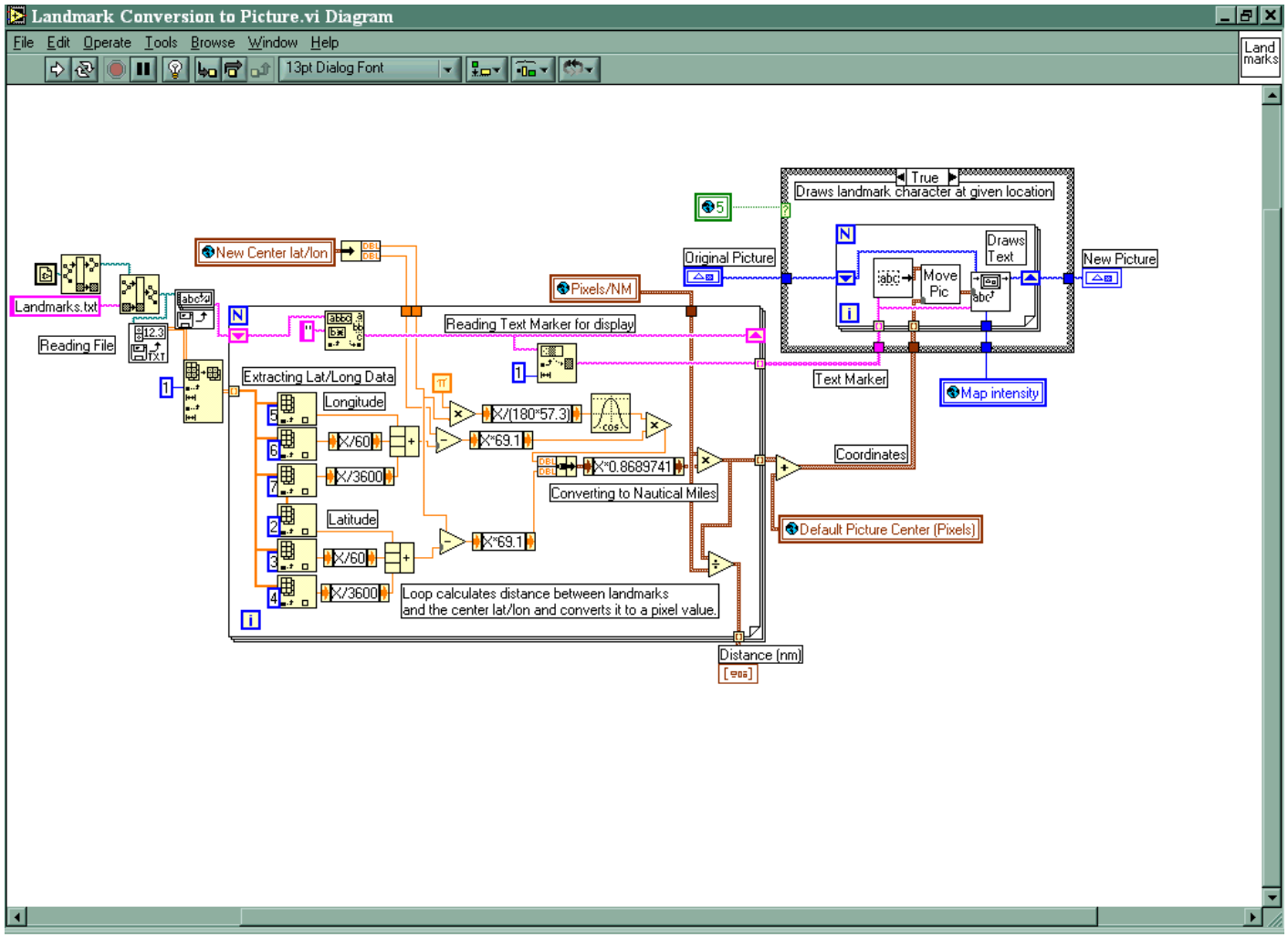


Figure A-8 Landmark Conversion to Picture VI Diagram (True)

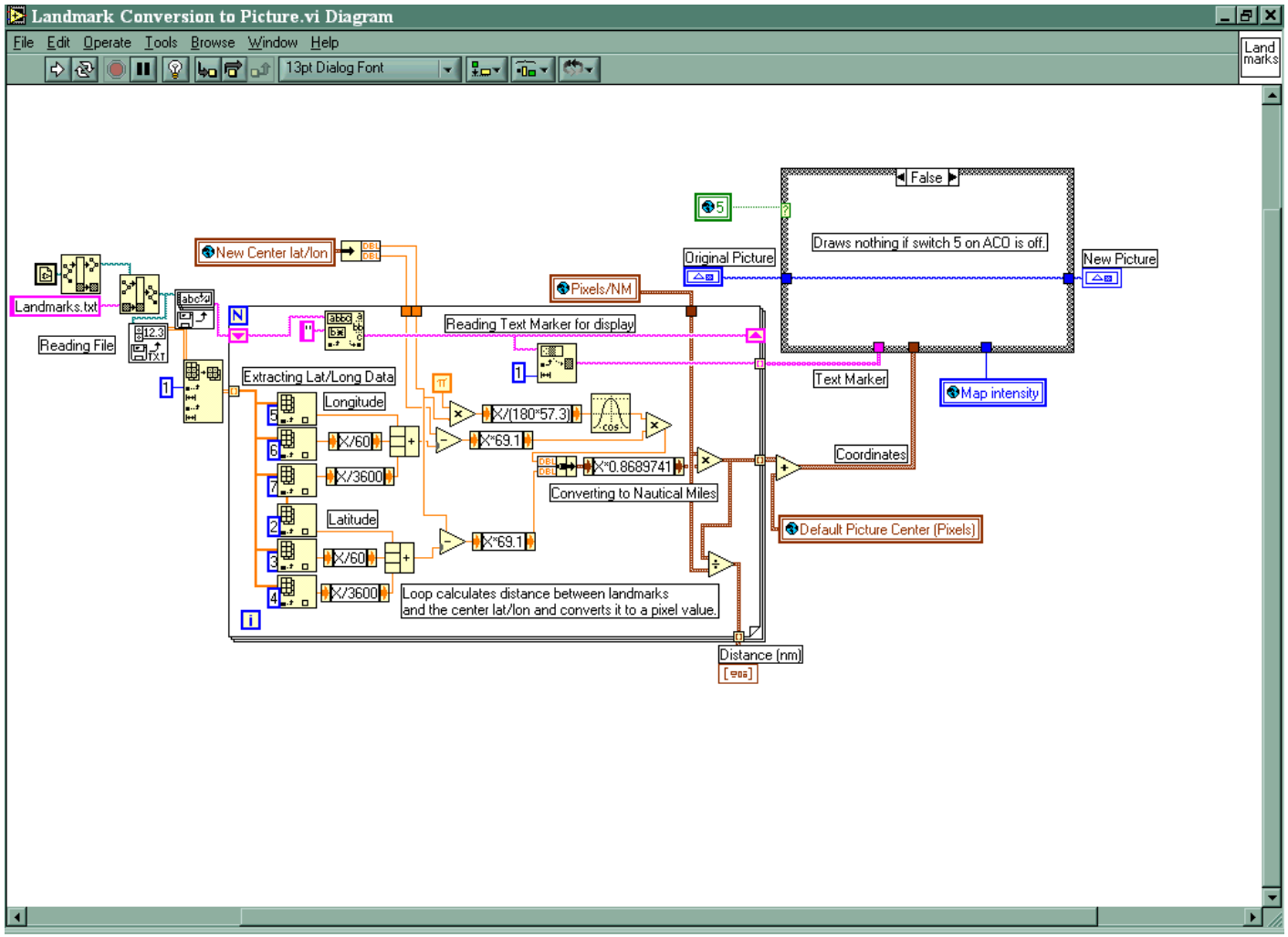


Figure A-9 Landmark Conversion to Picture VI Diagram

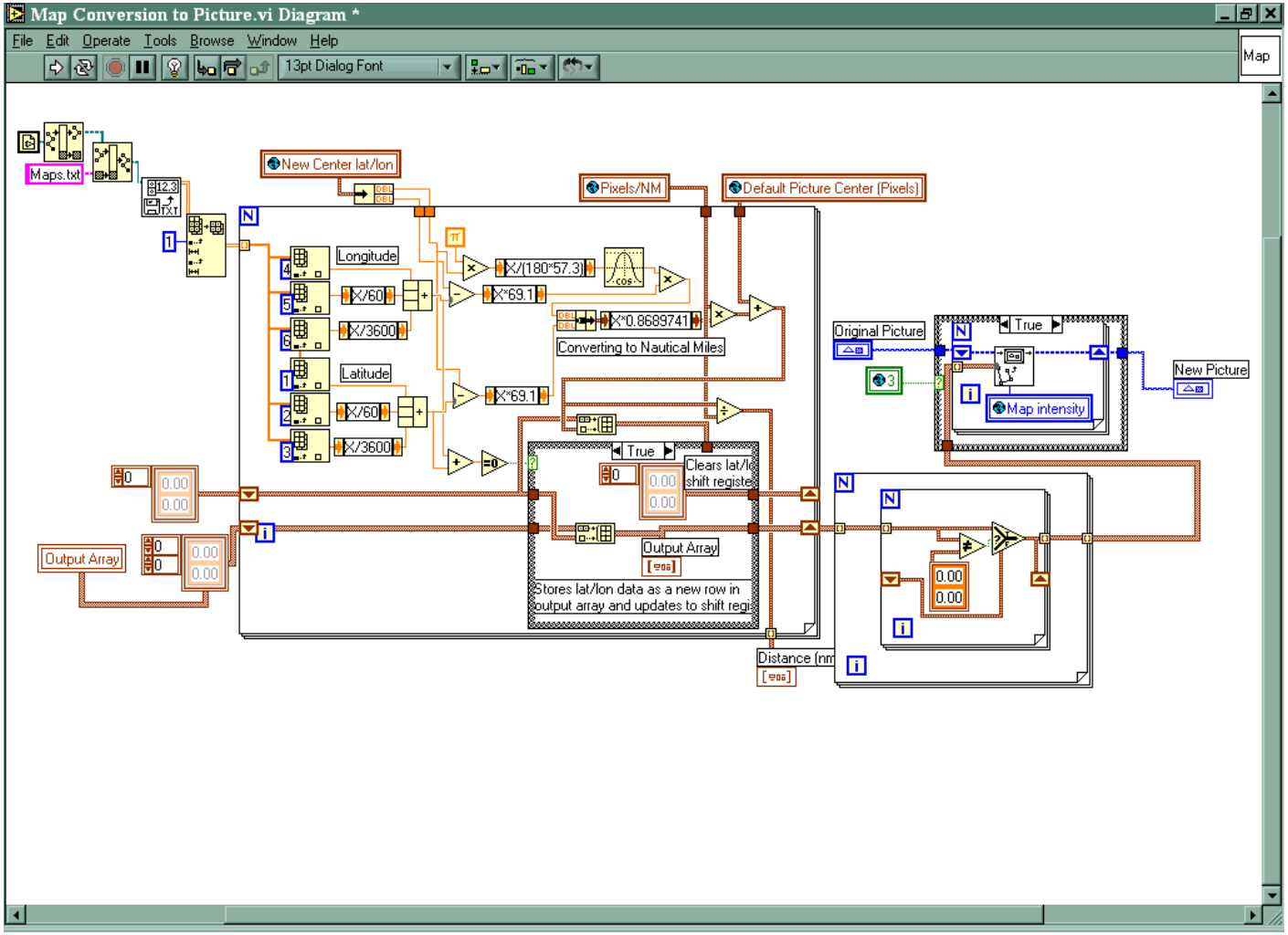


Figure A-10 Map Conversion to Picture VI Diagram

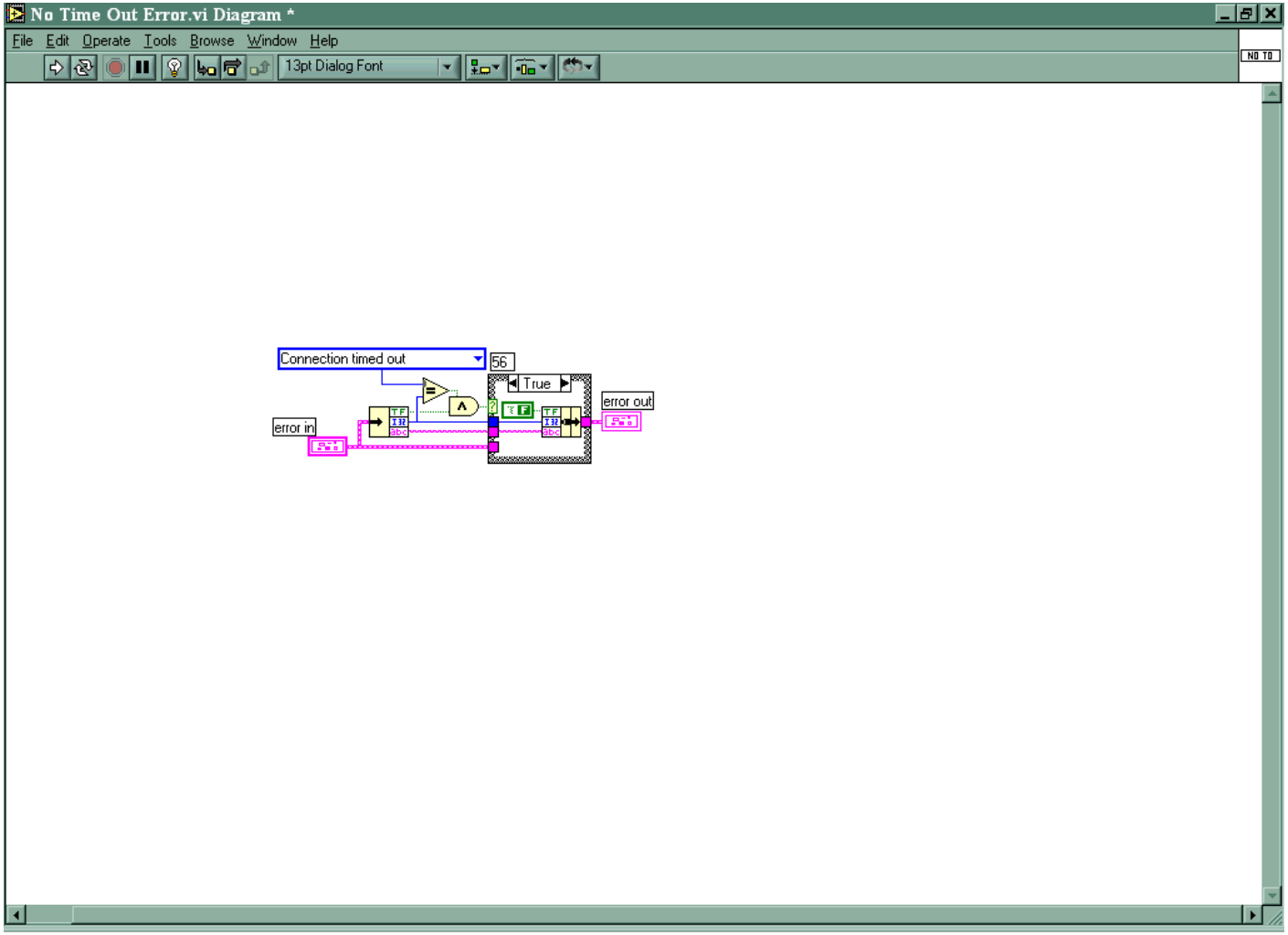


Figure A-11 No Time Out Error VI Diagram (True)

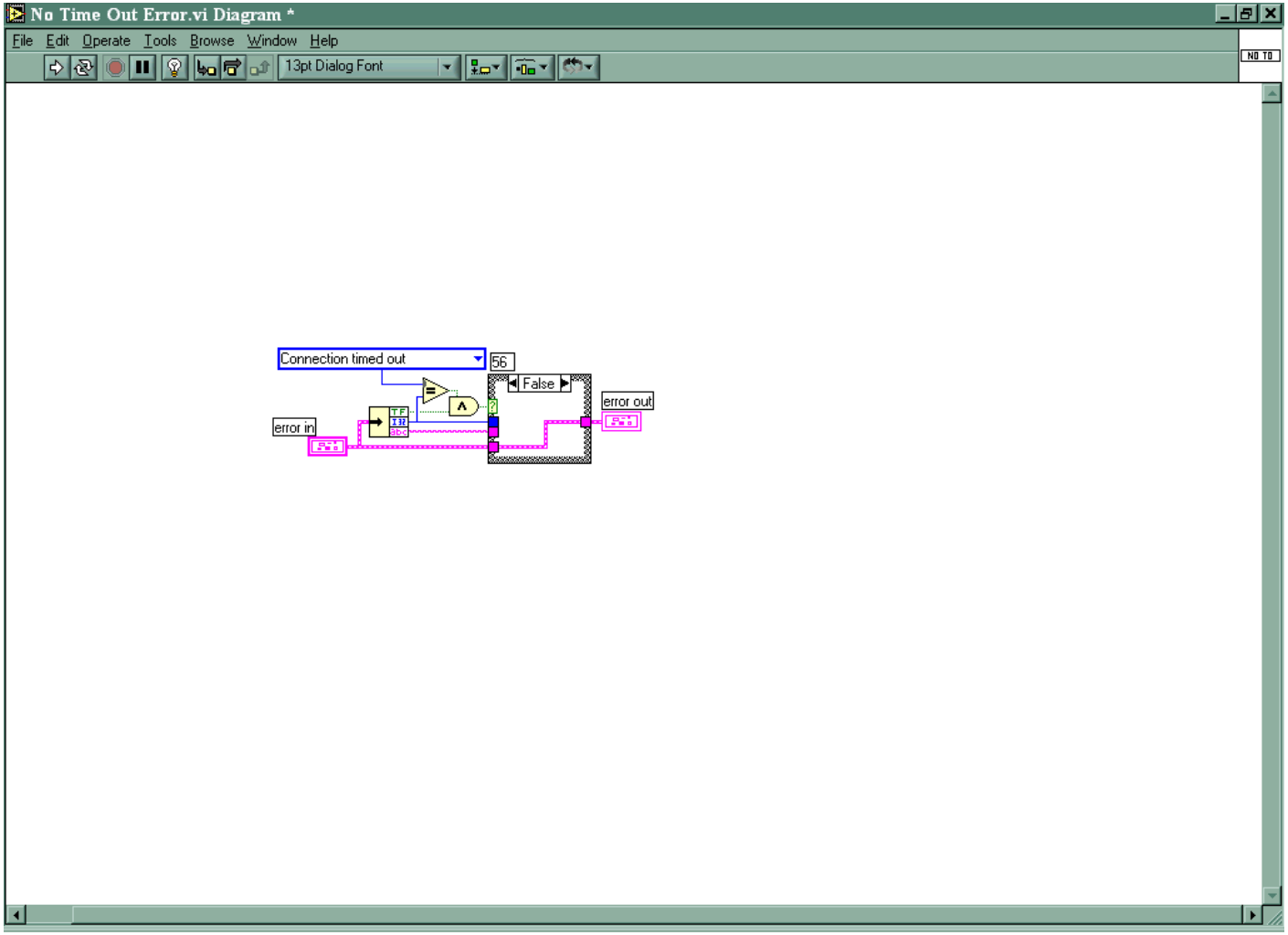


Figure A-12 No Time Out Error VI Diagram (False)

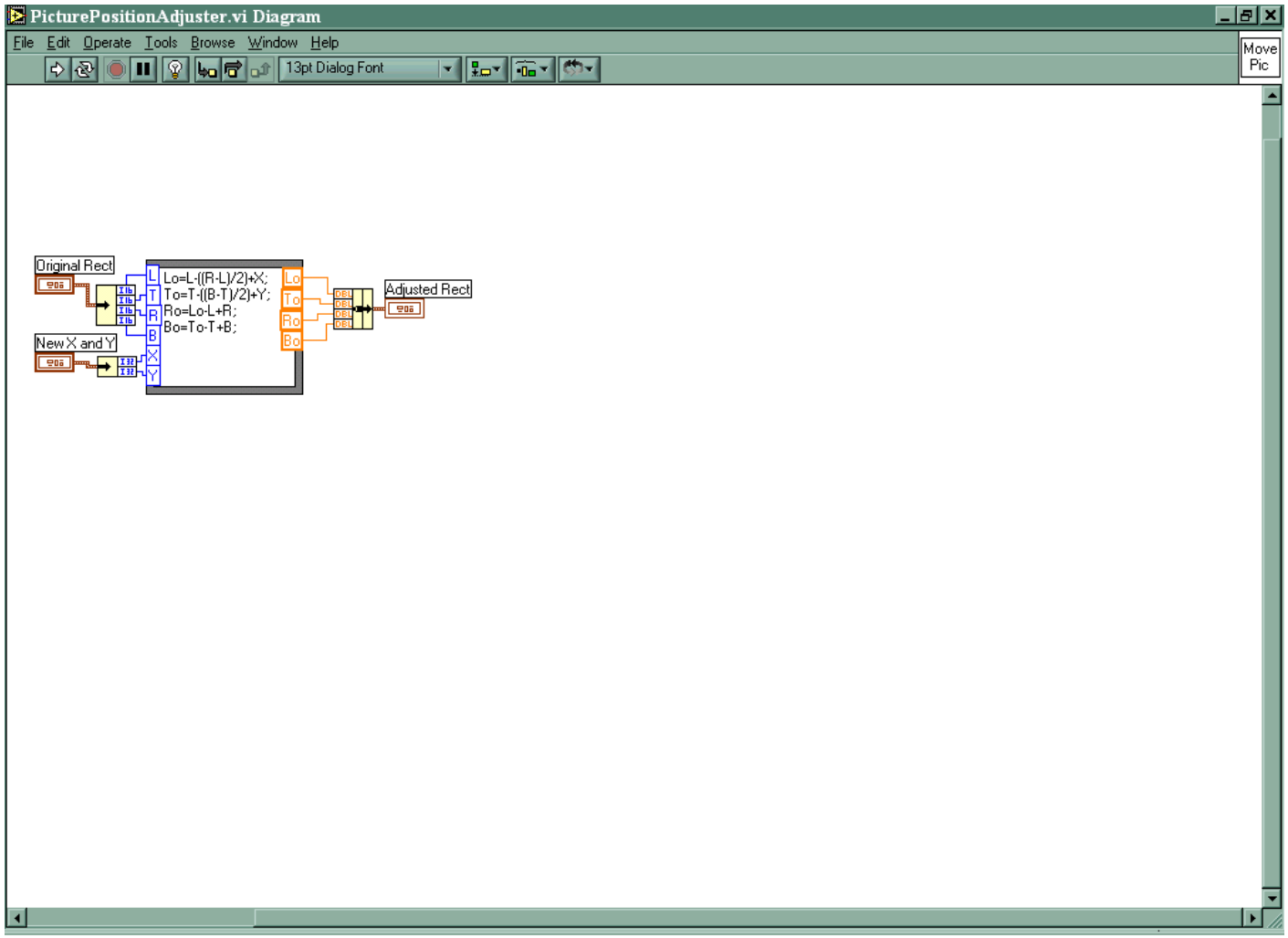


Figure A-13 Picture Position Adjuster VI Diagram

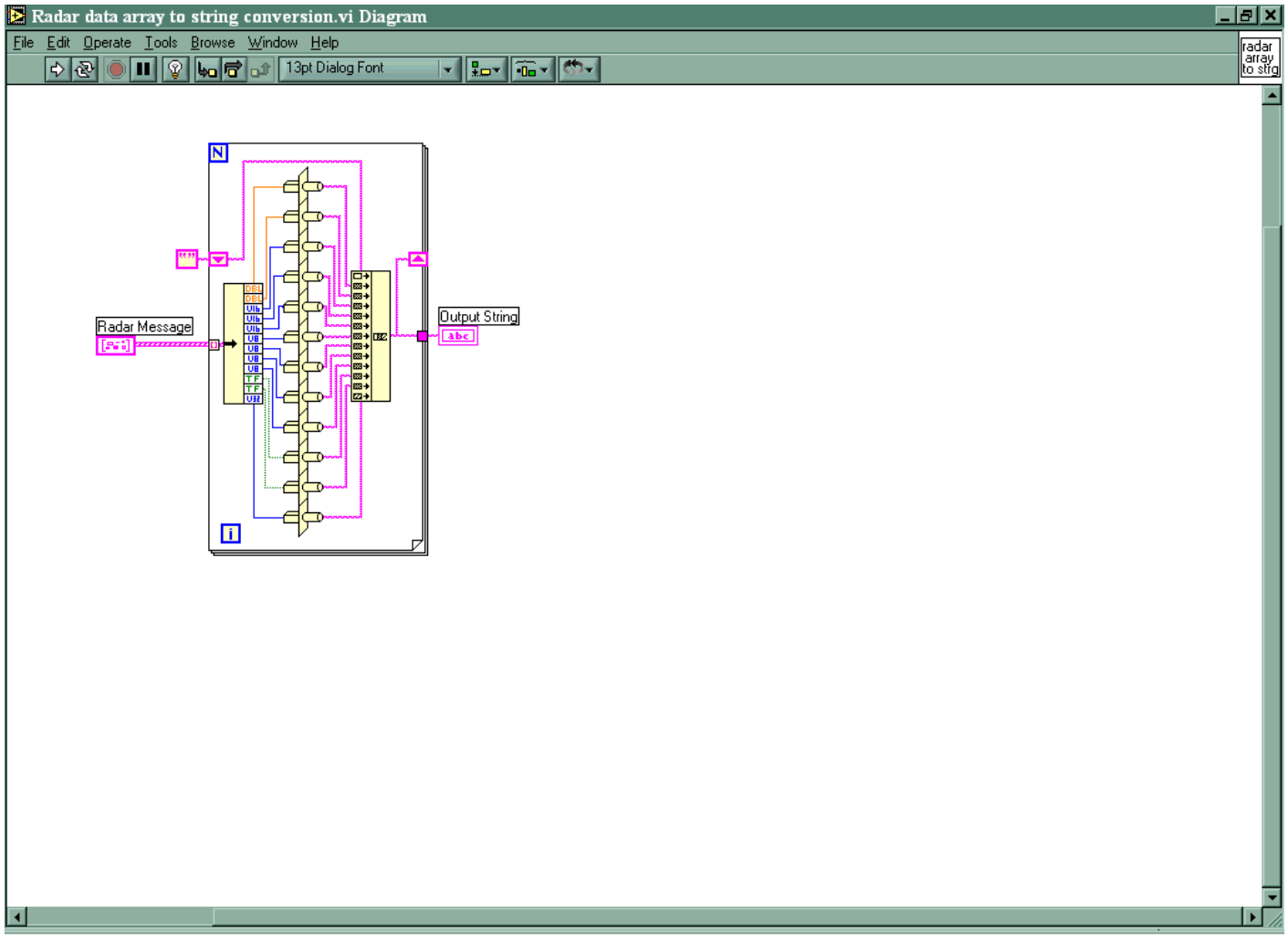


Figure A-14 Radar Data Array to String Conversion

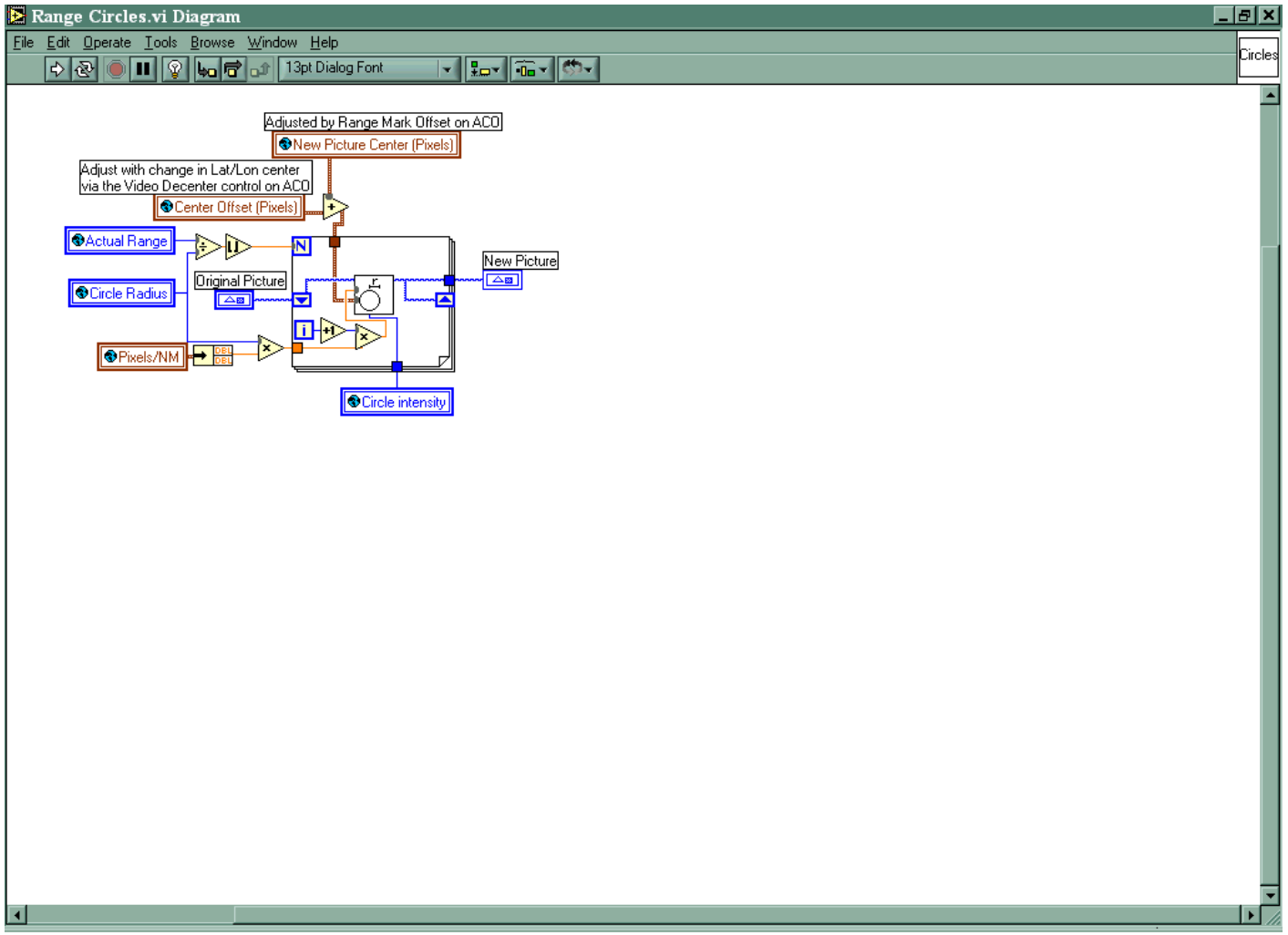


Figure A-15 Range Circles VI Diagram

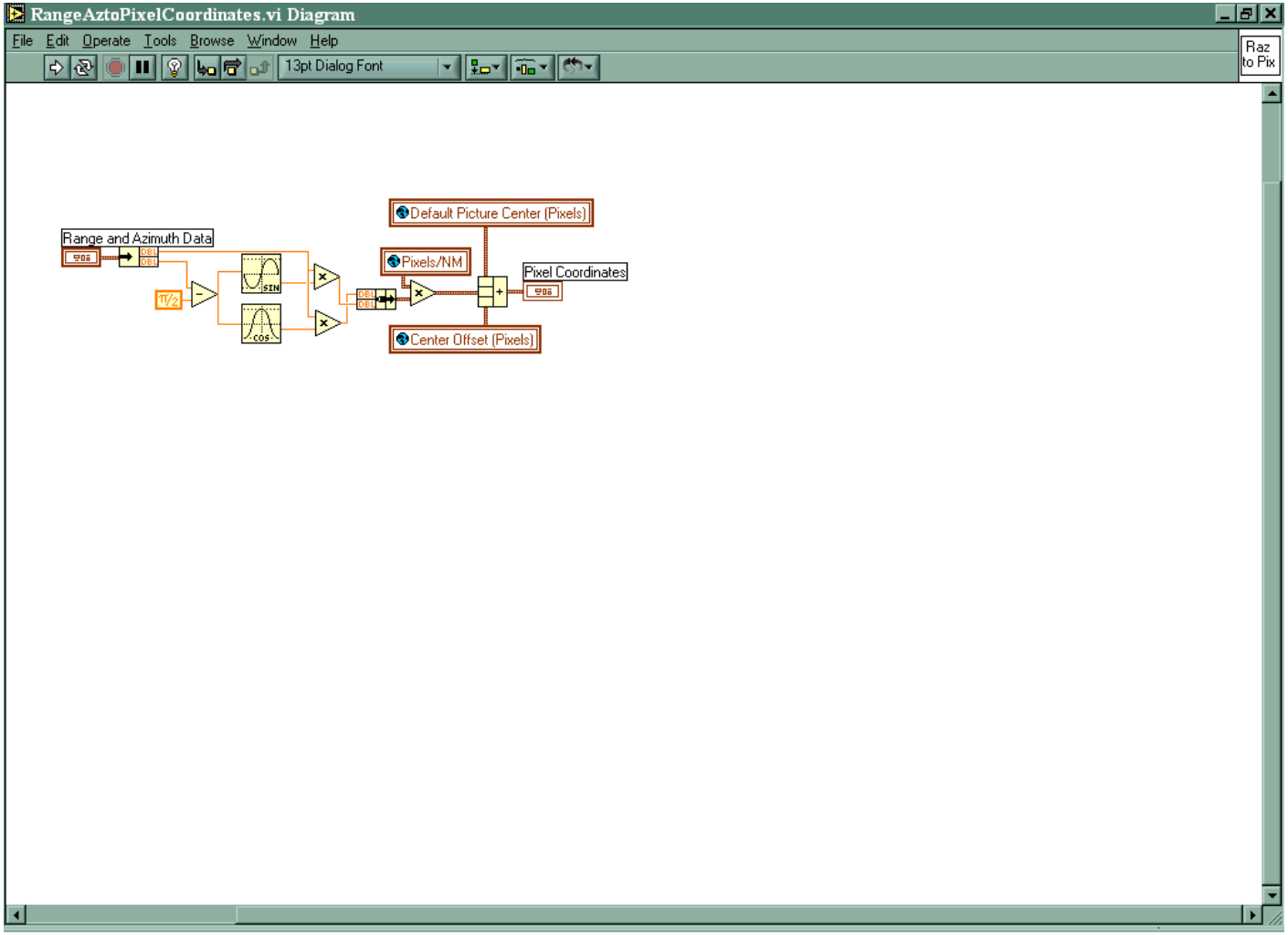


Figure A-16 Range Azimuth to Pixels Coordinates VI Diagram

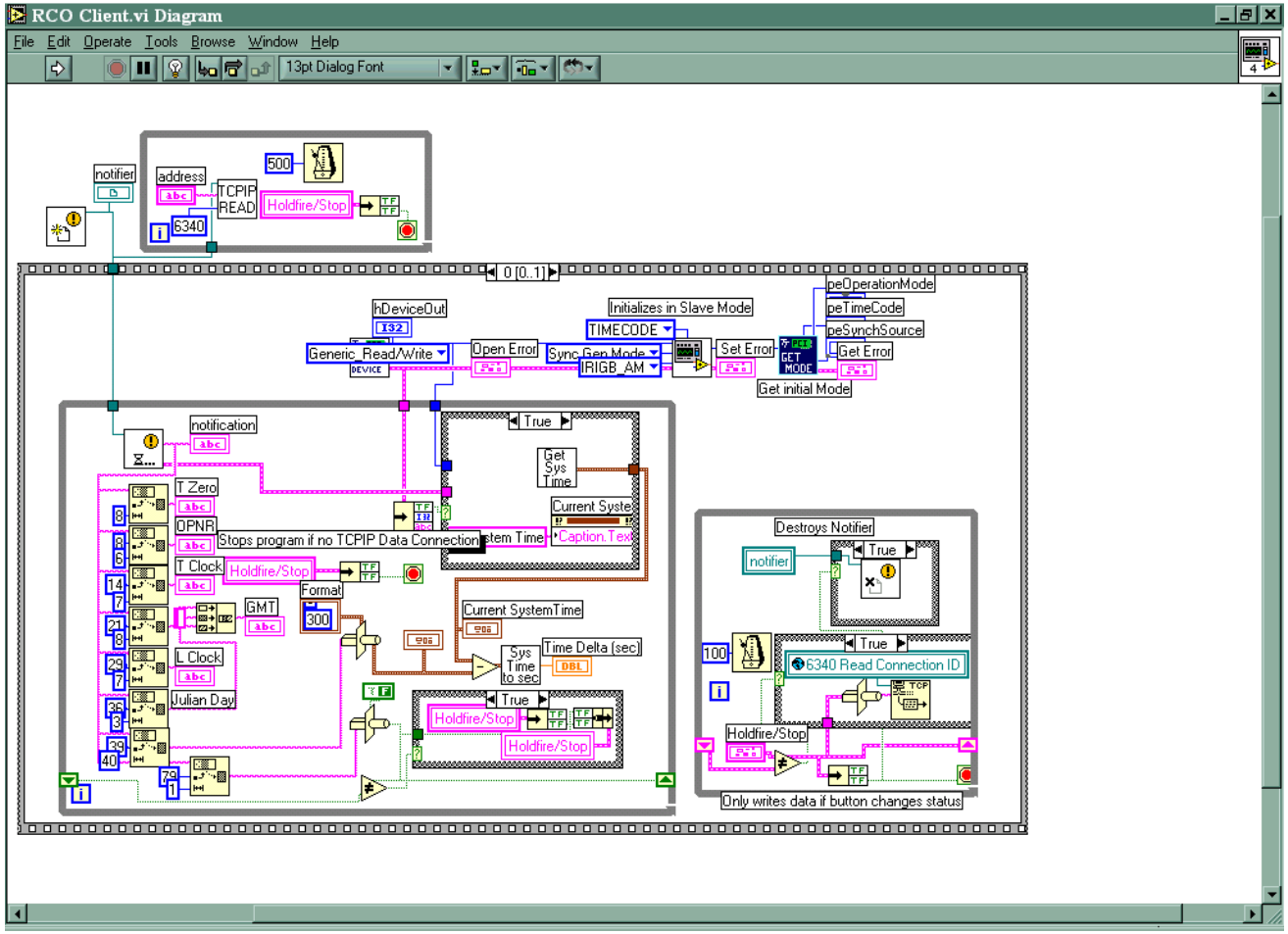


Figure A-17 RCO Client VI Diagram (Sequence 0, True)

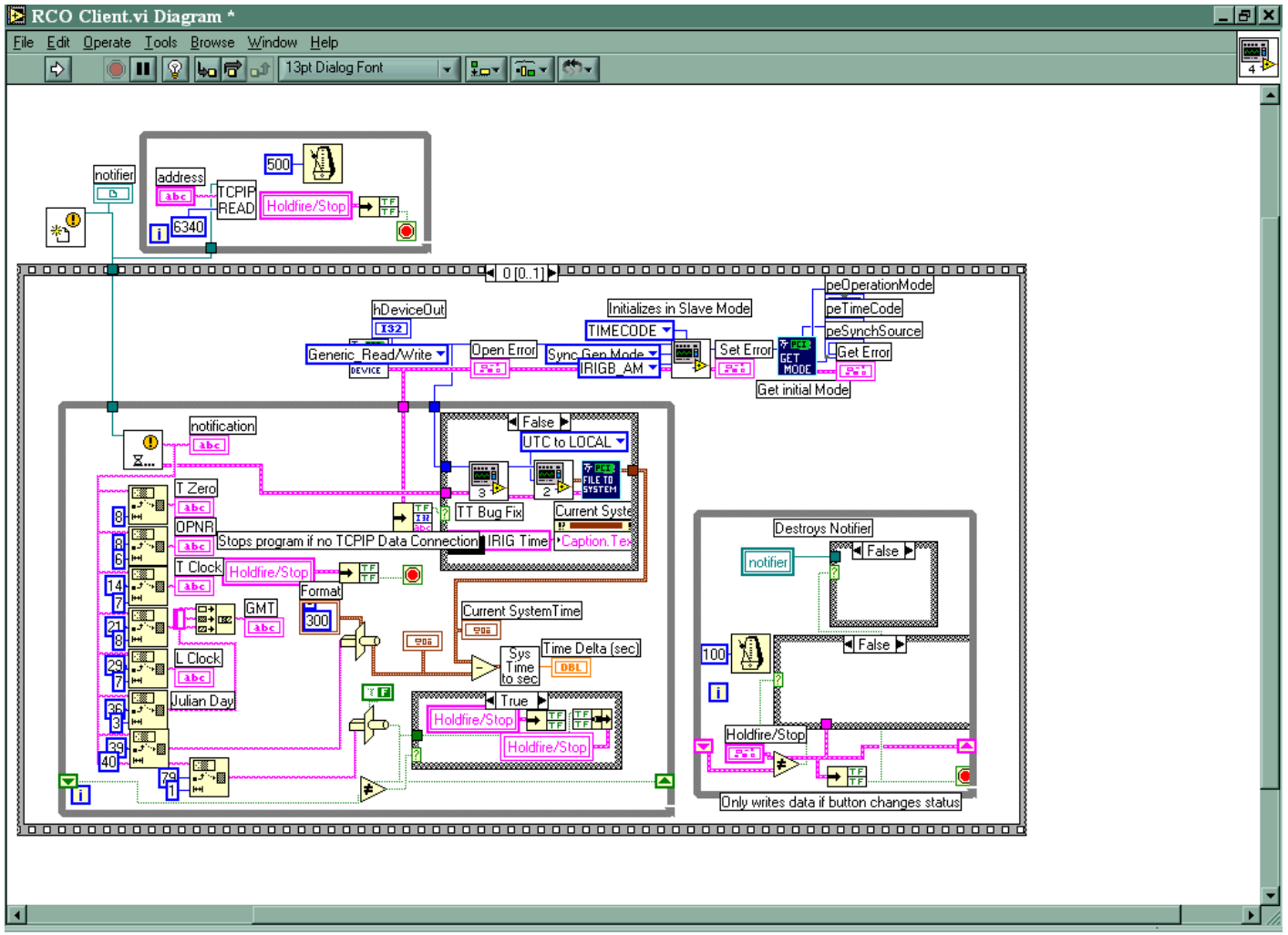


Figure A-18 RCO Client VI Diagram (Sequence 0, False)

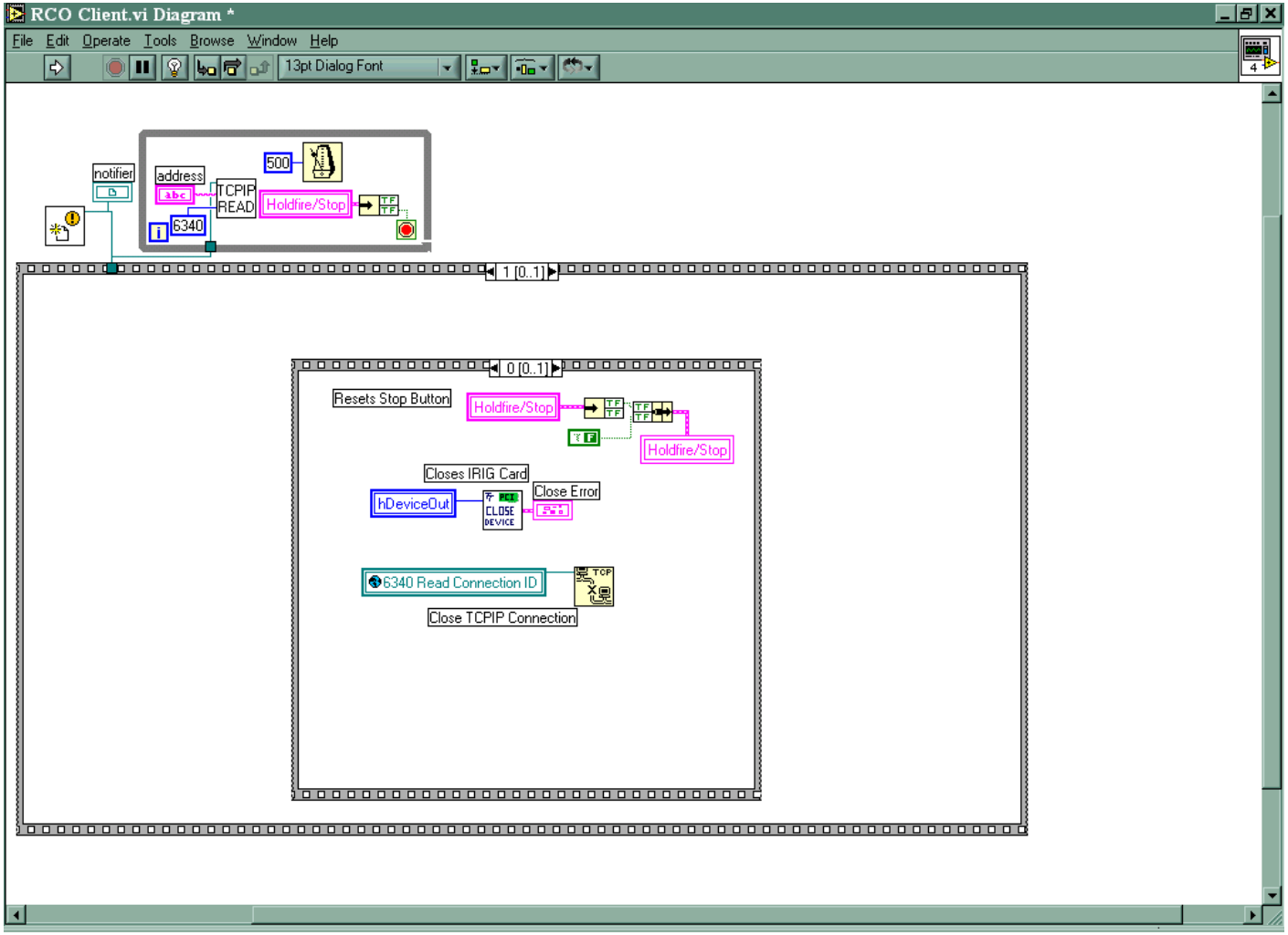


Figure A-19 RCO Client VI Diagram (Sequence 1,0)

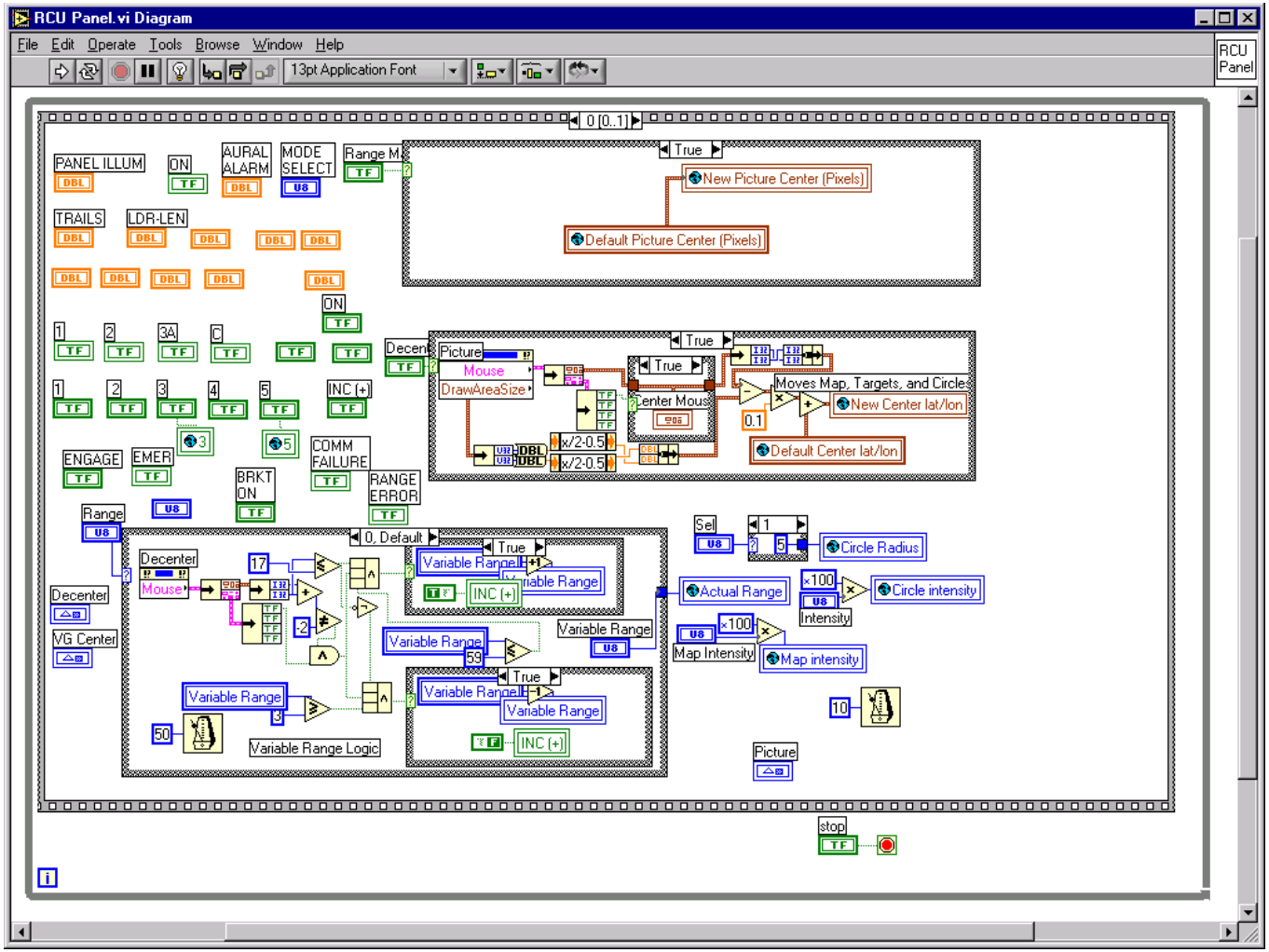


Figure A-20 RCU Panel (True, Sequence 0)

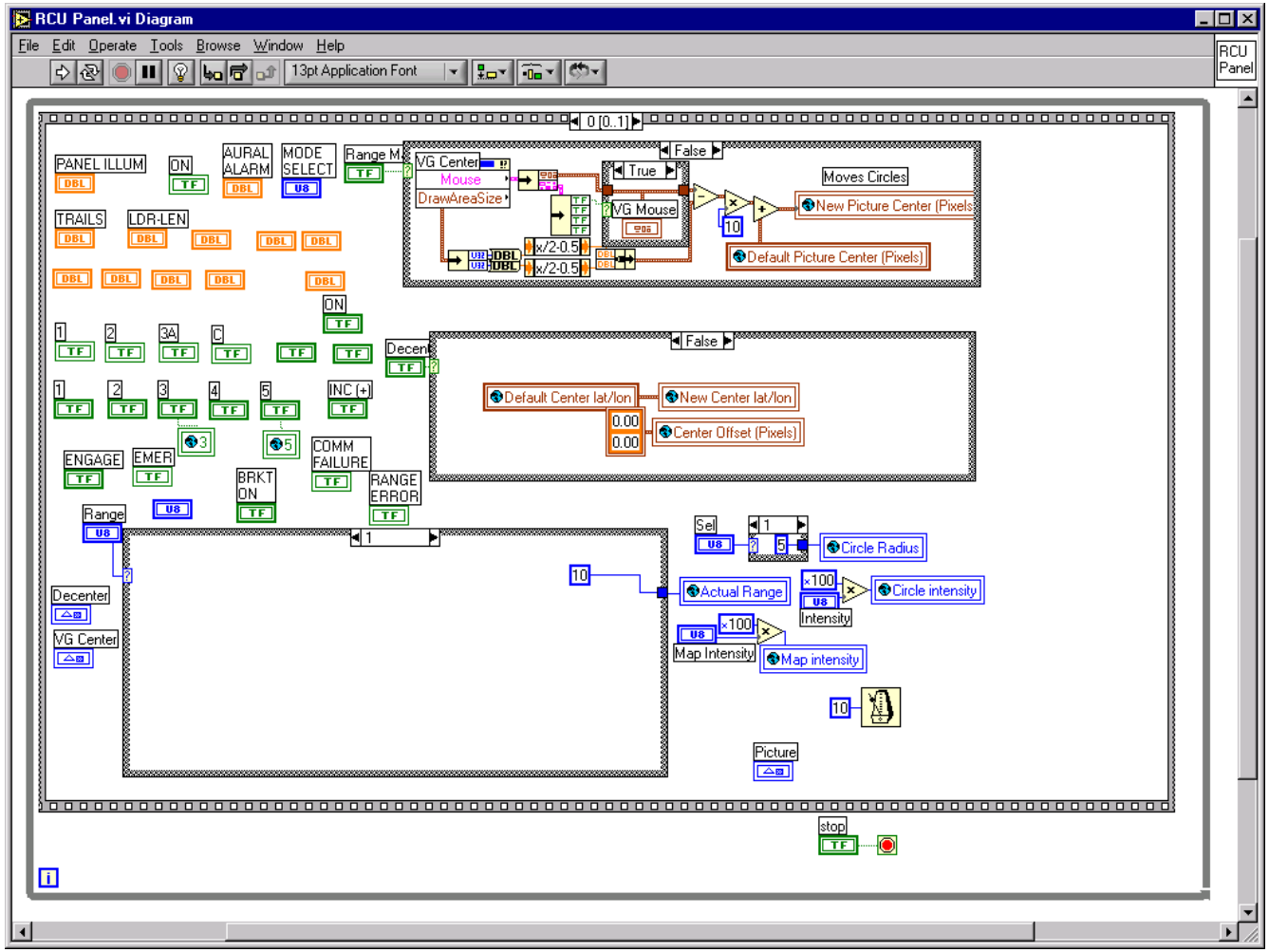


Figure A-21 RCU Panel (Sequence 0, False)

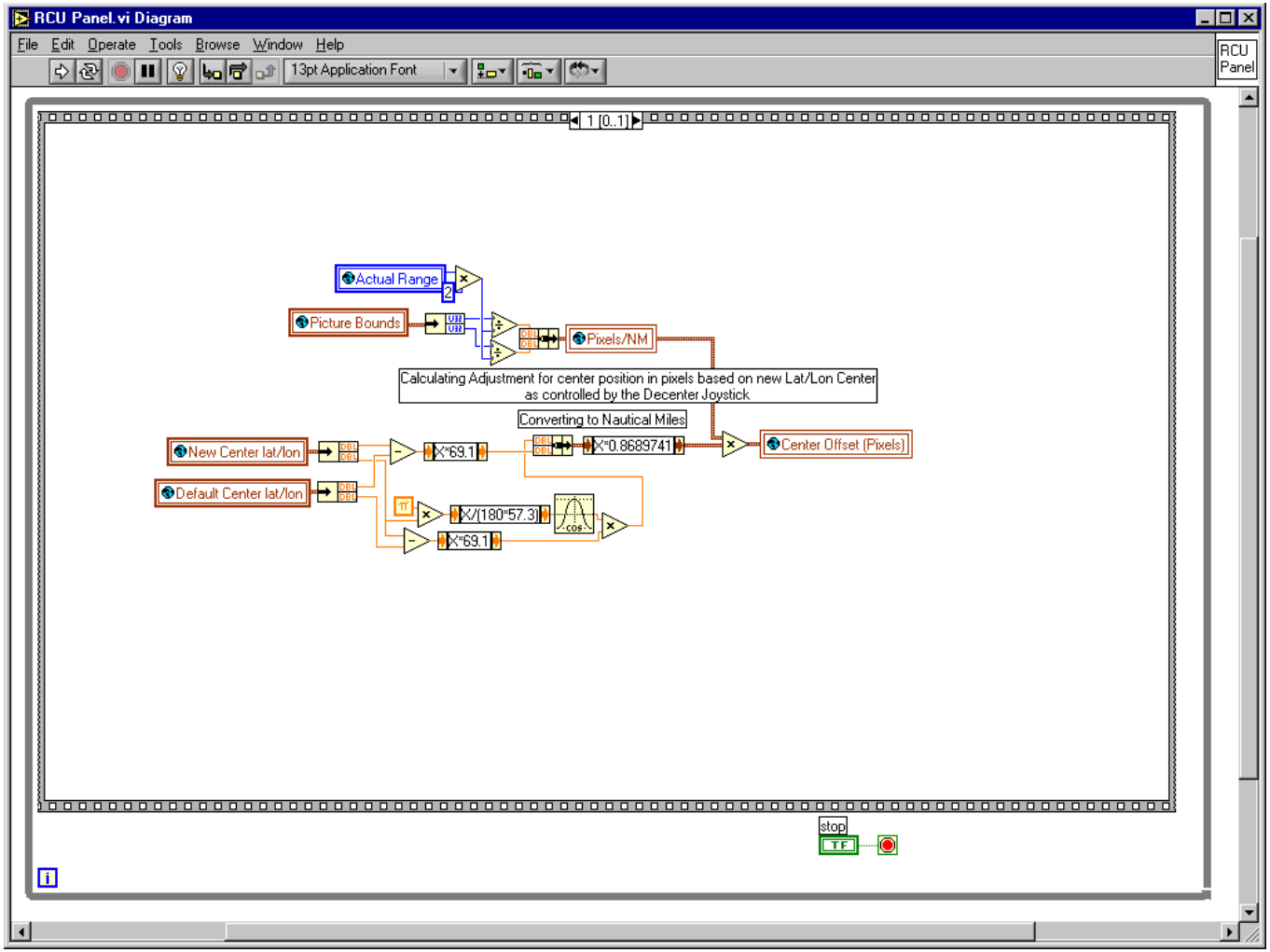


Figure A-22 RCU Panel VI Diagram (Sequence 1)

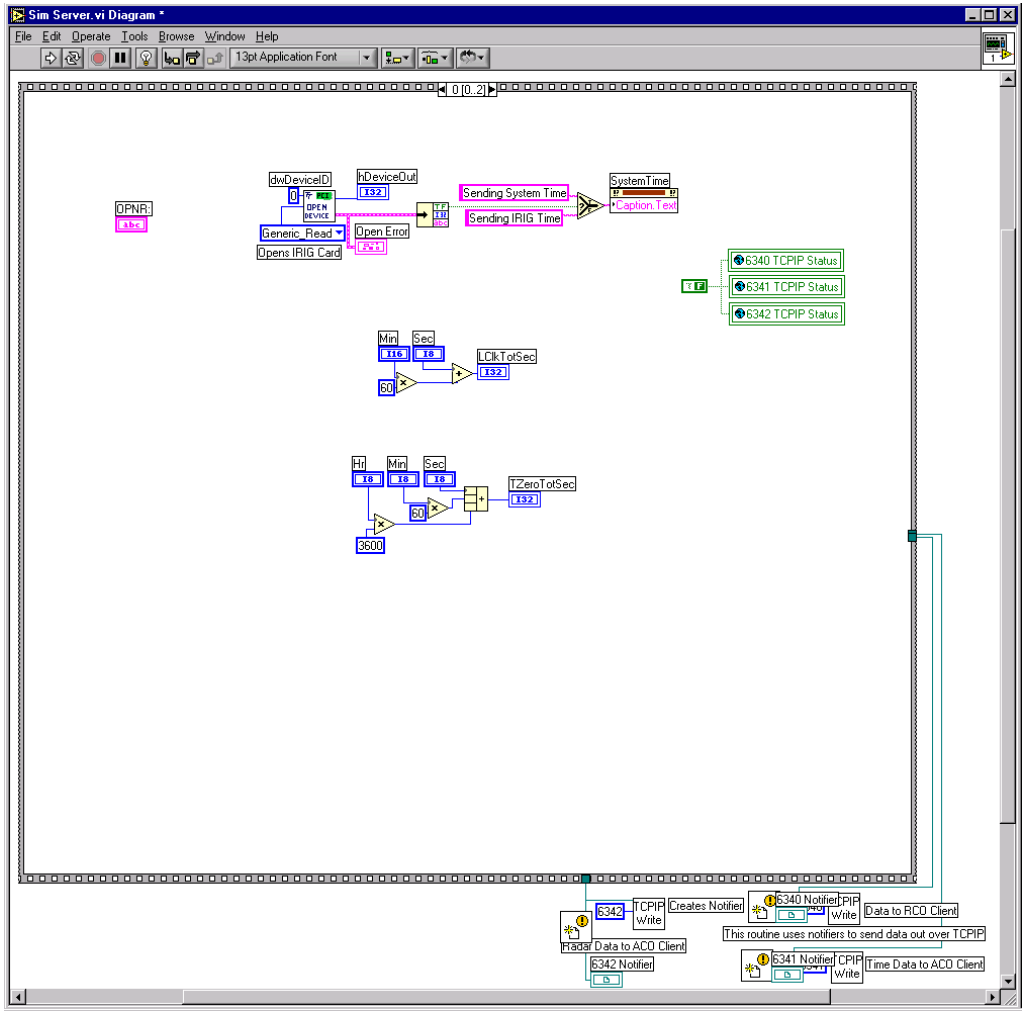


Figure A-23 Sim Server VI Diagram (Sequence 0)

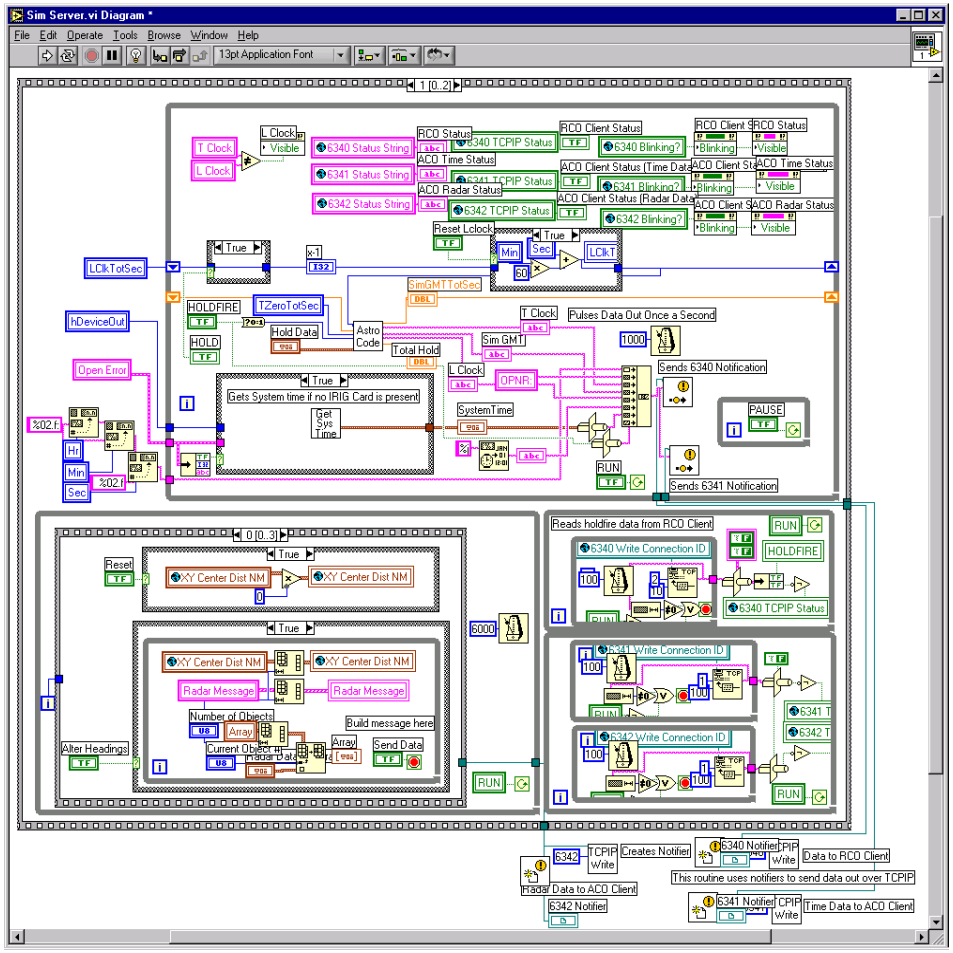


Figure A-24 Sim Server VI Diagram (Sequence 1-0, True)

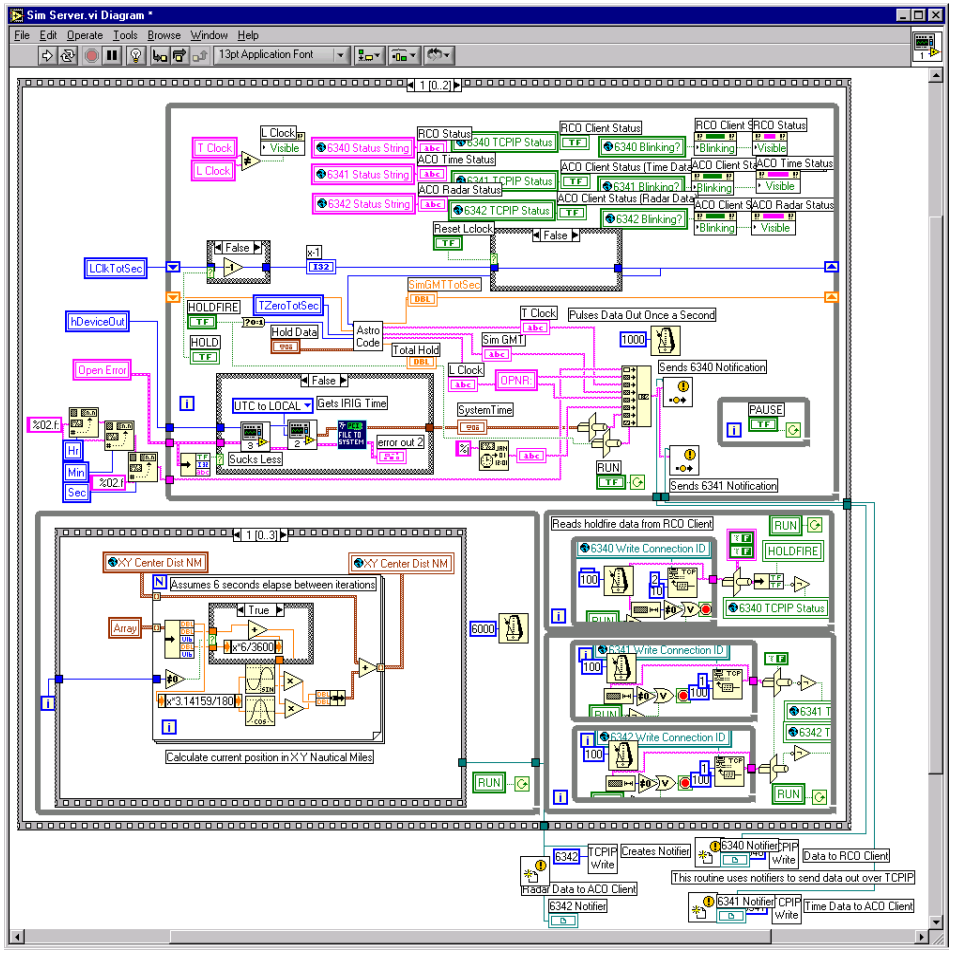


Figure A-25 Sim Server VI Diagram (Sequence 1-1, False)

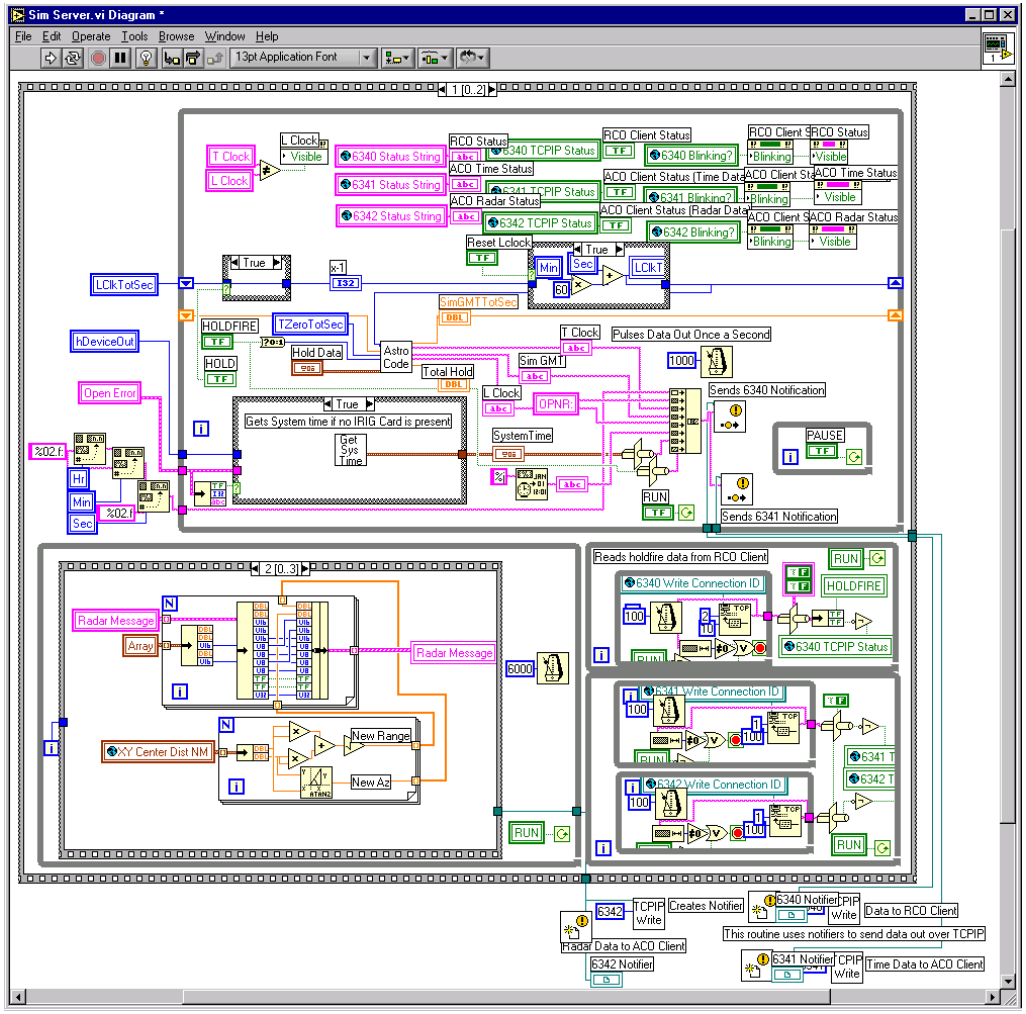


Figure A-26 Sim Server VI Diagram (Sequence 1-2, False)

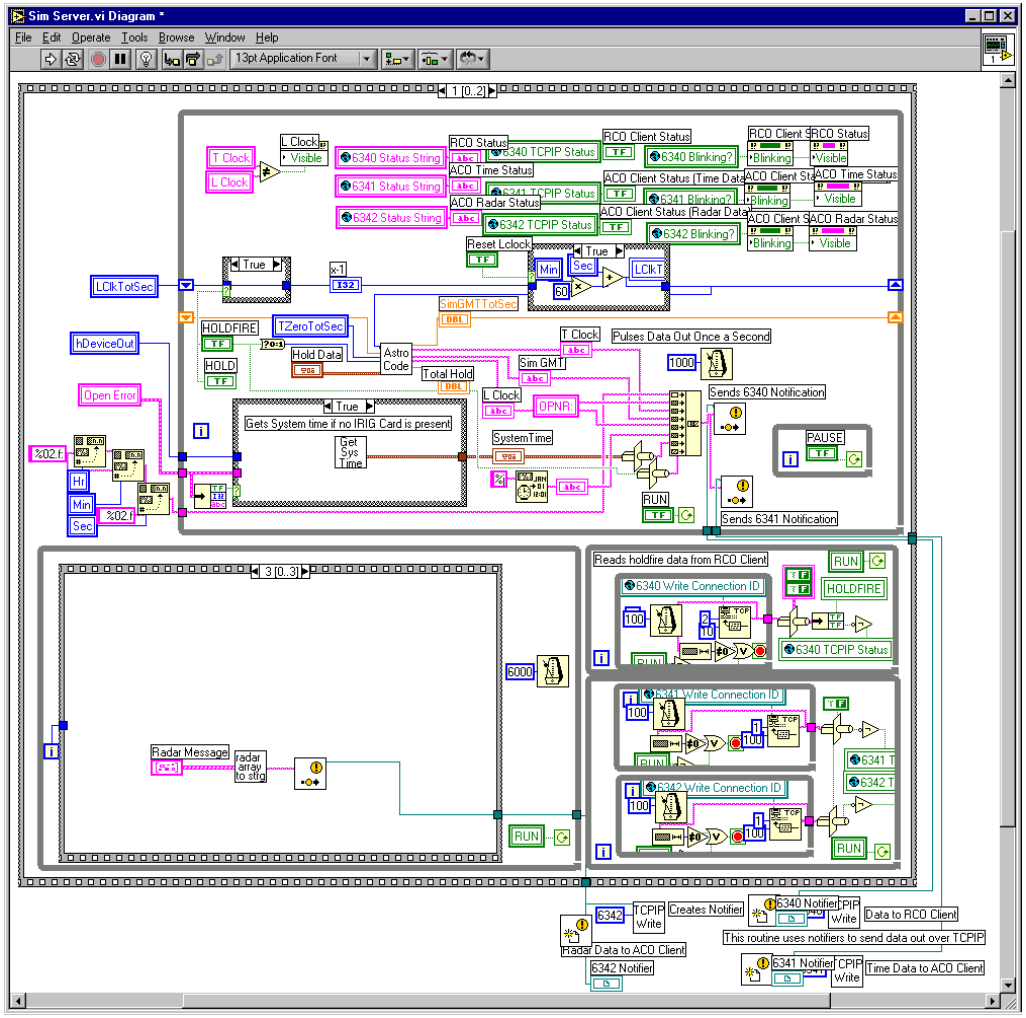


Figure A-27 Sim Server VI Diagram (Sequence 1-3, False)

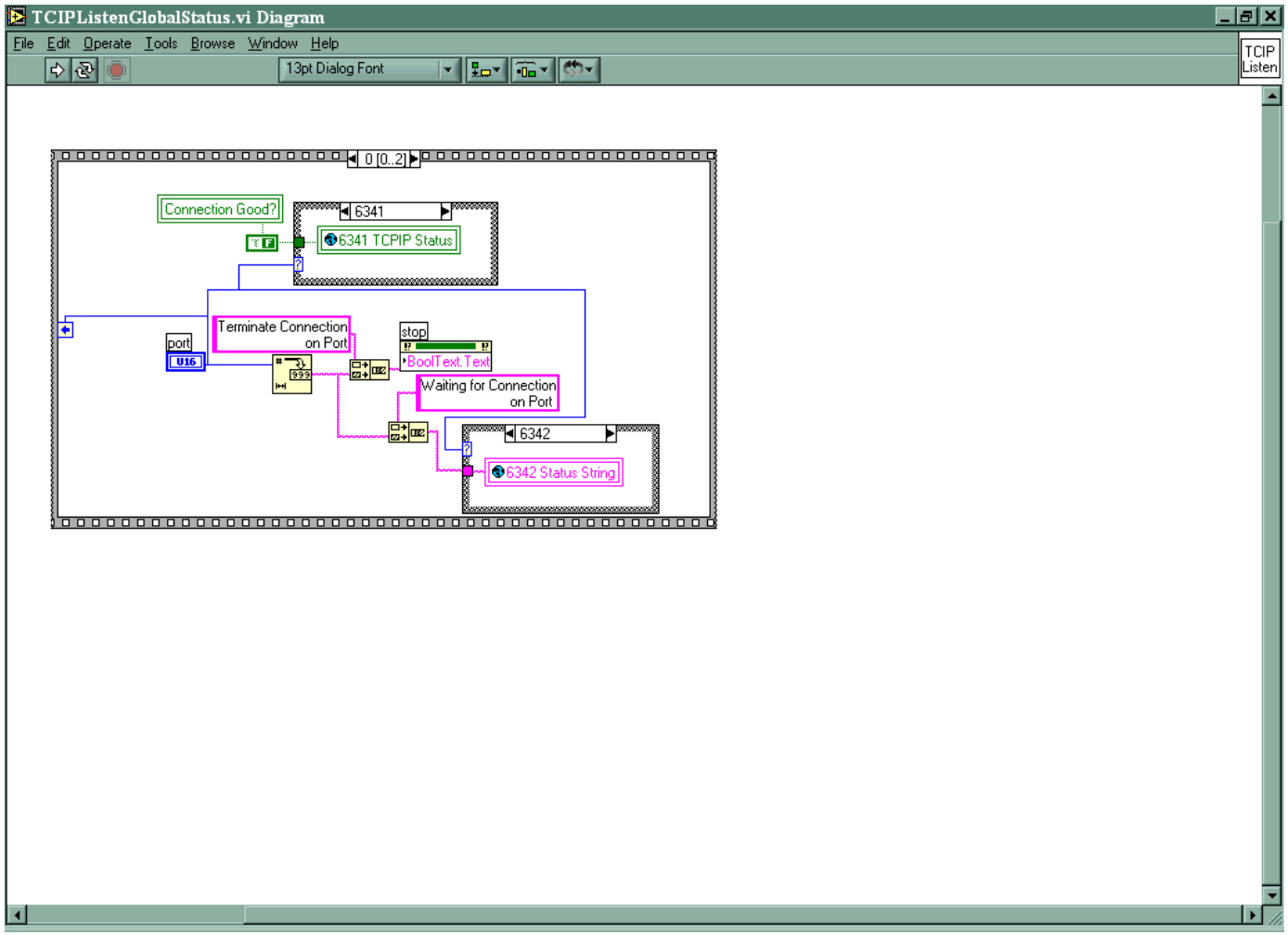


Figure A-28 TCIP Listen Global Status VI Diagram (Sequence 0)

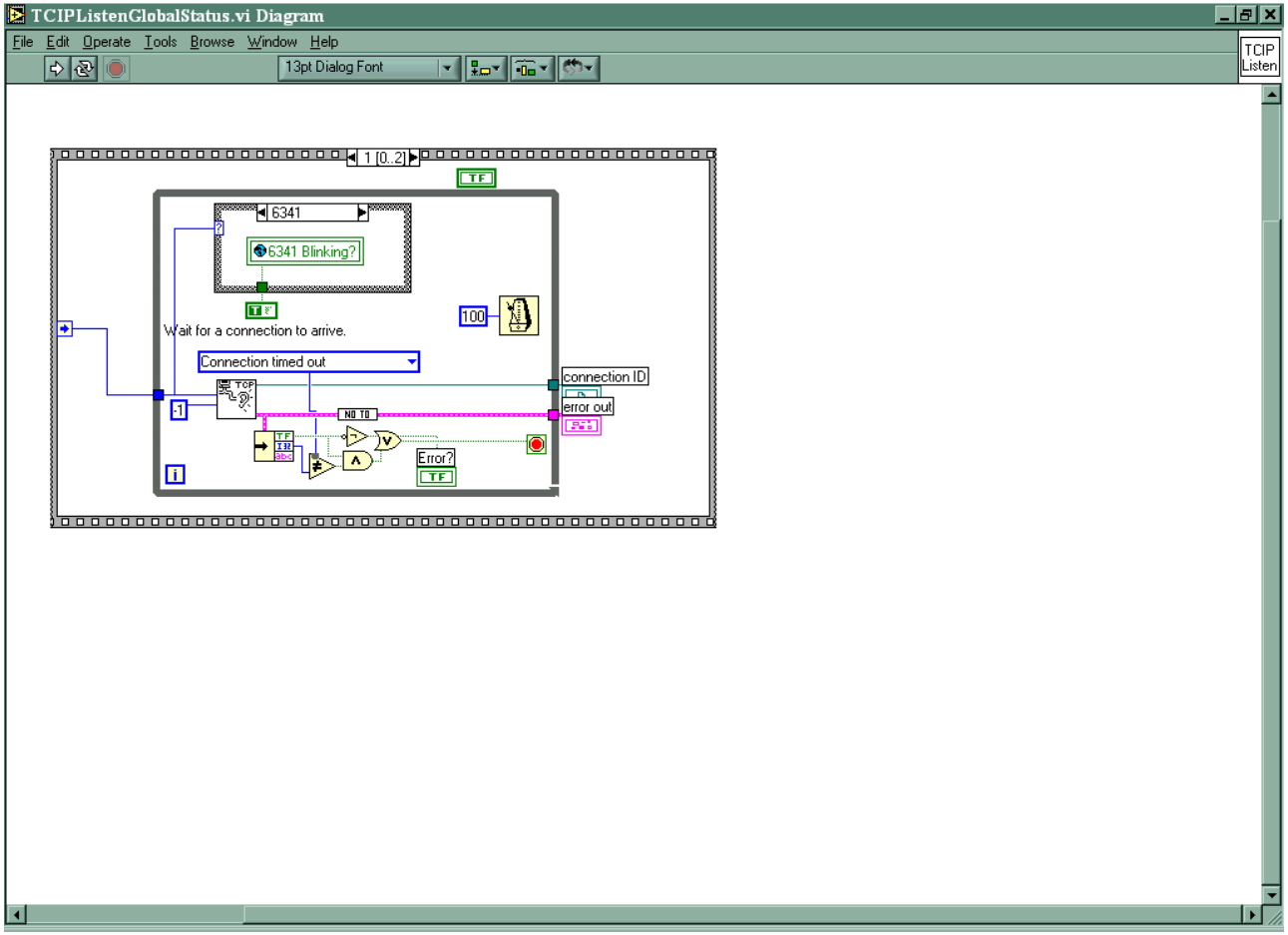


Figure A-29 TCIP Listen Global Status VI Diagram (Sequence 1)

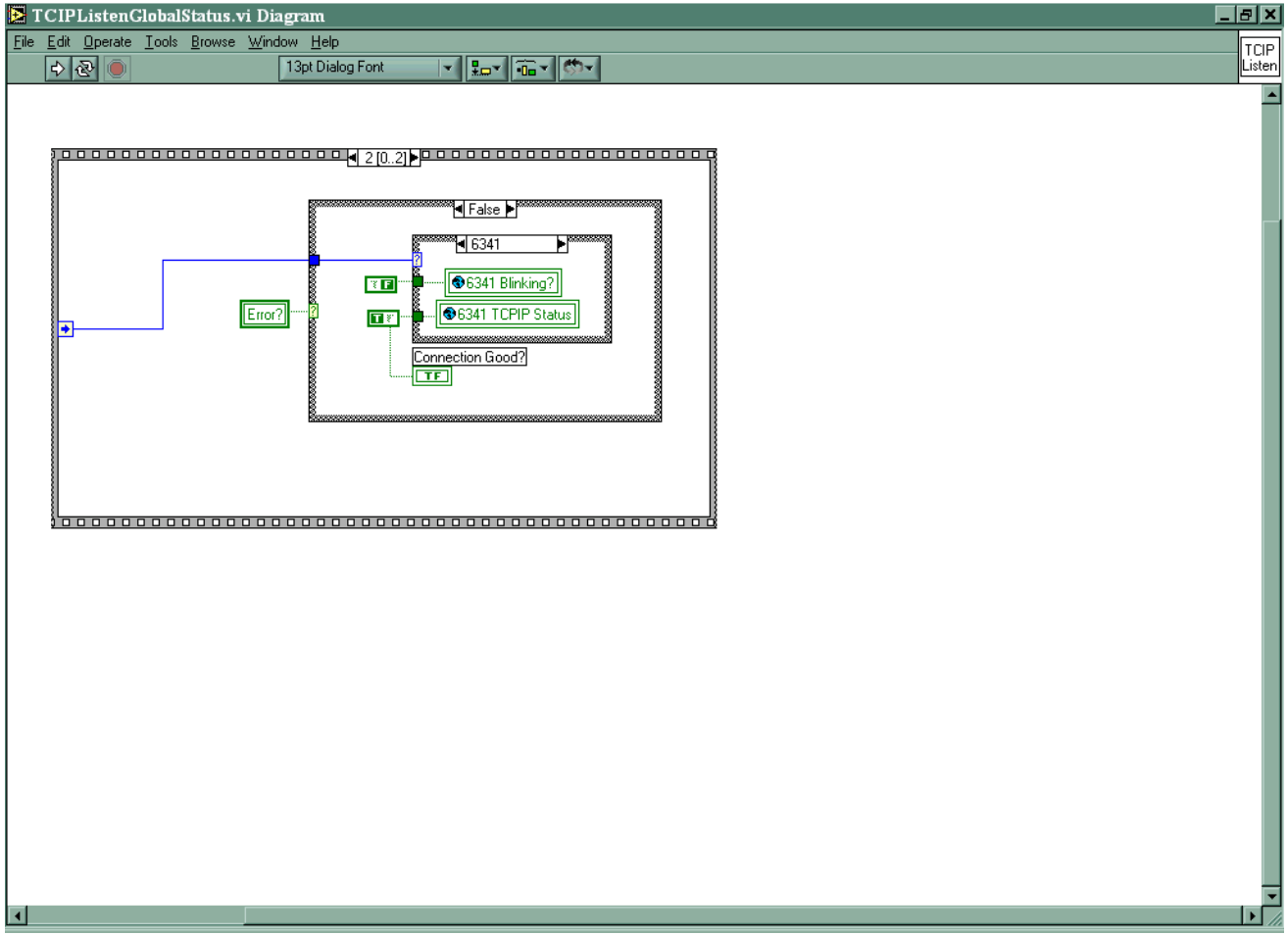


Figure A-30 TCIP Listen Global Status (Sequence 2)

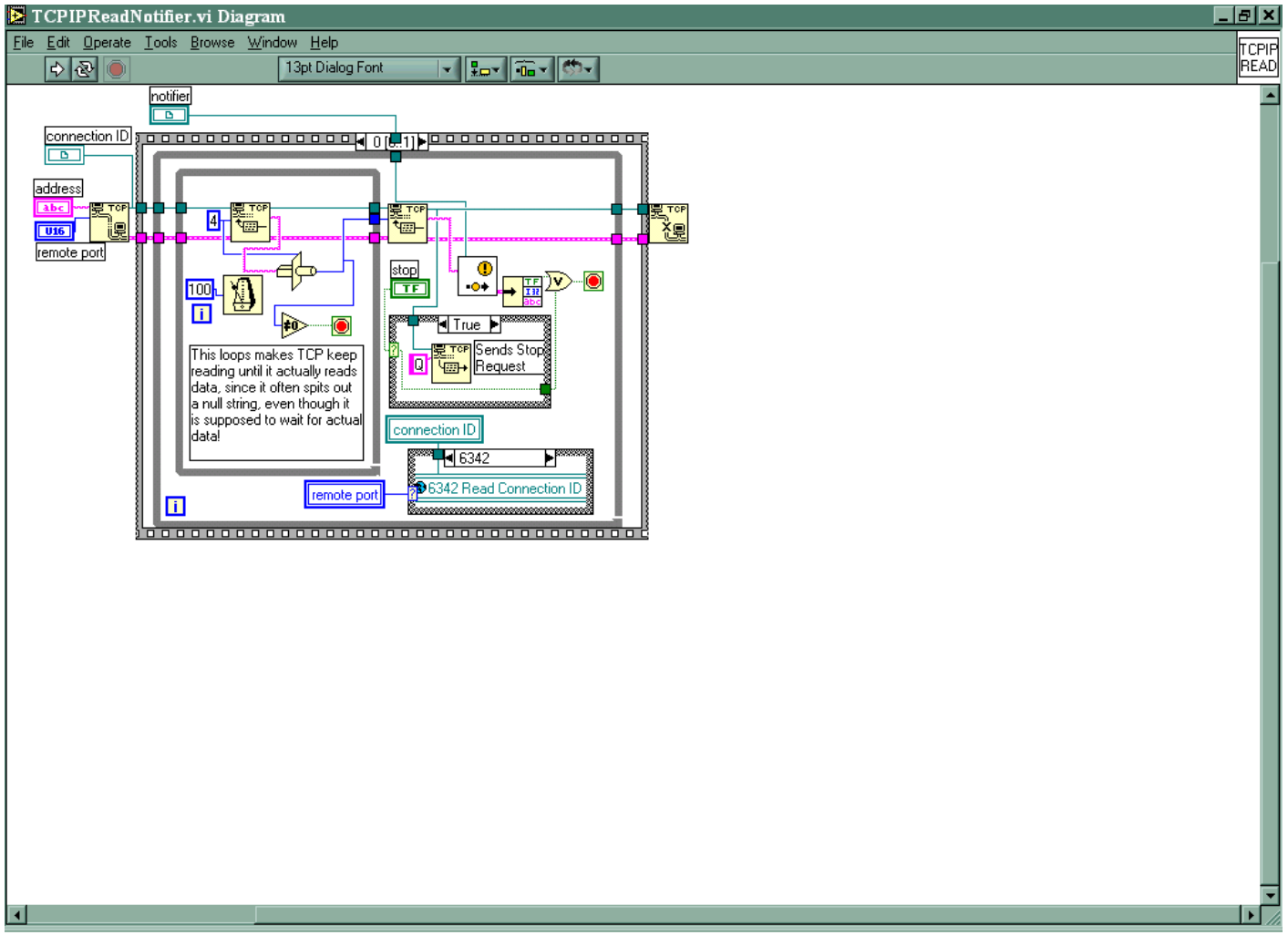


Figure A-31 TCPIP Read Notifier VI Diagram (Sequence 0, True)

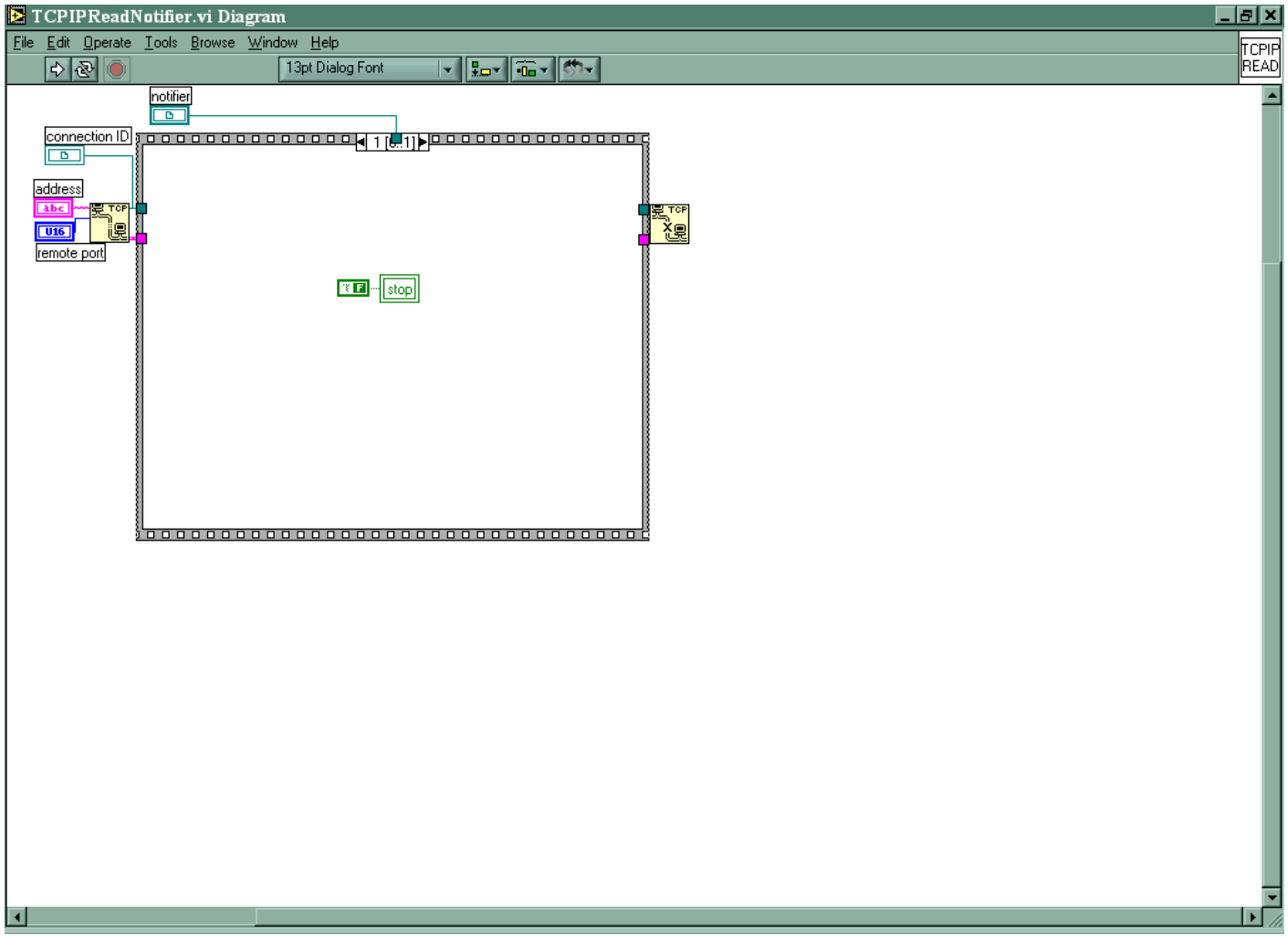


Figure A-32 TCPIP Read Notifier VI Diagram (Sequence 1)

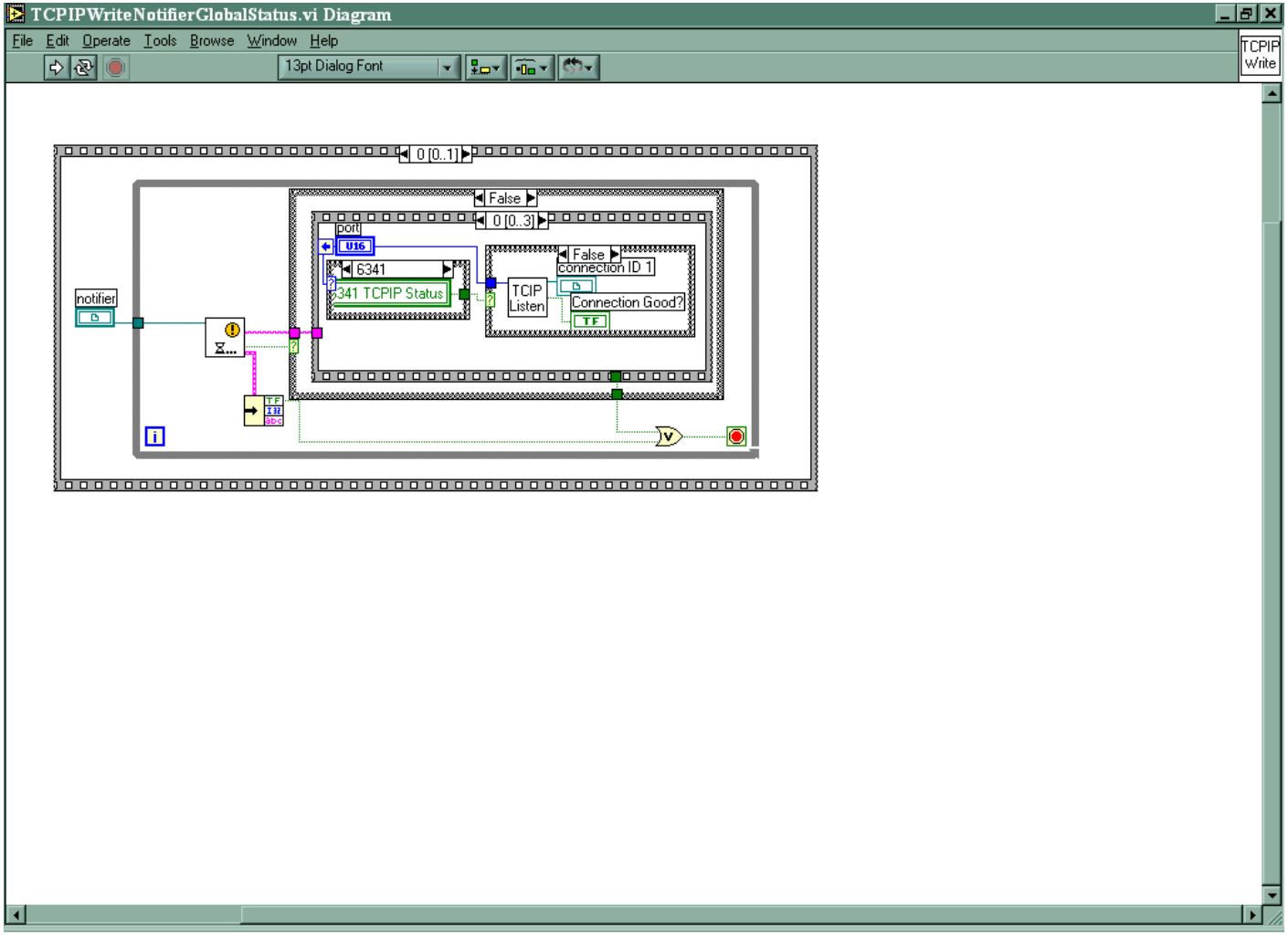


Figure A-33 TCPIP Write Notifier Global Status VI Diagram (Sequence 0, False)

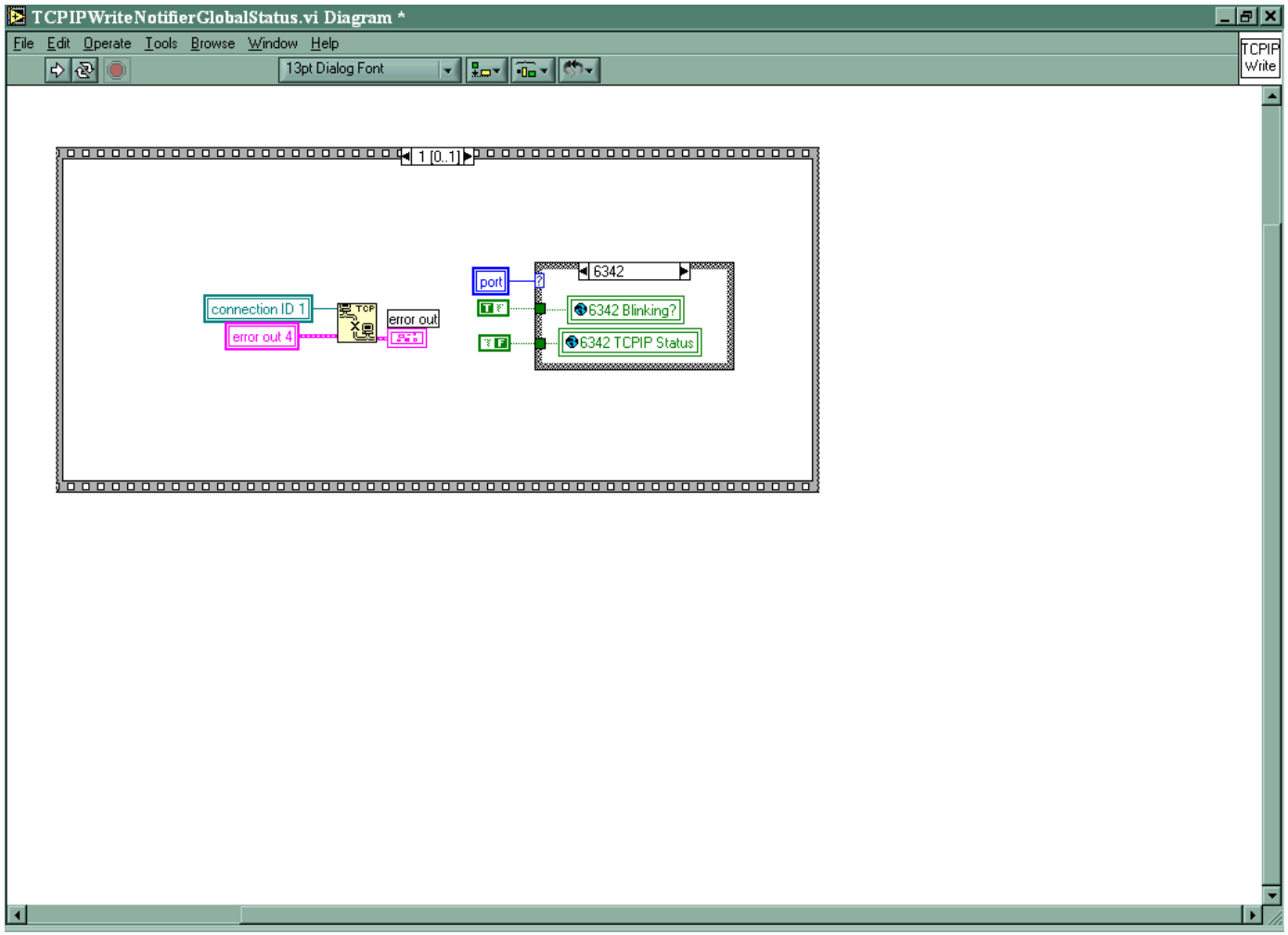


Figure A-34 TCPIP Write Notifier Global Status VI Diagram (Sequence 1)

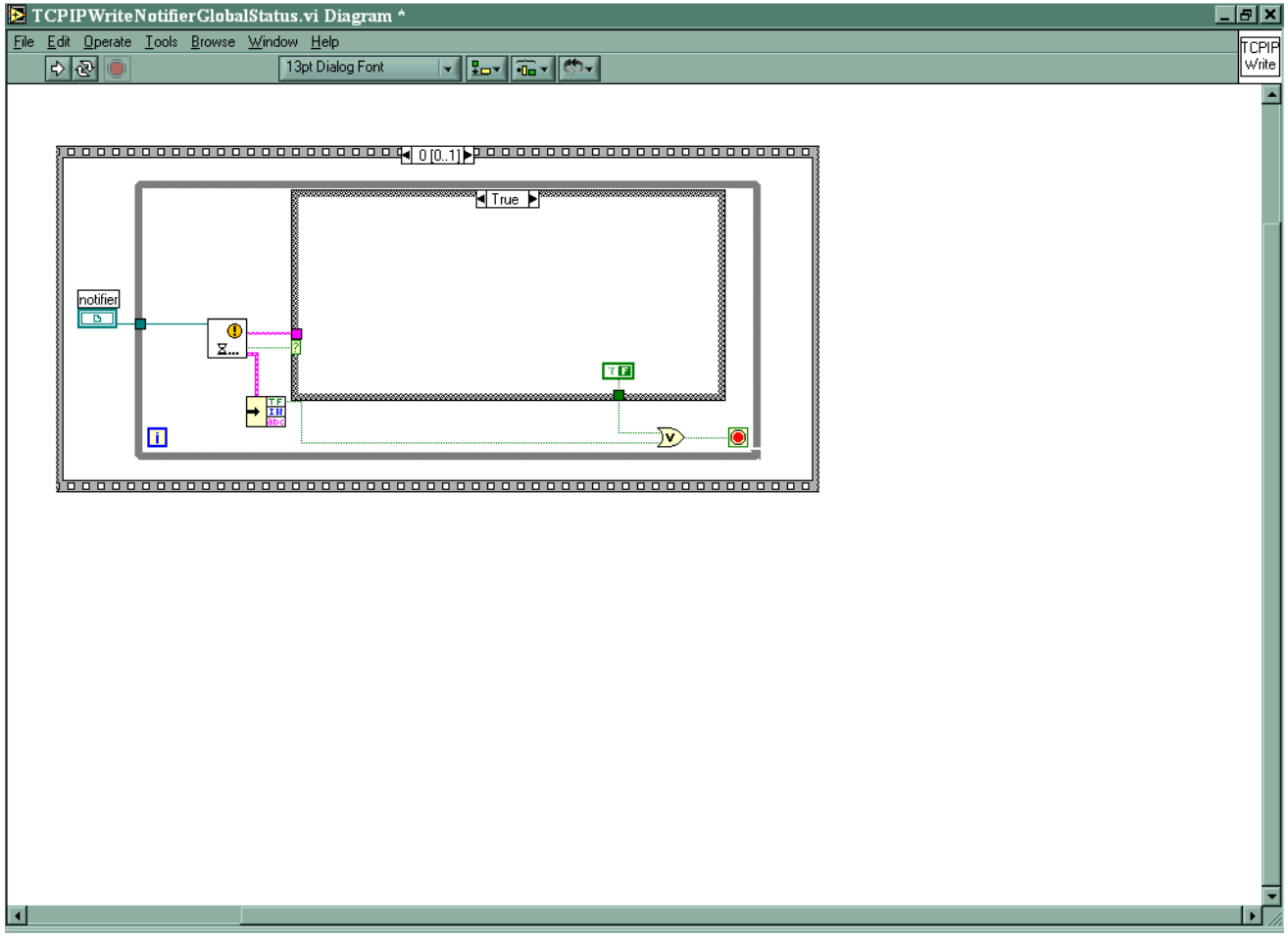


Figure A-35 TCPIP Write Notifier Global Status VI Diagram (Sequence 0, True)

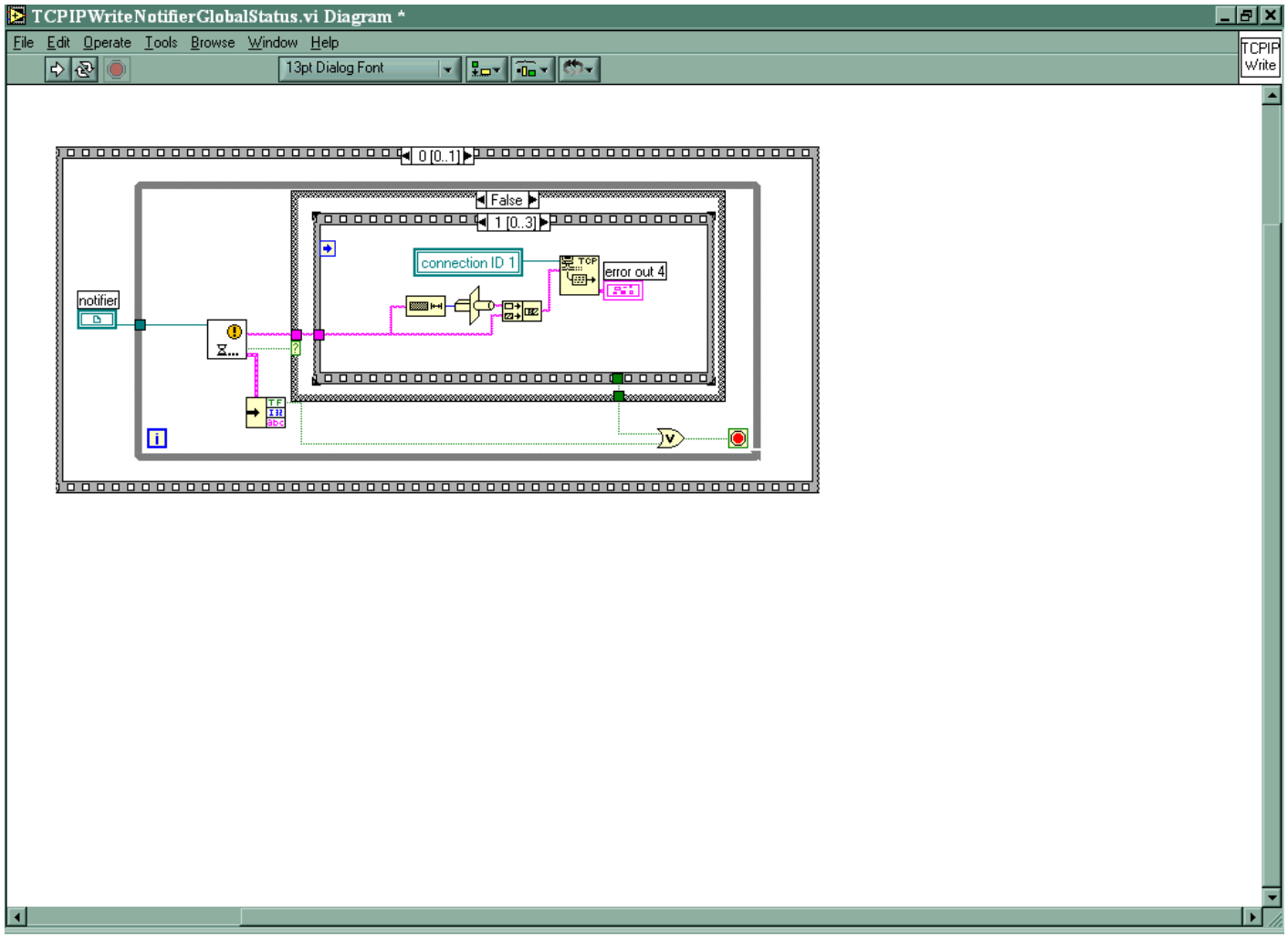


Figure A-36 TCPIP Write Notifier Global Status VI Diagram (Sequence 0-1, False)

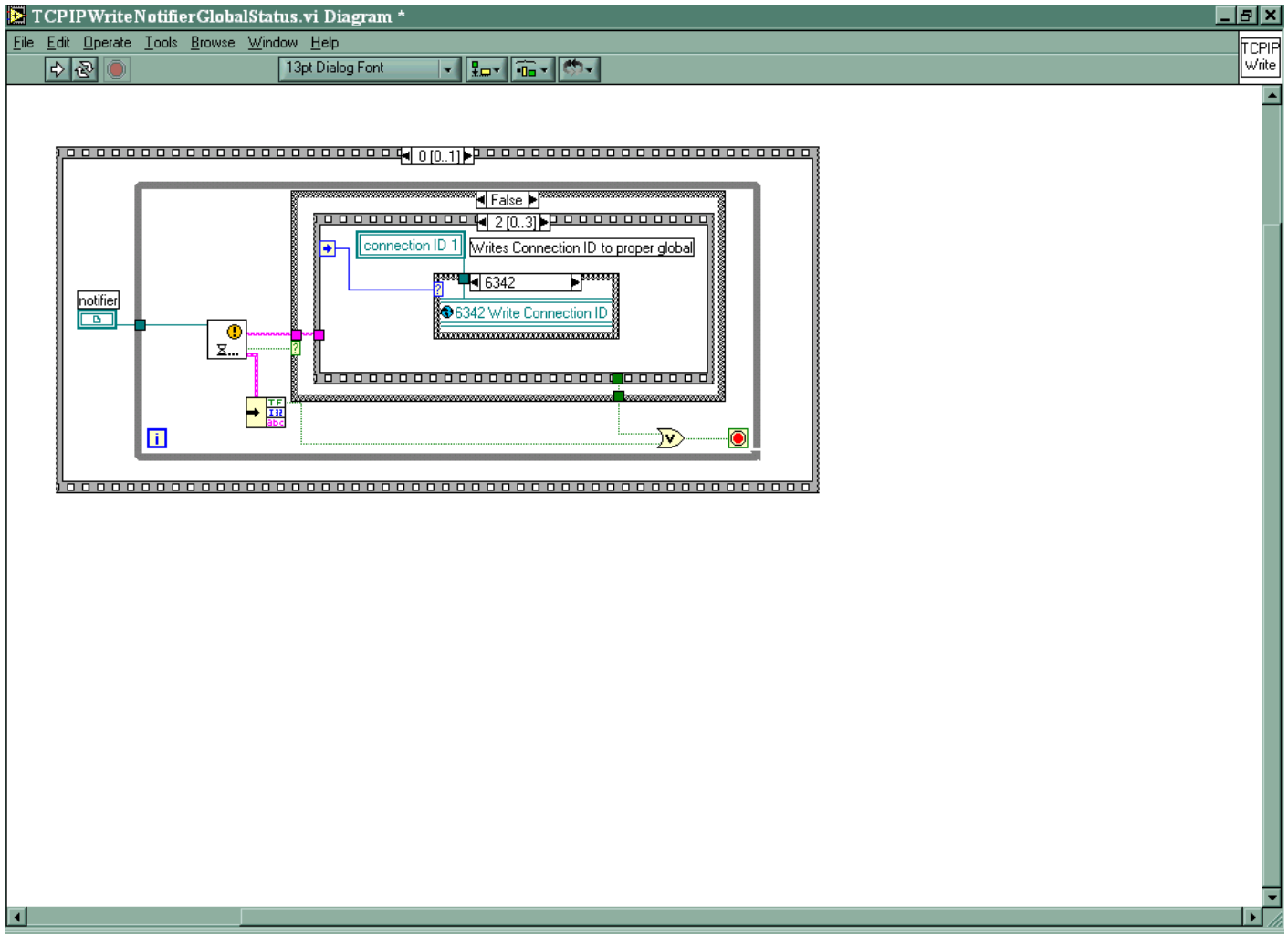


Figure A-37 TCPIP Write Notifier Global Status VI Diagram (Sequence 0-2, False)

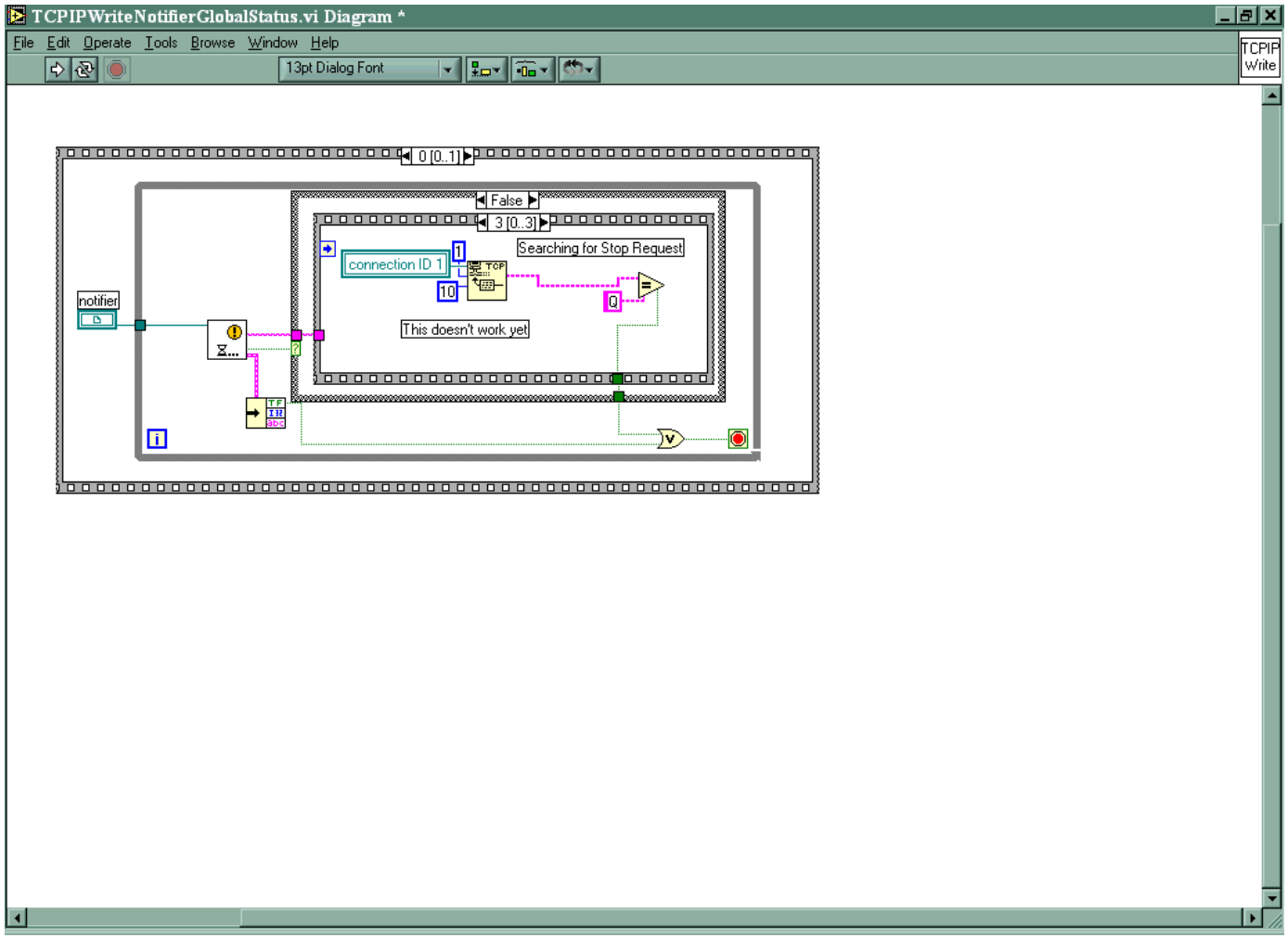


Figure A-38 TCPIP Write Notifier Global Status VI Diagram (Sequence 0-3, False)

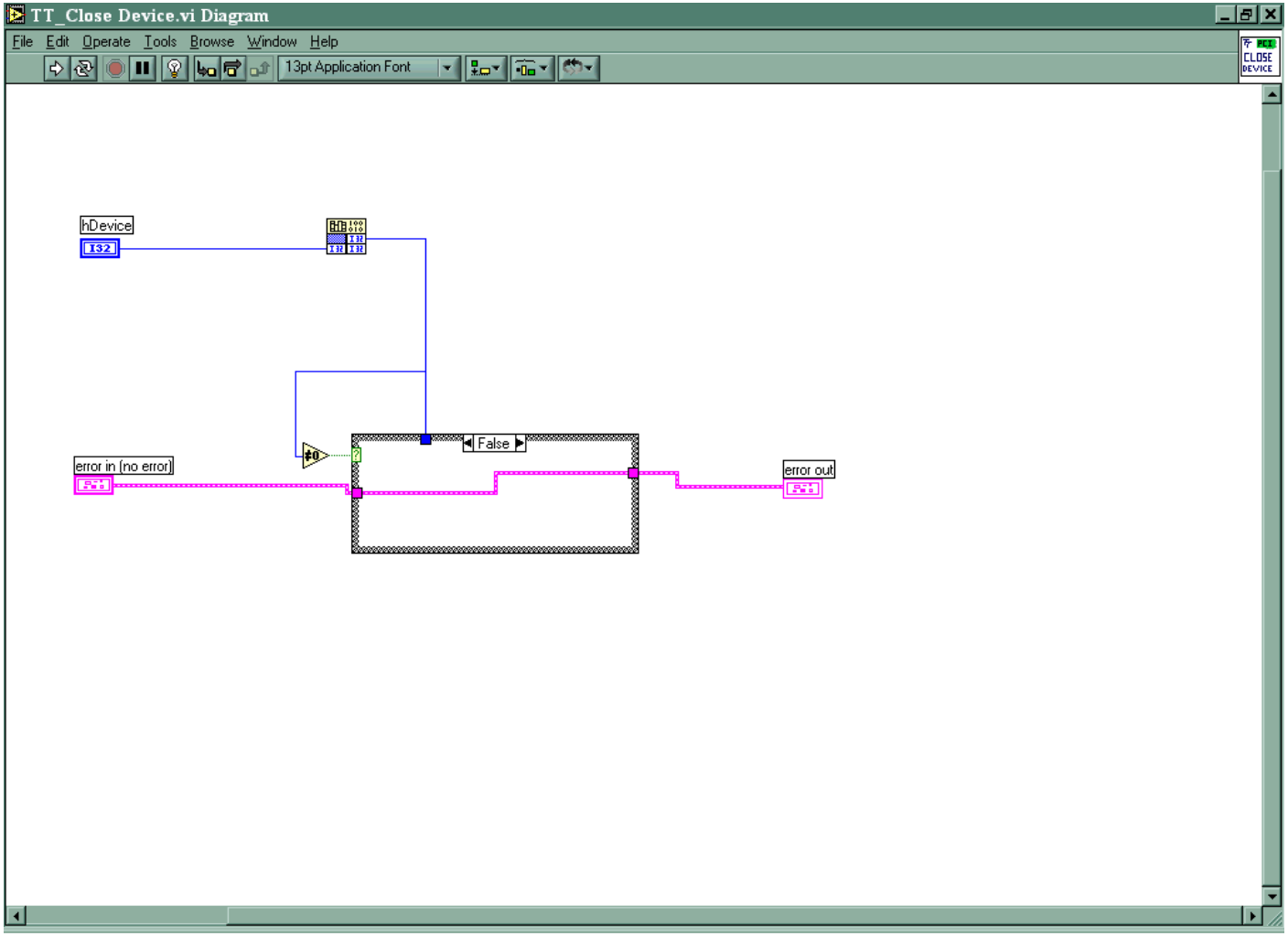


Figure A-39 True Time Close Device VI Diagram (False)

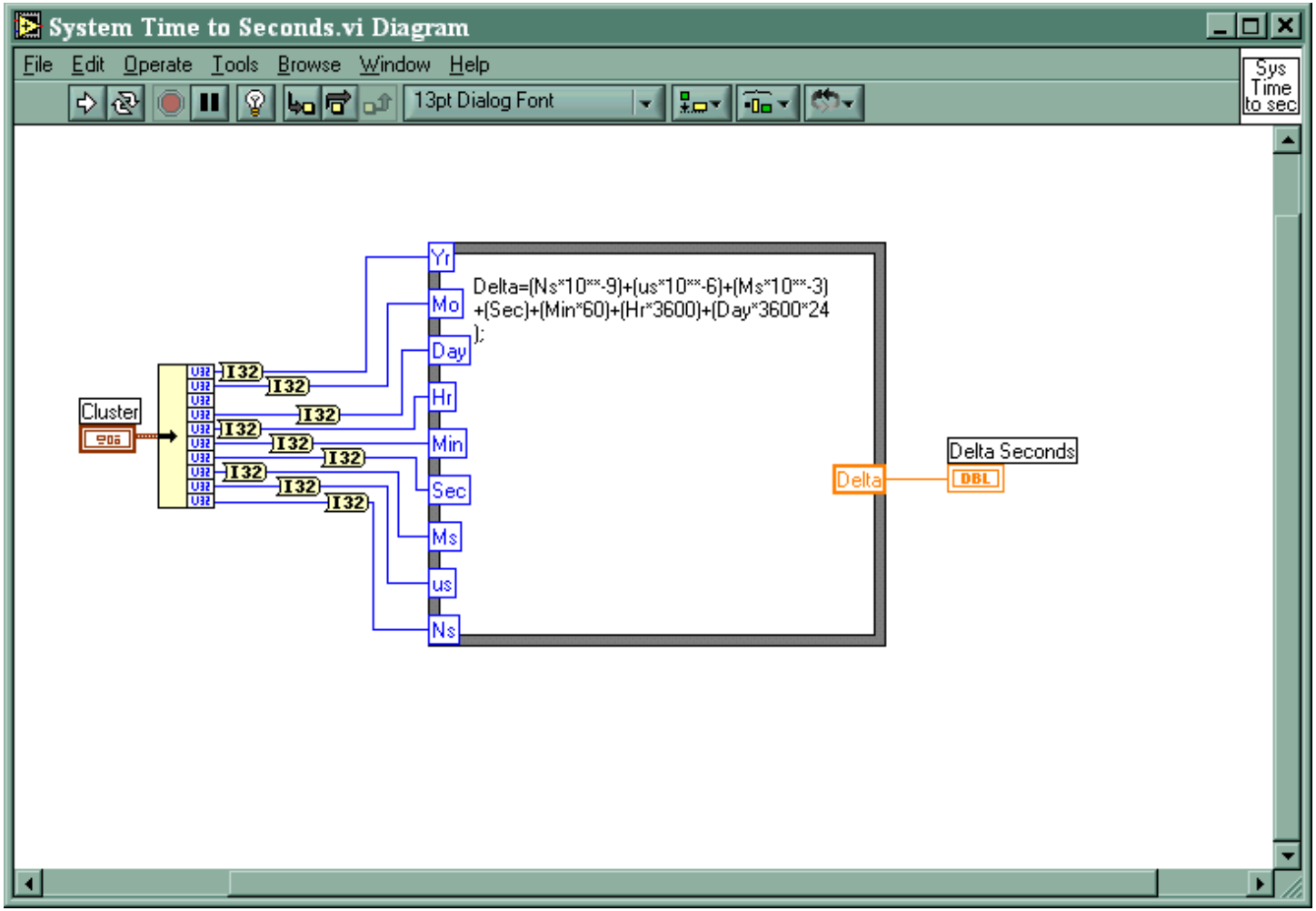


Figure A-40 True Time System Time to Seconds VI Diagram

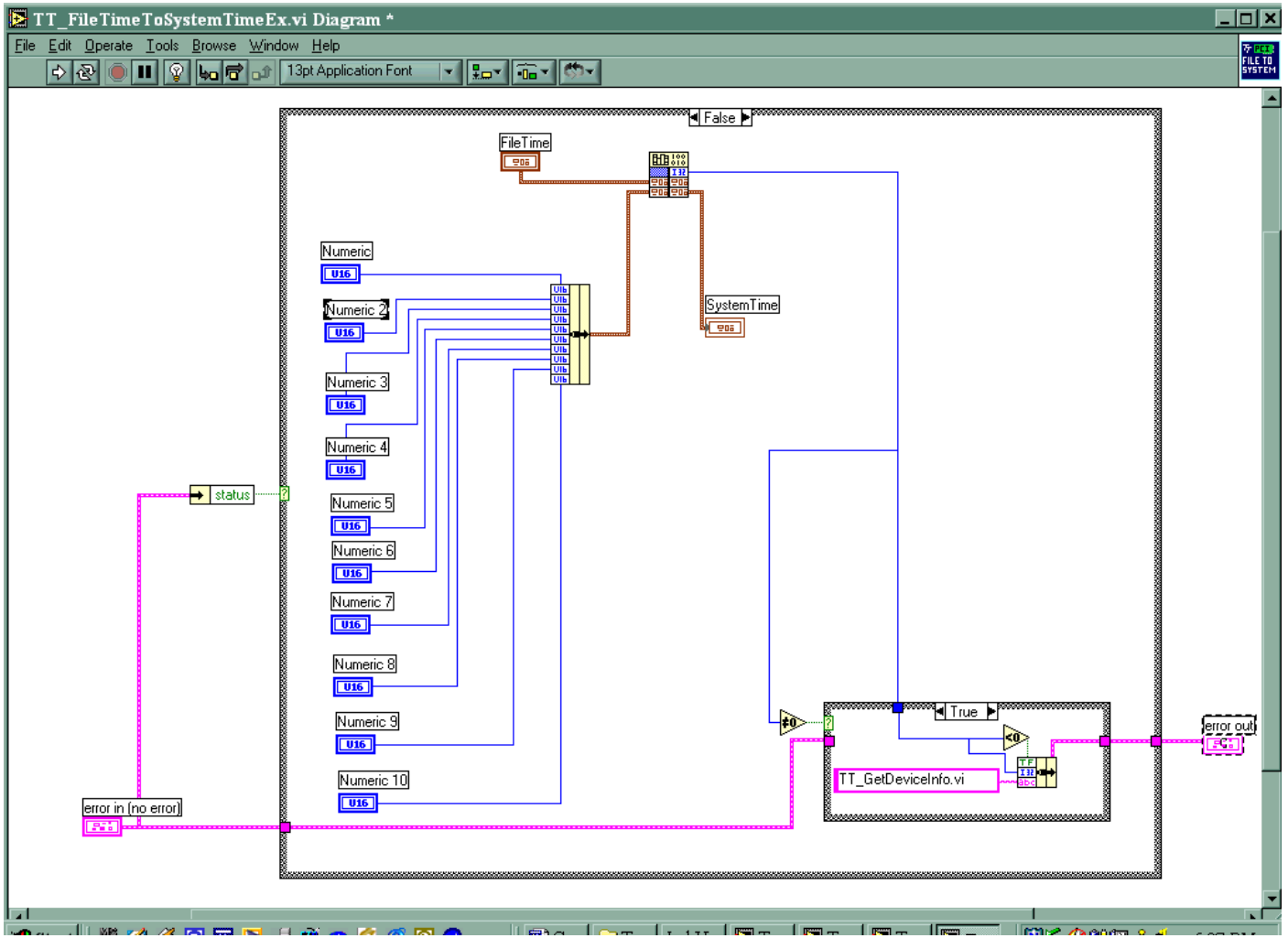


Figure A-41 True Time File Time to System Time VI Diagram (False)

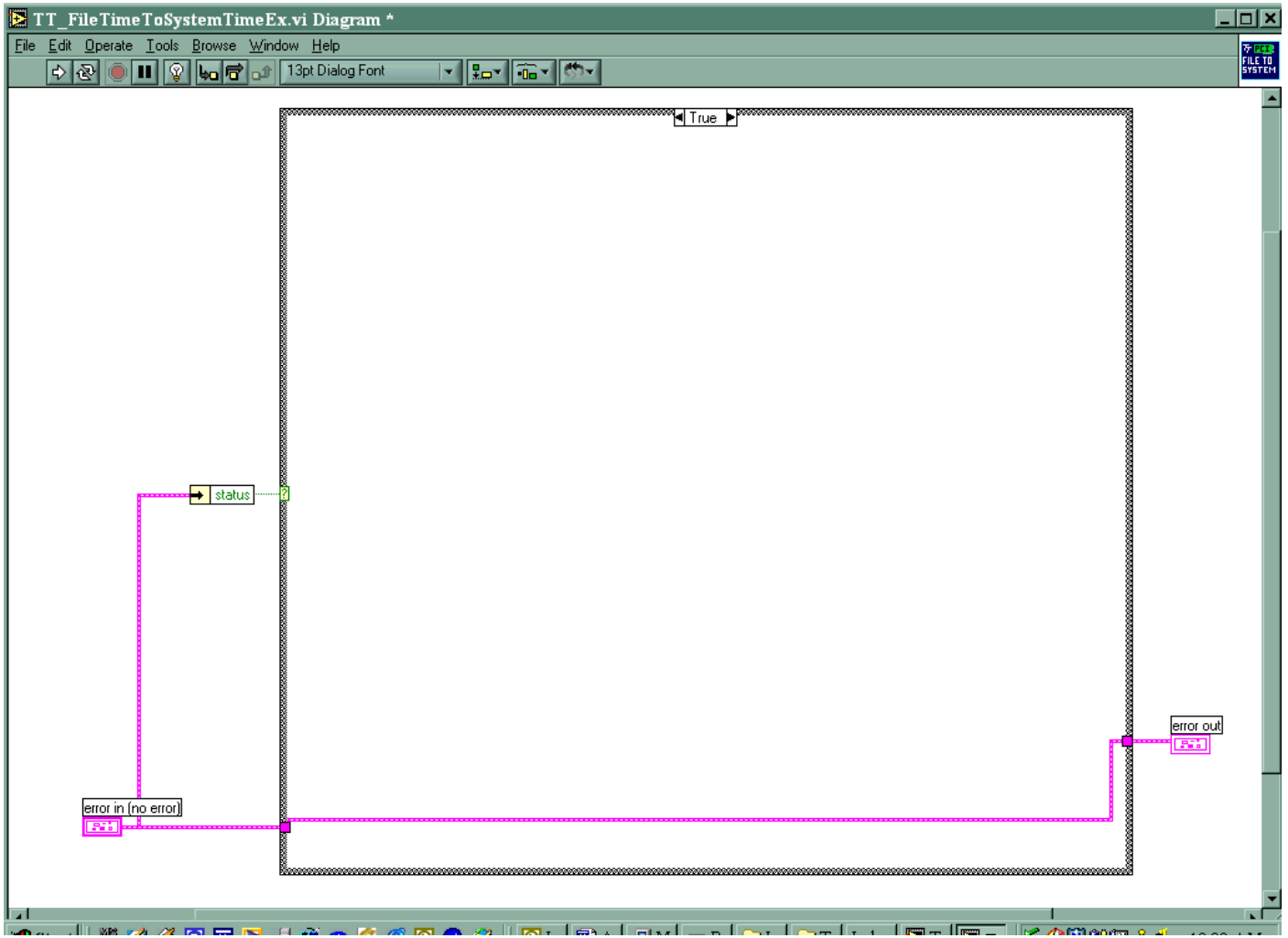


Figure A-42 True Time File Time to System Time Ex VI Diagram (True)

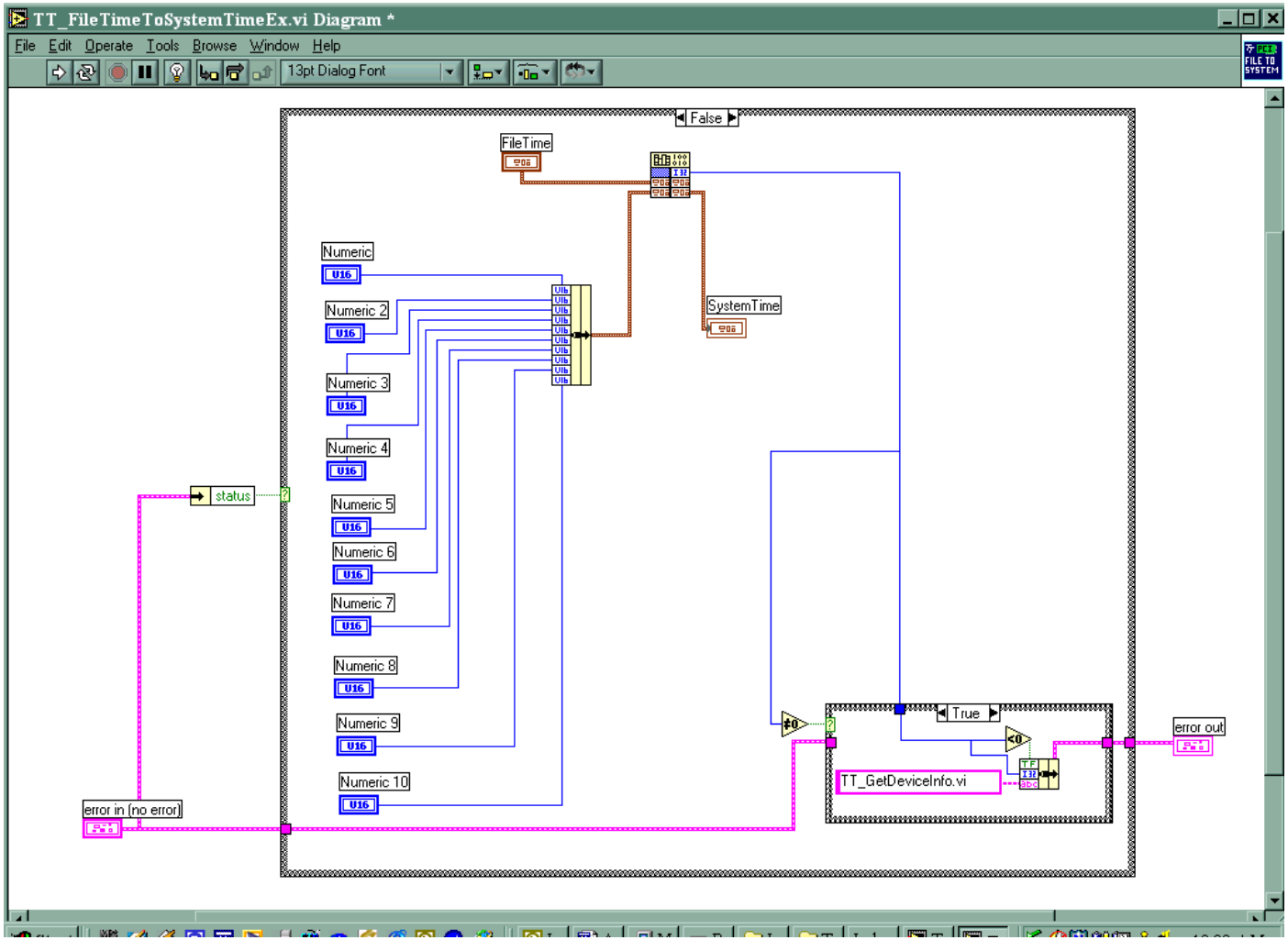


Figure A-43 True Time File Time to System Time Ex VI Diagram (False)

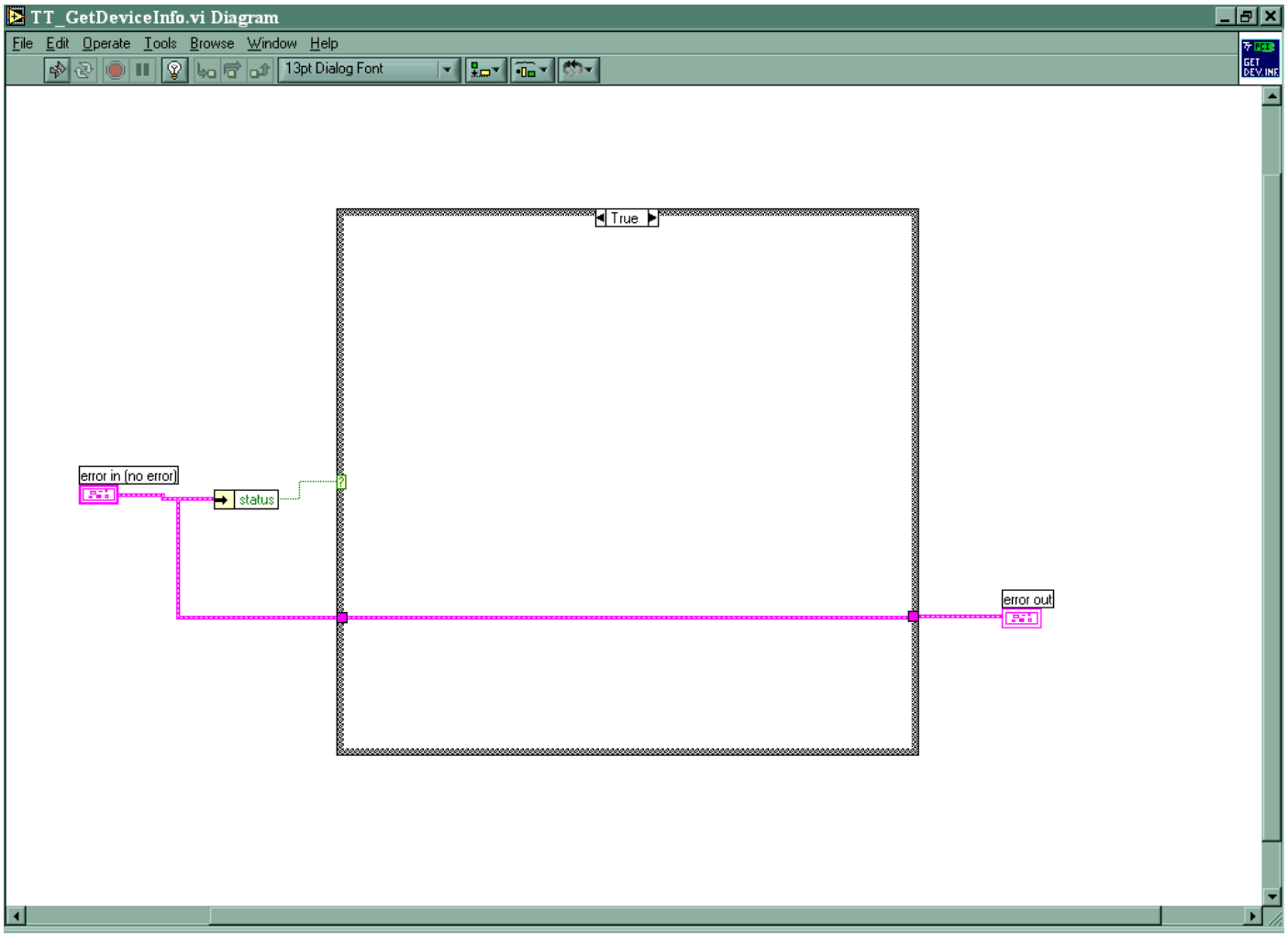


Figure A-44 True Time Get Device Info VI Diagram (True)

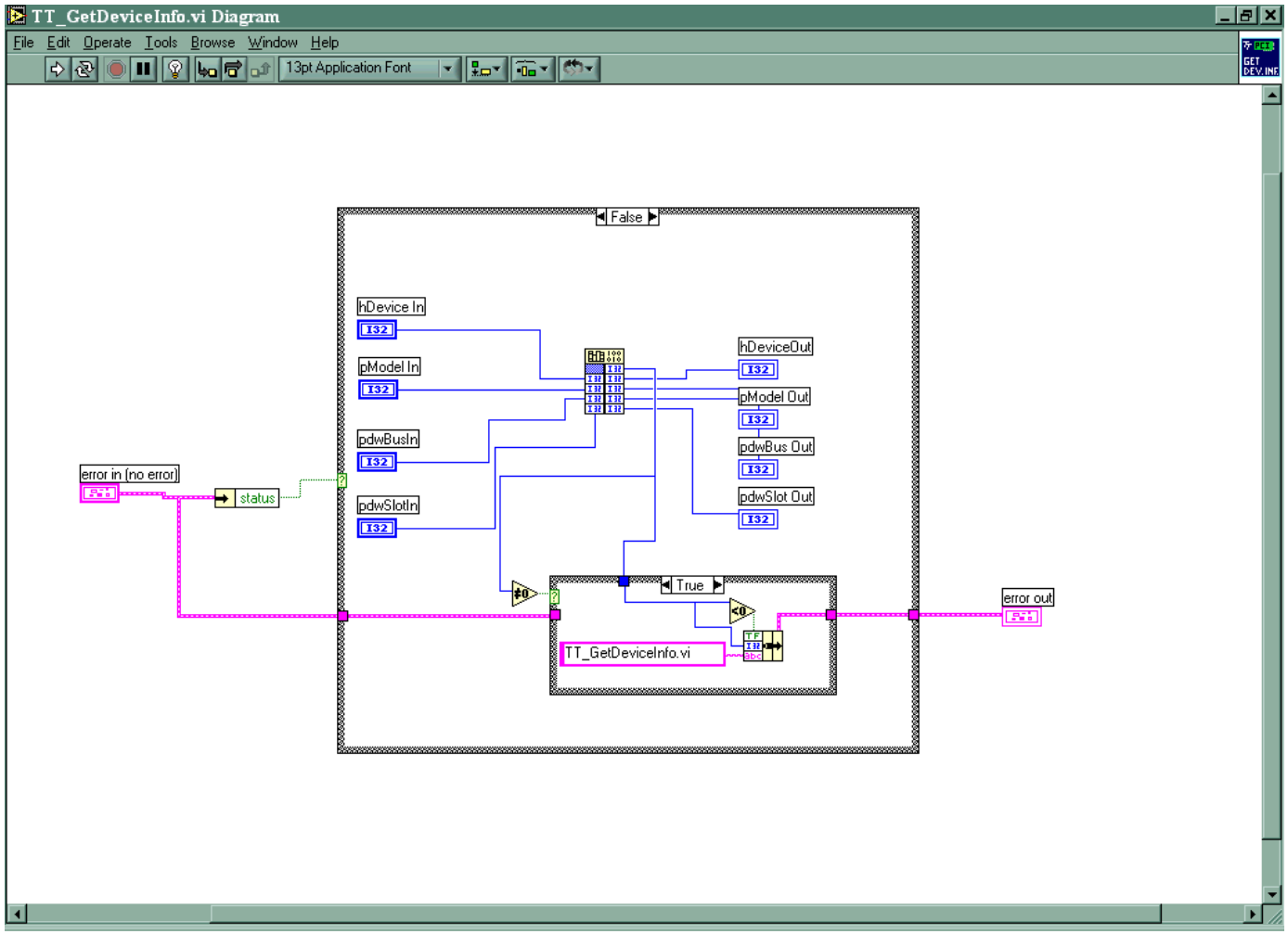


Figure A-45 True Time Get Device Info VI Diagram (False)

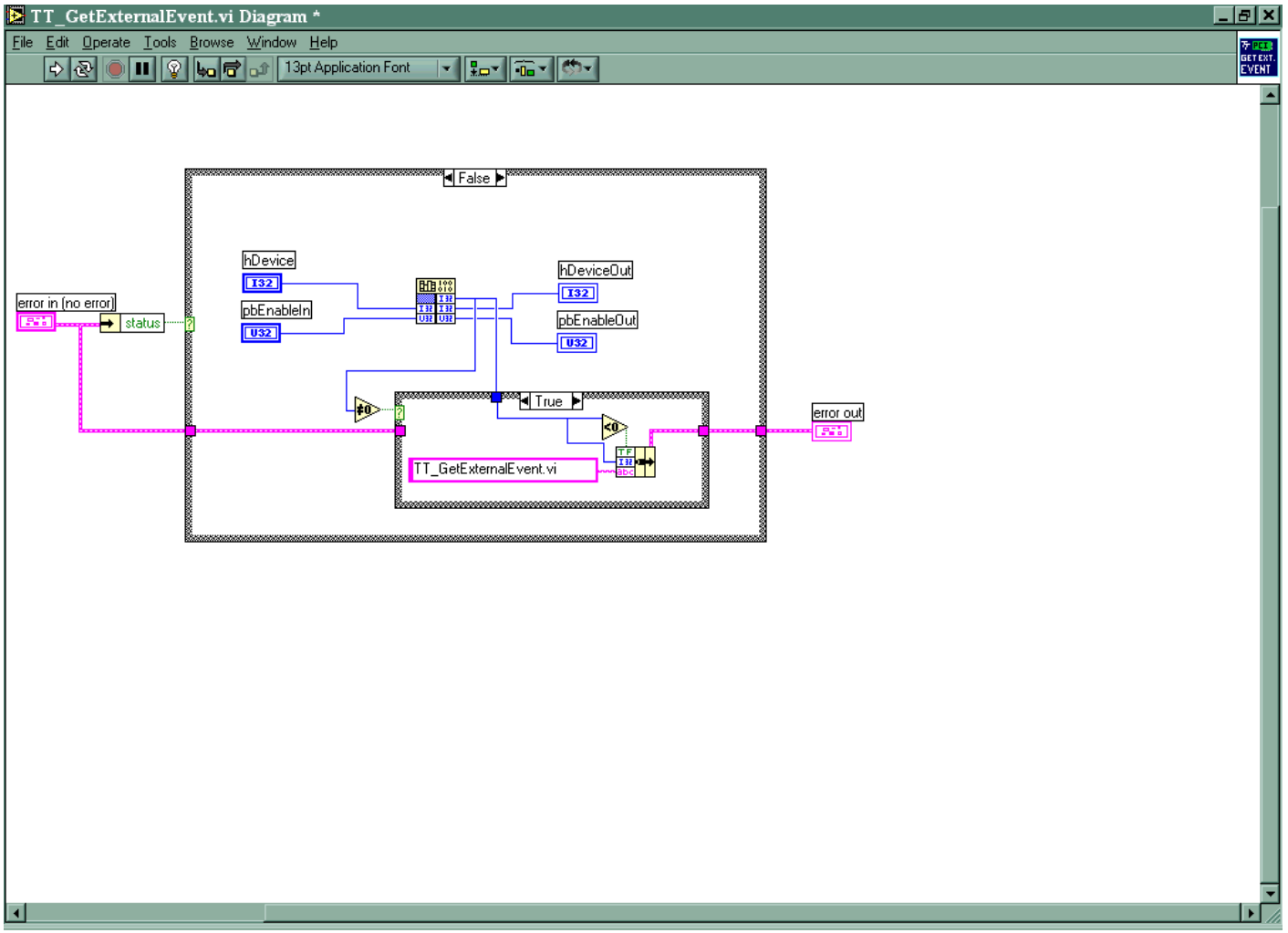


Figure A-46 True Time Get External Event VI Diagram (False)

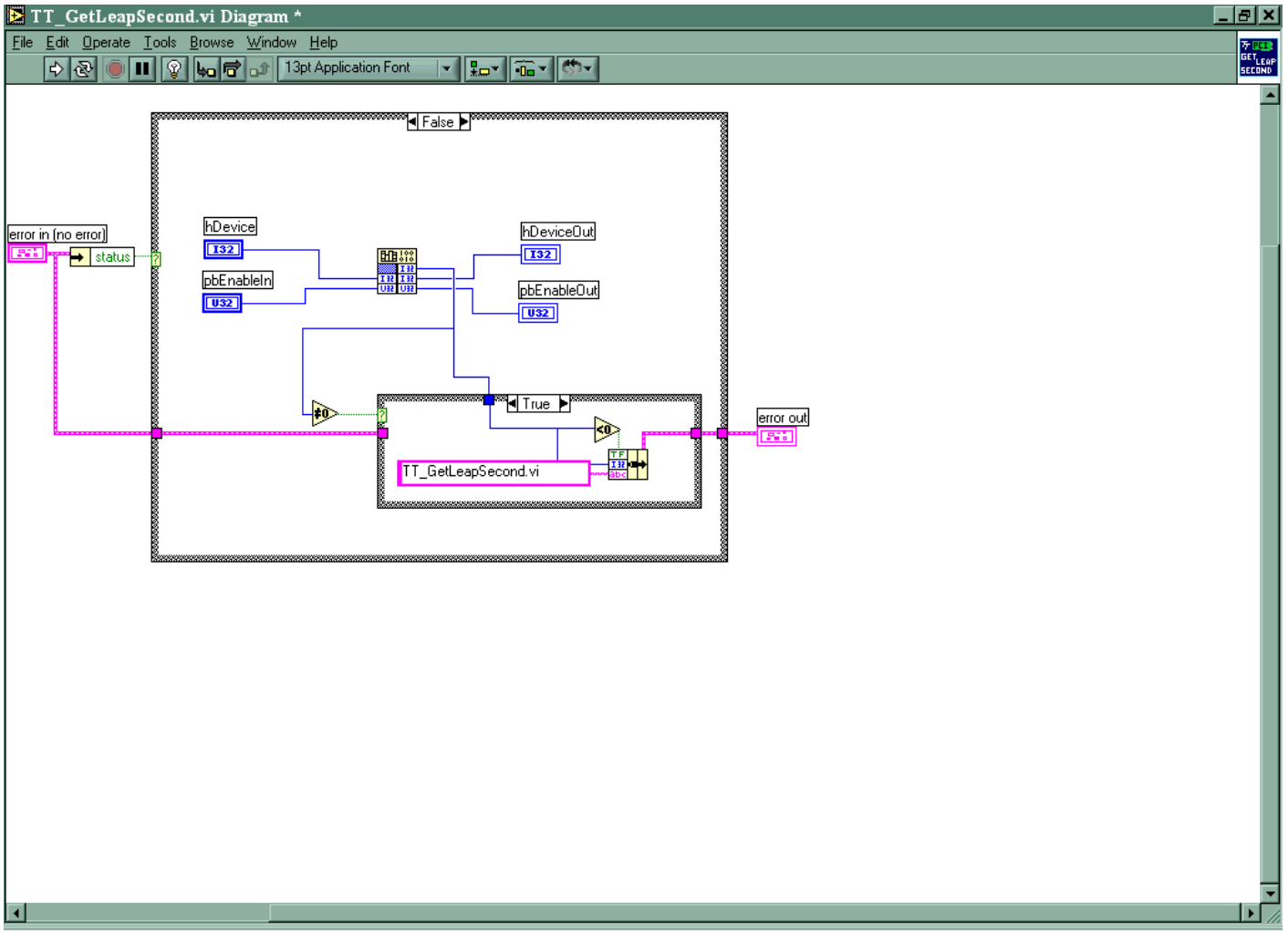


Figure A-47 True Get Leap Second VI Diagram (False)

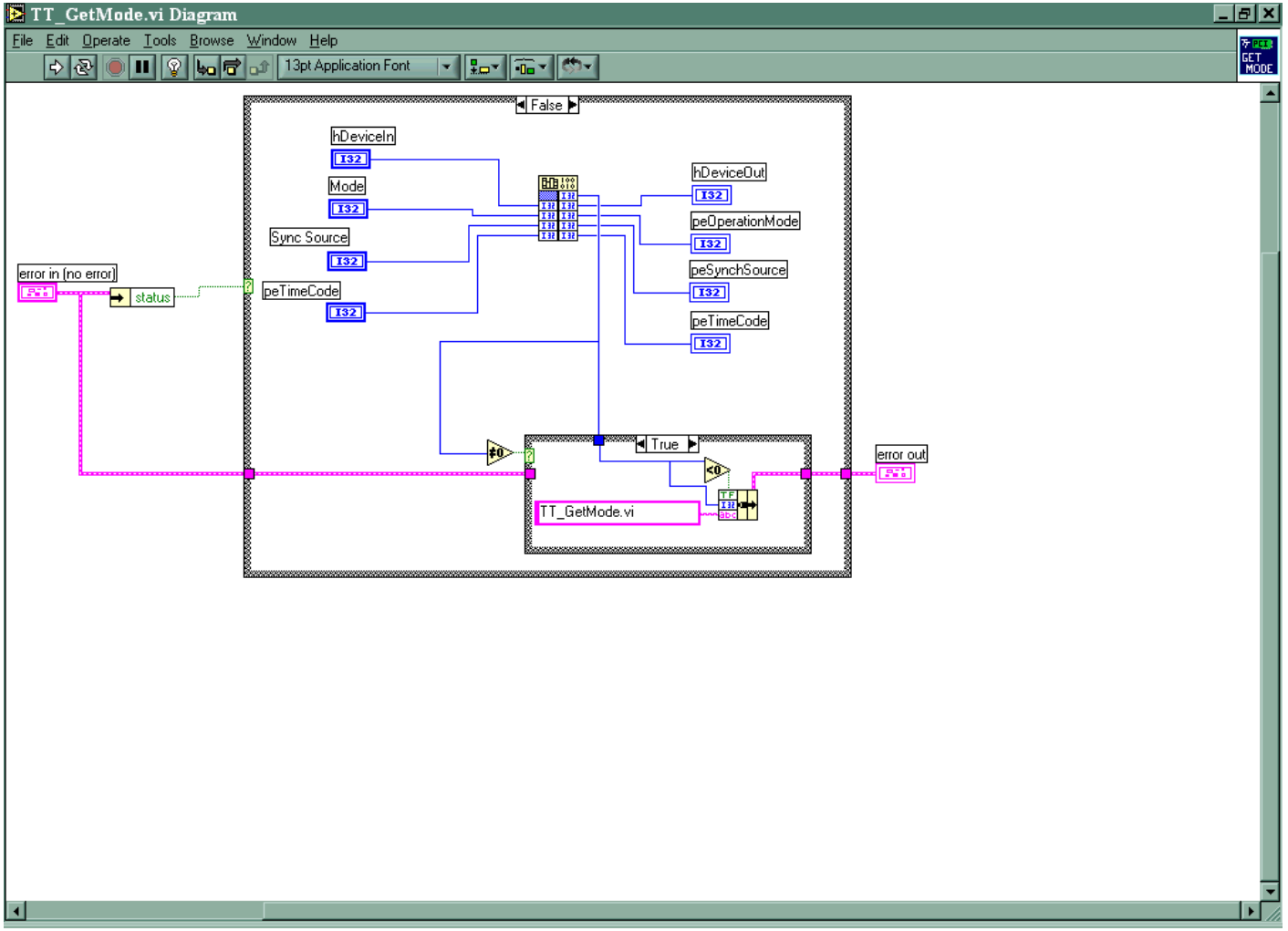


Figure A-48 True Time Get Mode VI Diagram (False)

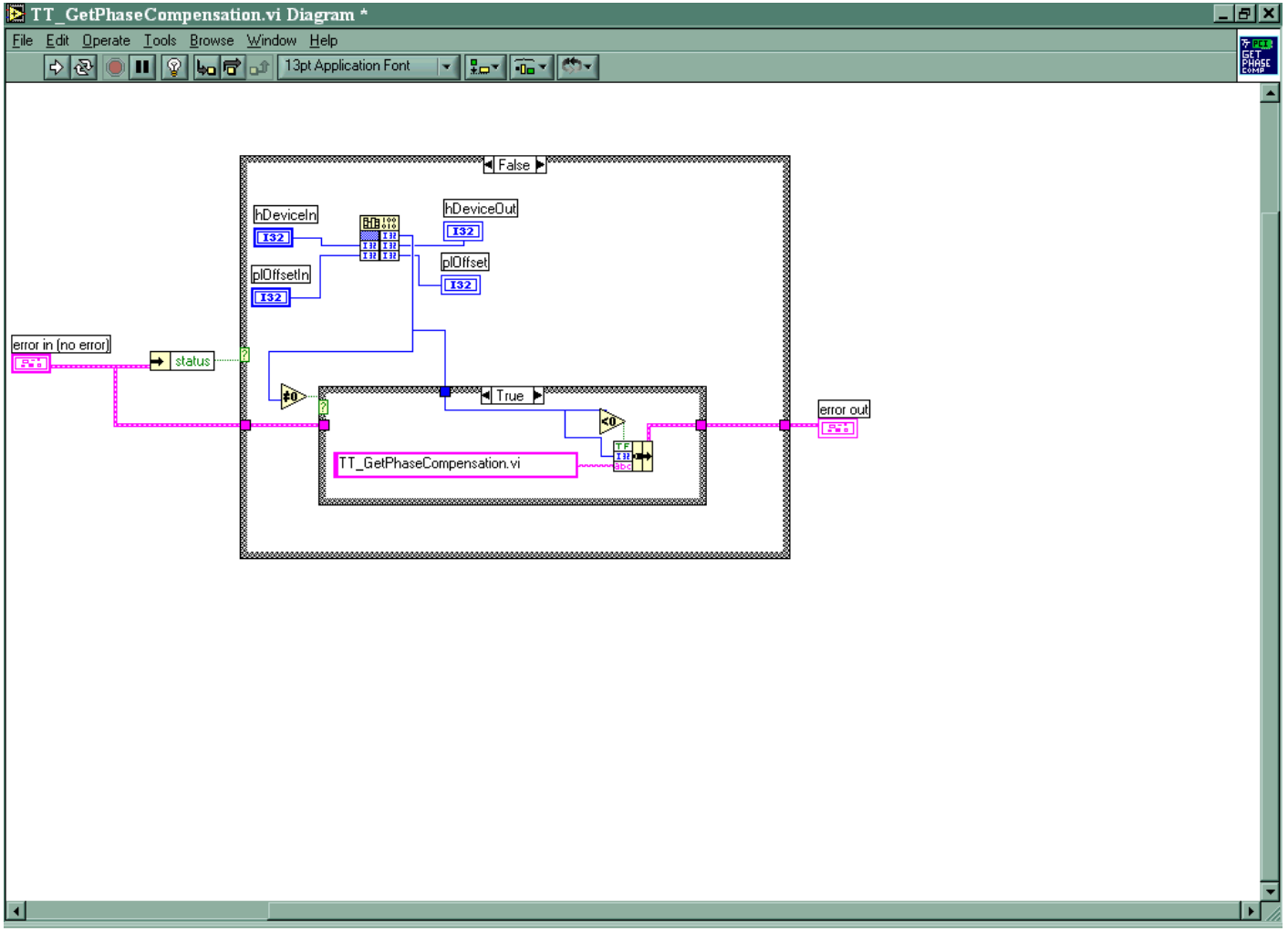


Figure A-49 True Time Get Phase Compensation VI Diagram (False)

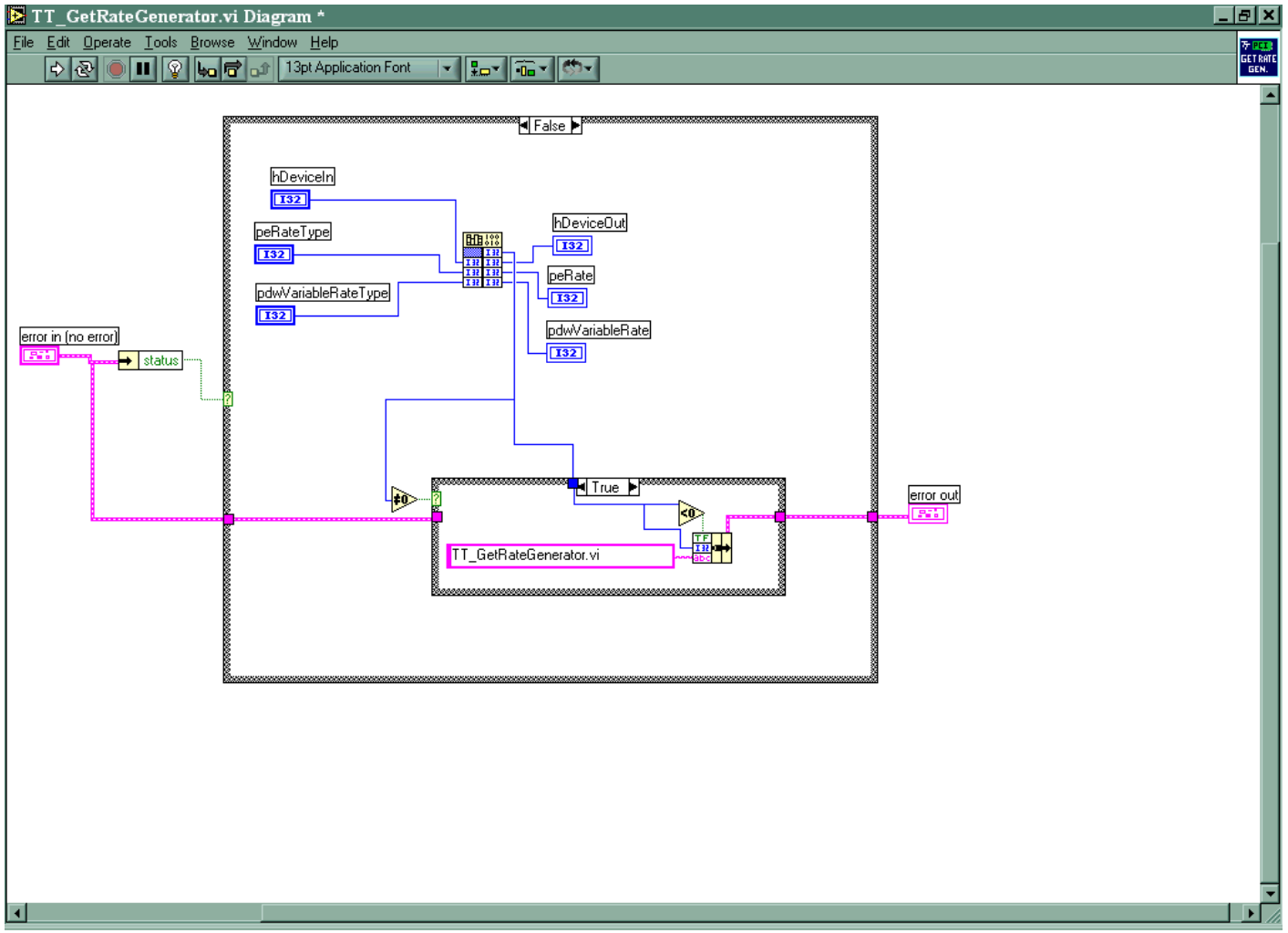


Figure A-50 True Time Get Rate Generator VI Diagram (False)

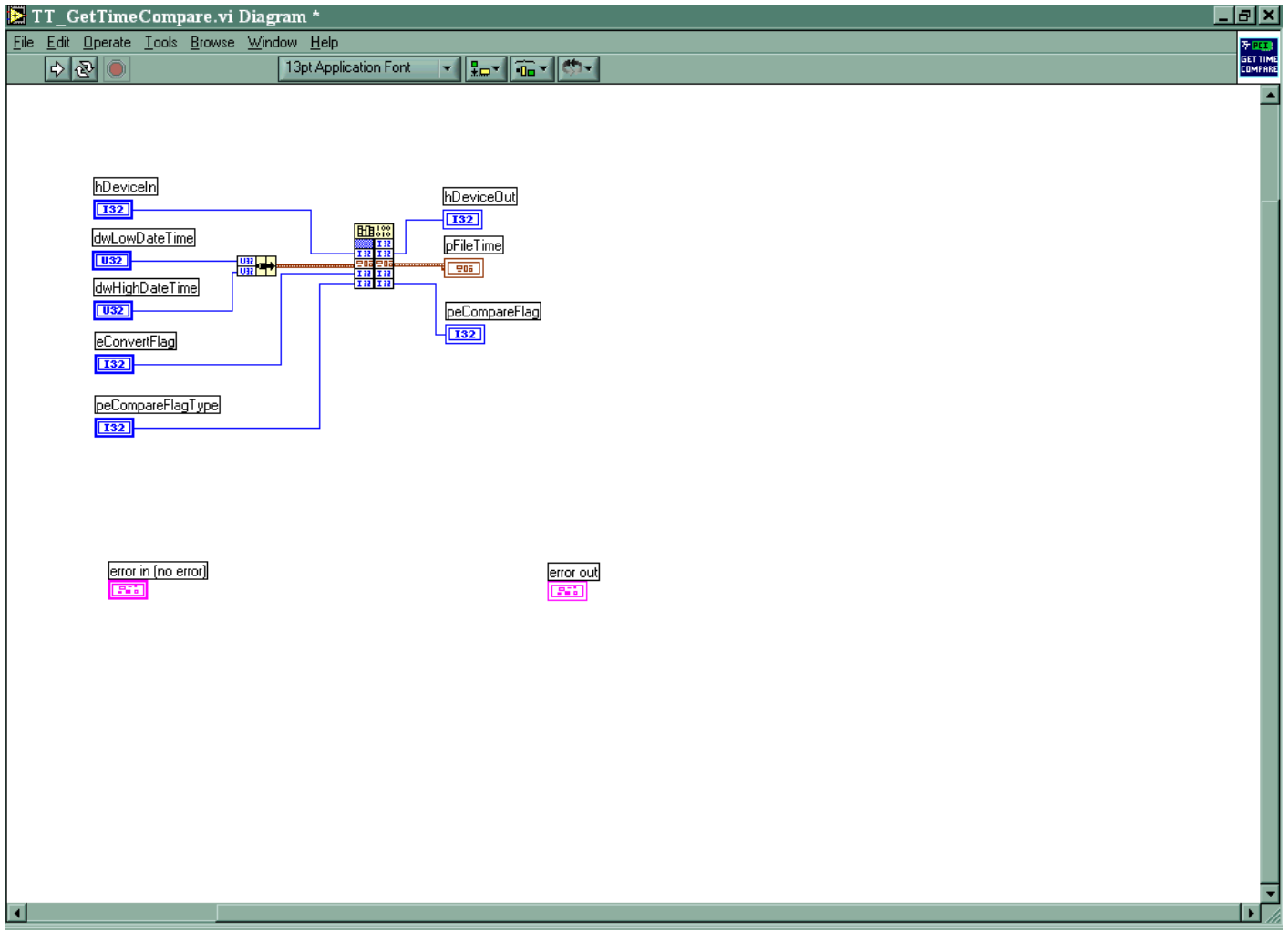


Figure A-51 True Time Get Time Compare VI Diagram

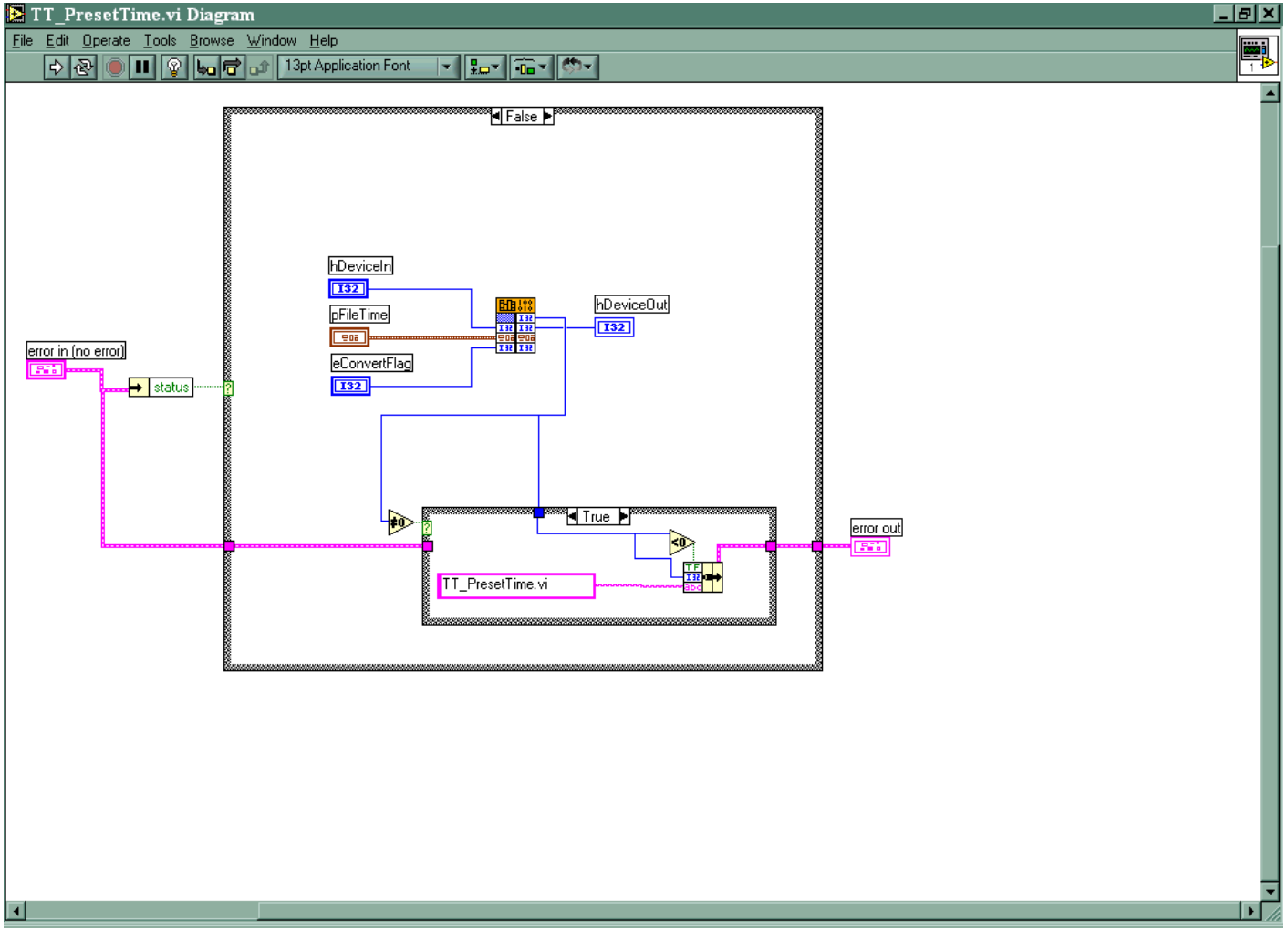


Figure A-52 True Time Preset Time VI Diagram (False)

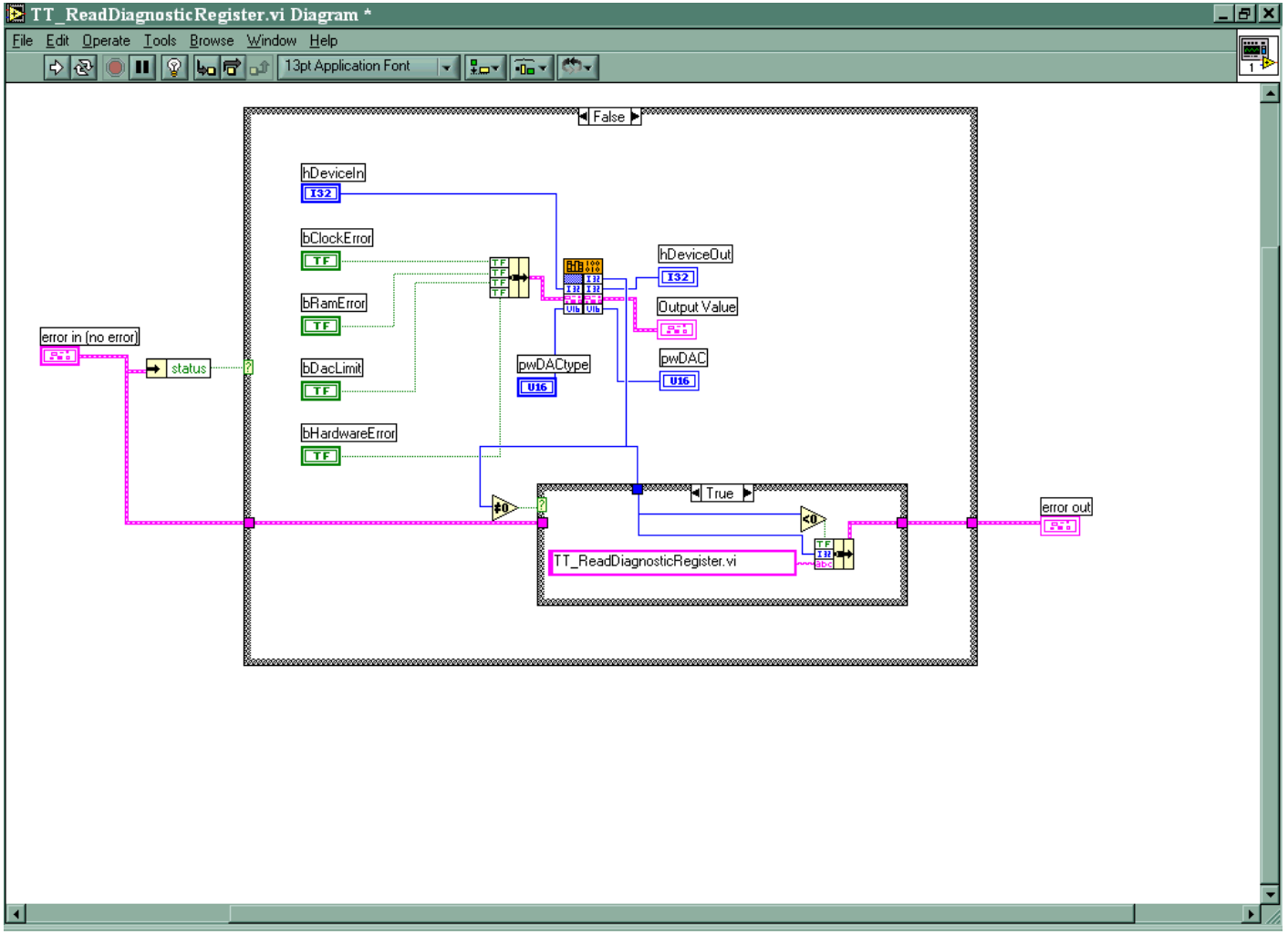


Figure A-53 True Time Read Diagnostic Register VI Diagram (False)

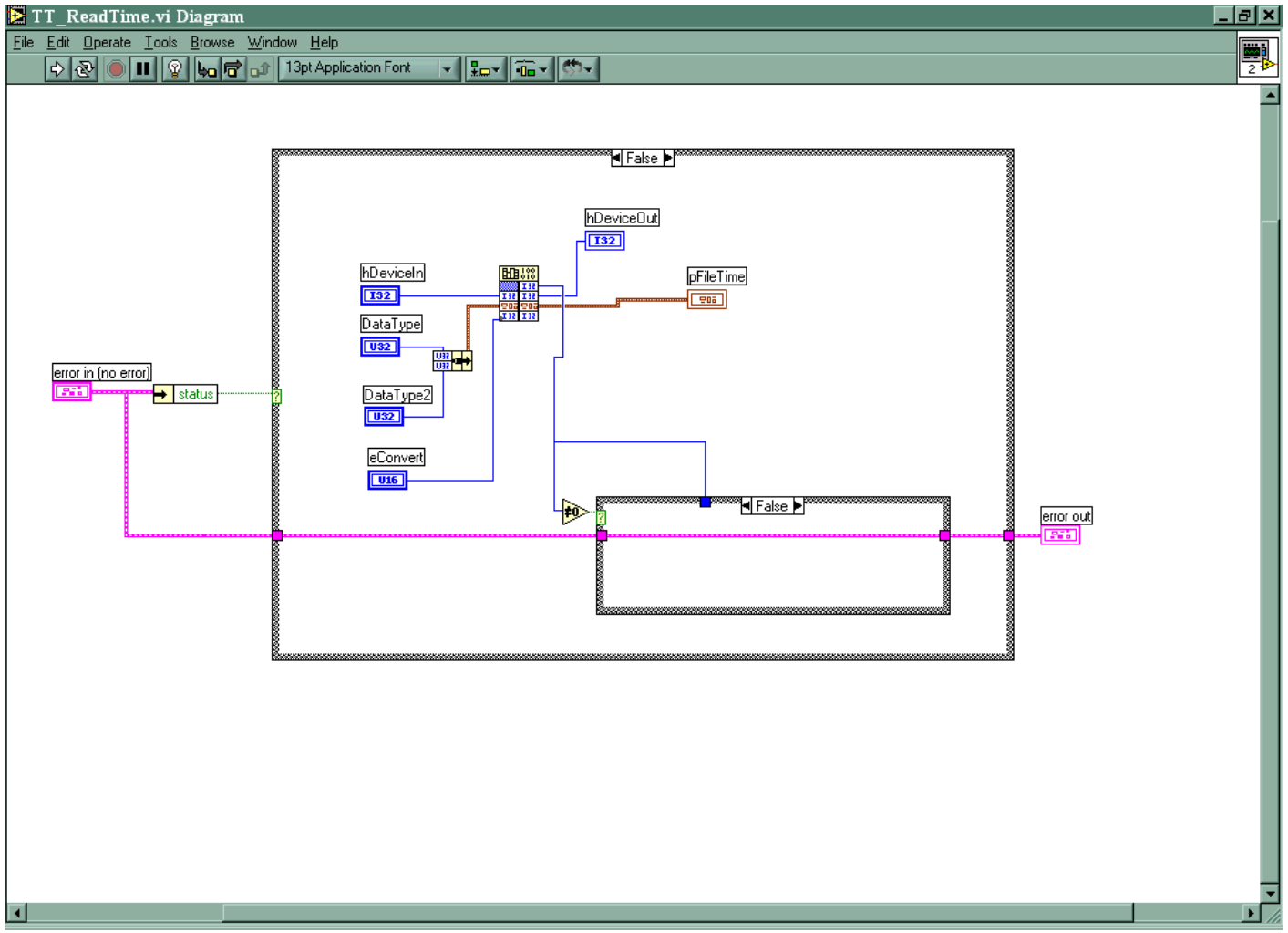


Figure A-54 True Time Read Time VI Diagram (False)

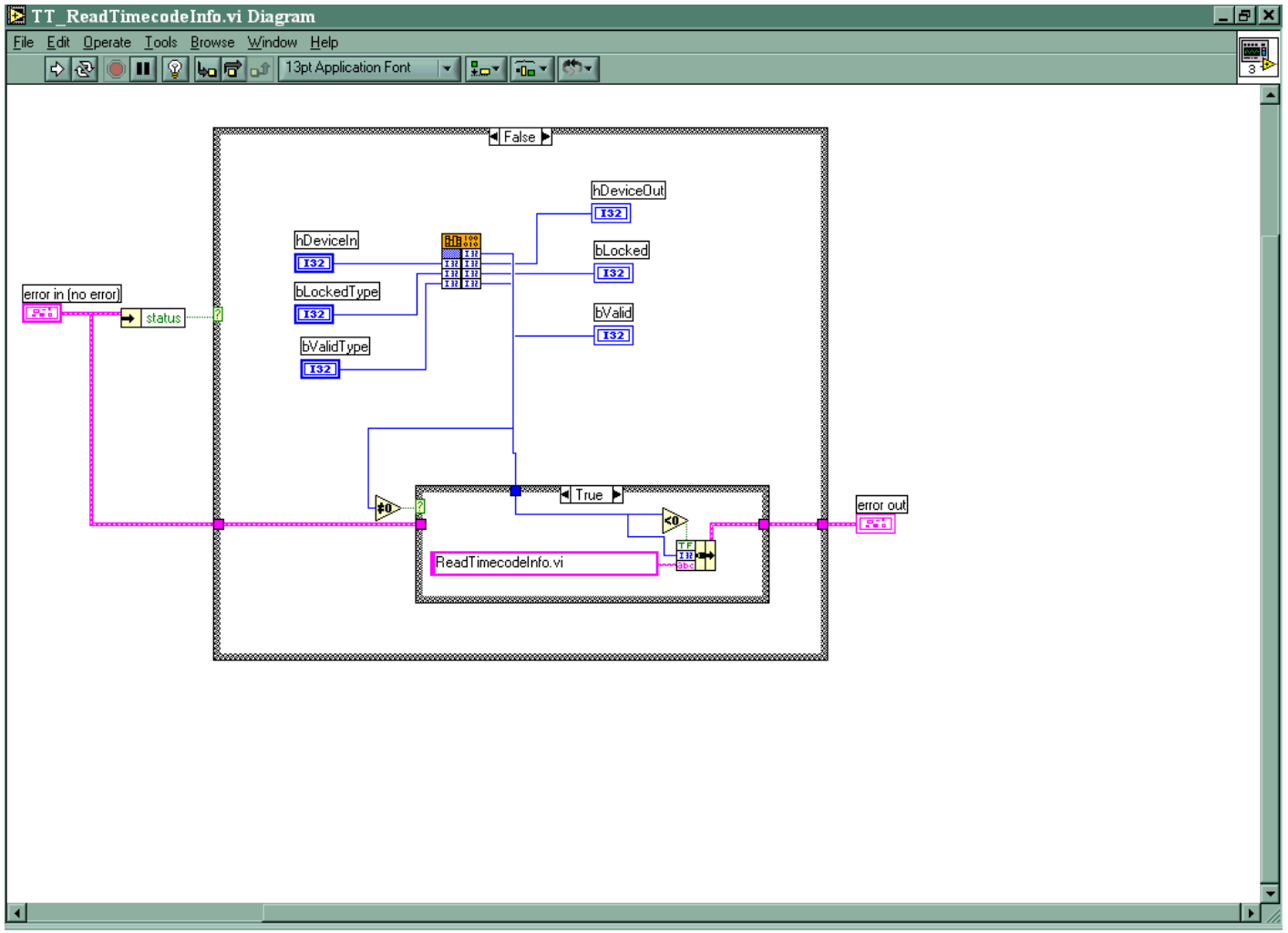


Figure A-55 True Time Read Time Code Info VI Diagram (False)

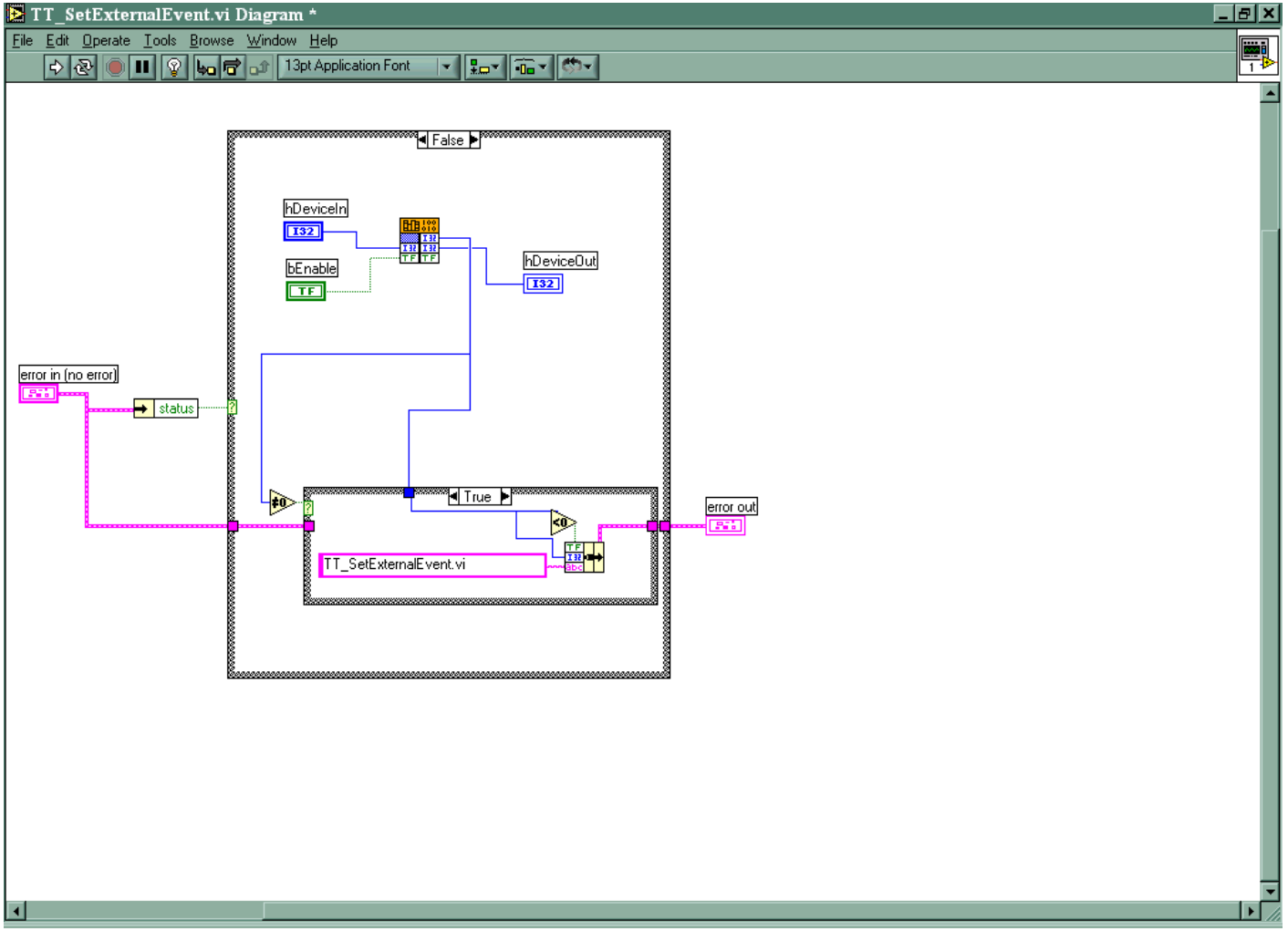


Figure A-56 True Time Set External Event VI Diagram (False)

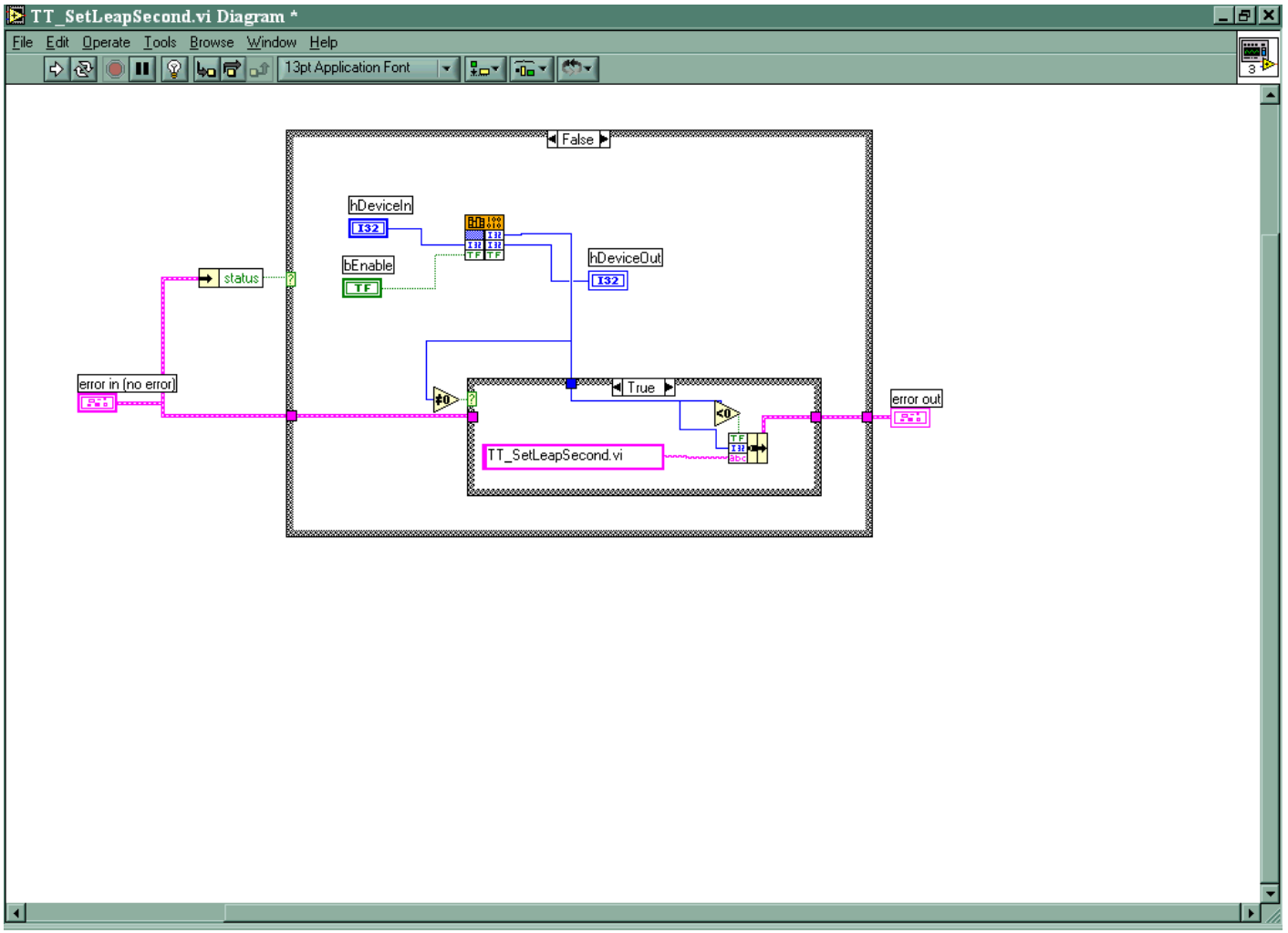


Figure A-57 True Time Set Leap Second VI Diagram (False)

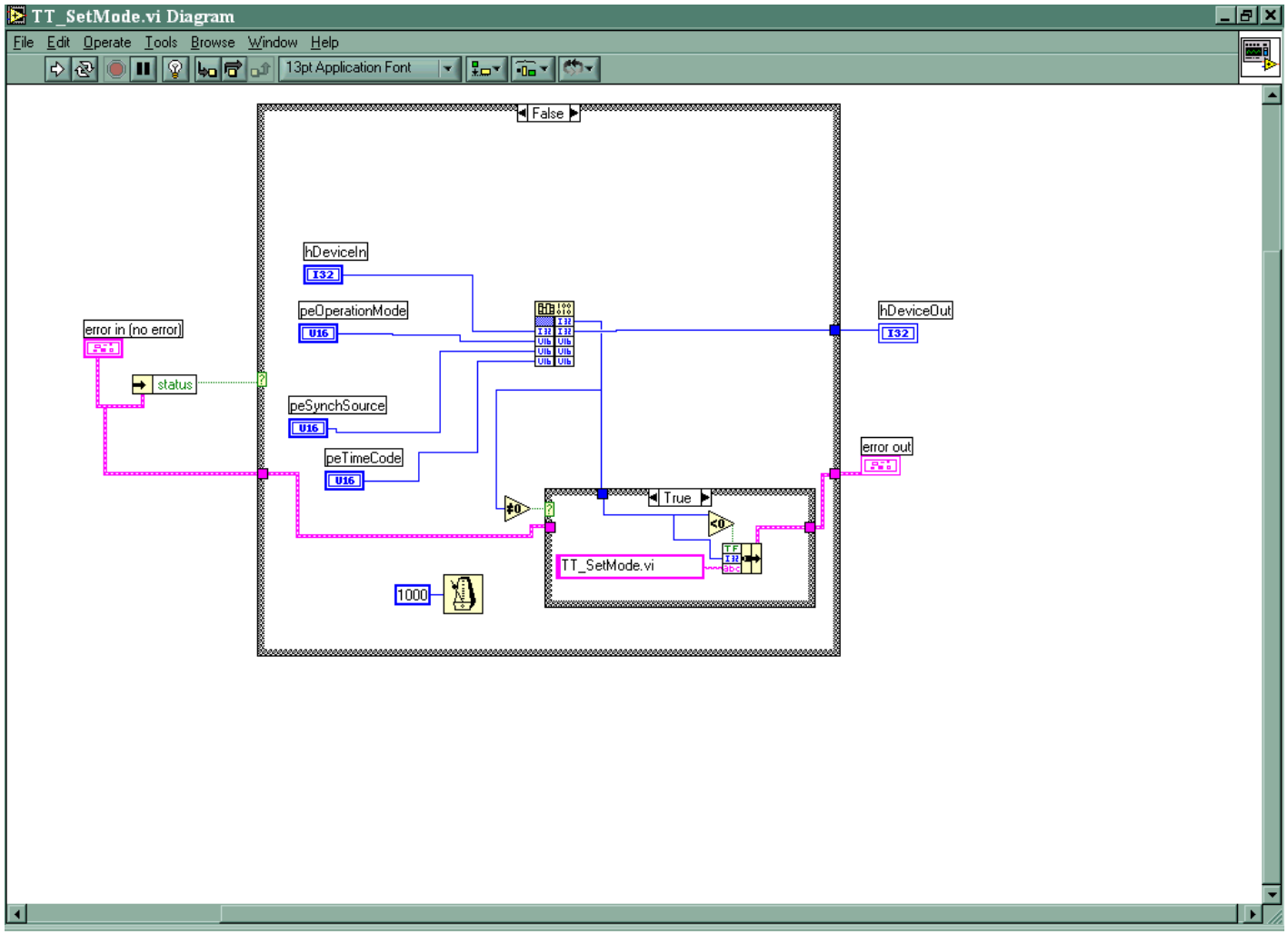


Figure A-58 True Time Set Mode VI Diagram (False)

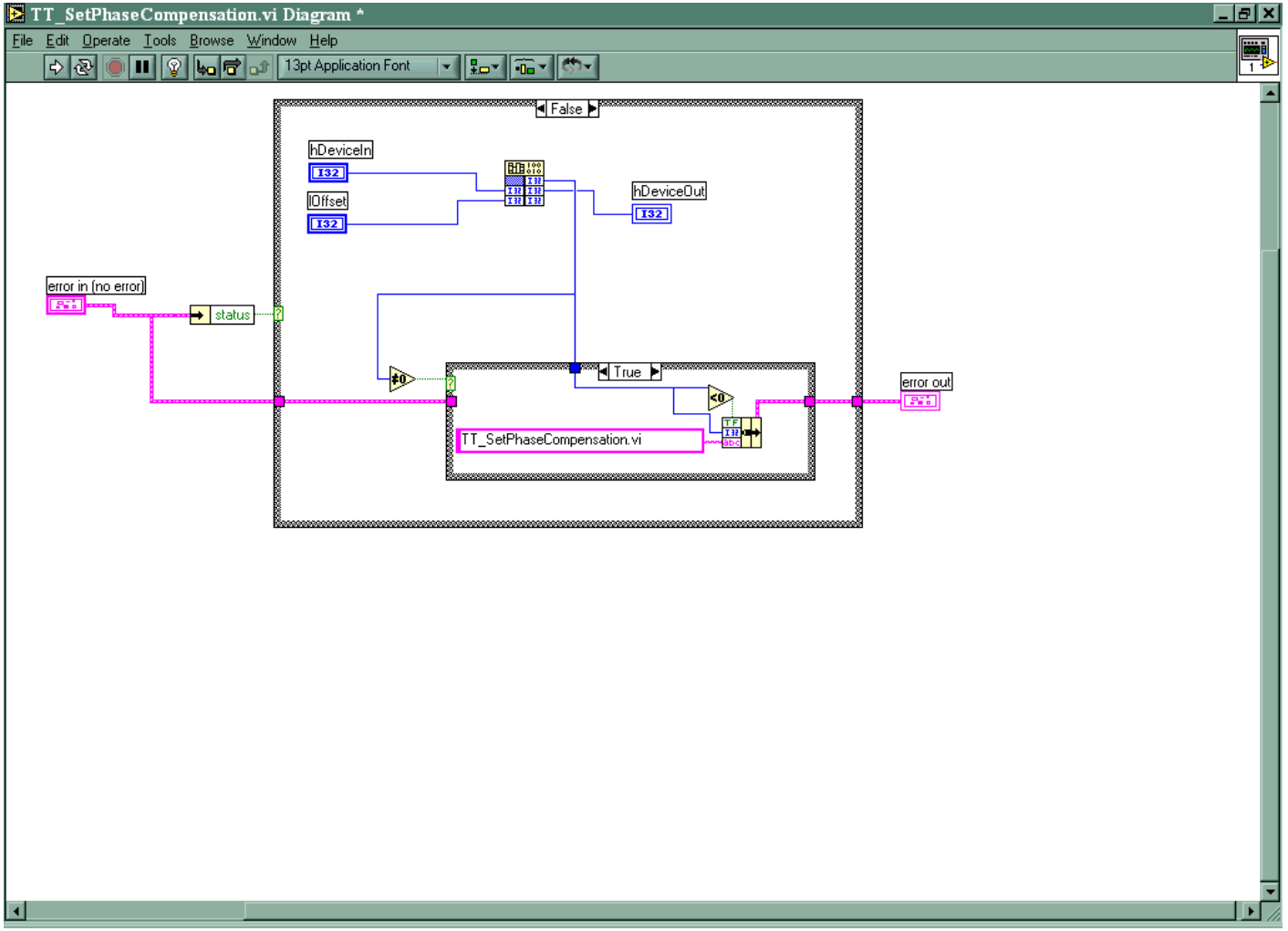


Figure A-59 True Time Set Phase Compensation VI Diagram (False)

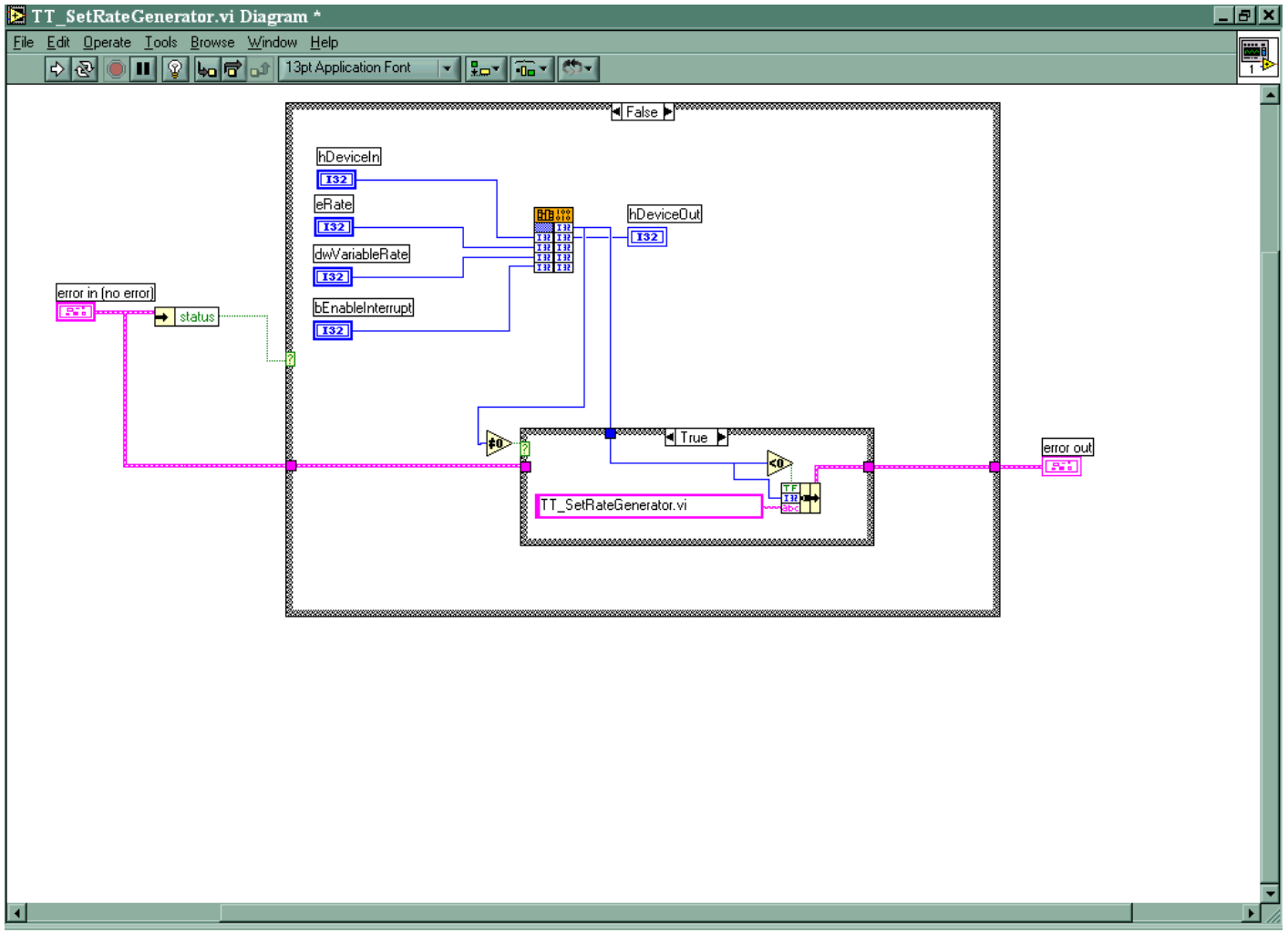


Figure A-60 True Time Set Rate Generator VI Diagram (False)

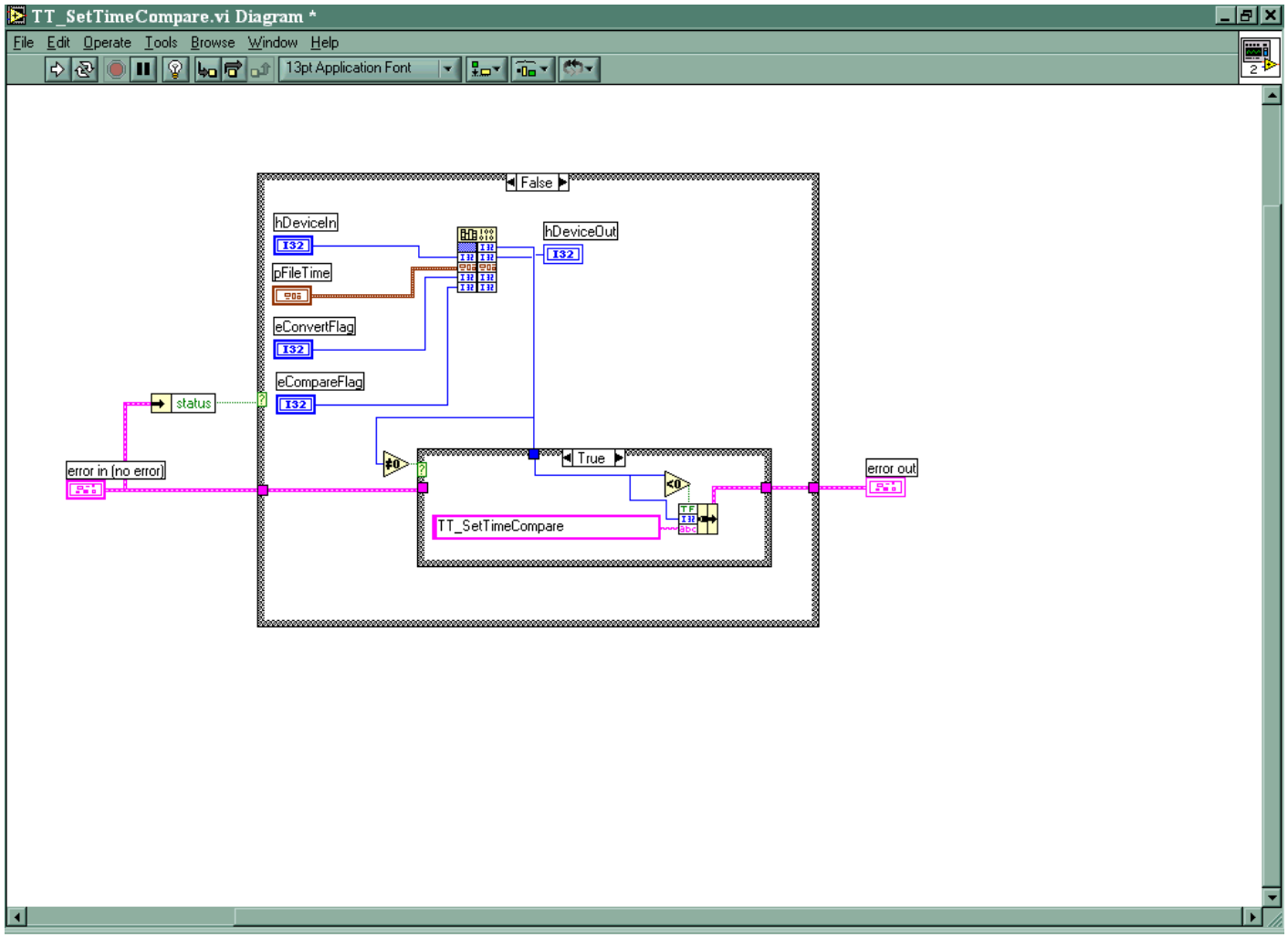


Figure A-61 True Time Set Time Compare VI Diagram (False)

A.2 True Time PCI Specifications

- 1 microsecond accuracy to UTC
- GPS, IRIG A or B input
- PCI local bus operation
- Zero latency
- IRIG B output
- 1 PPS output
- Programmable pulse rate output/interrupt
- External event occurrence interrupt
- Time compare input/interrupt
- Optional software development kit and drivers



Figure A-62 True Time GPS-PCI Card

The GPS-PCI provides very precise time, with zero latency, to the bus of a PCI-compatible host computer. Time is derived from the GPS satellite system with an accuracy of 1 microsecond to UTC. The GPS-PCI is an ideal master clock solution for synchronizing one or more computers to the UTC time reference. Applications include time tagging processed data, test data reduction, and range instrument synchronization.

Time can also be derived from an IRIG A or B time code input or the internal oscillator in the stand-alone generator mode. Synchronization to an external 1 PPS is also possible. The frequency of the internal oscillator is precisely disciplined to that of the external synchronization input.

Time, microseconds through years, and status information and position are supplied on demand over the 32-bit PCI bus. In addition to time and status, the GPS-PCI provides a 1 PPS pulse rate, a programmable time-compare register, a programmable frequency pulse rate, an external event time capture, and an IRIG B serial time code output.

Rear panel BNC connectors are used for the IRIG code input/output and the antenna input for the GPS. A rear panel mounted multi-pin connector contains the 1 PPS pulse rate output, the programmable pulse rate output, the external event input signal and the input/output connections for the RS-422 versions of the input/output IRIG time code. You can also configure the single-ended analog input code with various input impedance choices. A transformer coupling option is also available. The output code is single ended in its standard configuration or you can specify the balanced transformer coupling option.

Information provided over the PCI bus includes time, status, antenna position and the time of occurrence of the external event. Interrupts generated by the programmable rate generator, the occurrence of an external event input, and the time compare occurrence are also provided. Depending upon the operating mode, you can program the hours offset from UTC, leap second, year and daylight savings time. Year and leap second insertion are automatically provided when GPS mode is specified.

A TrueTime software development kit, SDK for PCI/CPCI, is optionally available for Windows 95/98 and Windows NT. The SDK includes a Windows NT kernel mode device driver, a Windows 95/98 VxD device driver, a DLL for accessing either of the drivers, a sample program, and code examples. This TrueTime SDK is a tremendous

time-saving tool for quickly integrating all of the features of the GPS-PCI into an application program. Complete access to timing information, status, and control is easily available using the SDK. See the TrueTime SDK for PCI/CPCI data sheet for complete specifications [True99]. See Section A.2 in the appendix.

Table A.1 True Time GPS-PCI Specifications

GPS SYNCHRONIZATION MODE	
Timing Accuracy:	1 microsecond to UTC (with SA)
Position Accuracy:	25 meters SEP (without SA)
Position Accuracy:	25 meters SEP (without SA)
Receiver Input:	1575 MHz L1 C/A code
Tracking:	6 parallel channels
Acquisition Time:	Warm start (has ephemeris data and position) <3 minutes. Cold start <20 minutes.
UTC to Local Offset:	User selectable in hours and minutes
Daylight Savings:	User programmable to select hour and day when DST begins and ends.
Leap Second:	User programmable for day of occurrence, automatic with optional GPS mode.
Antenna:	L1 GPS, 40 dB gain. RG-59/U cable, 50' supplied; maximum cable length 200'. For longer cable runs, see Options.
Tracking:	6 parallel channels
Acquisition Time:	Warm start (has ephemeris data and position) <3 minutes. Cold start <20 minutes.
UTC to Local Offset:	User selectable in hours and minutes
Daylight Savings:	User programmable to select hour and day when DST begins and ends.
Leap Second:	User programmable for day of occurrence, automatic with optional GPS mode.
Antenna:	L1 GPS, 40 dB gain. RG-59/U cable, 50' supplied; maximum cable length 200'. For longer cable runs, see Options.

Table A.2 True Time GPS-PCI Synchronized Generator Mode Specifications

SYNCHRONIZED GENERATOR MODE	
Analog Input Code:	IRIG A or B **Ratio:** 2:1 to 5:1 **Amplitude:** 0.5 to 10 Vpp **Impedance:** 50-600-10k ohms, internal switch (single-ended) selectable **Connector:** BNC **Timing Accuracy:** 2 microseconds
RS-422 Input Code:	IRIG A or B **Timing Accuracy:** 1 microsecond **Input Termination:** Selectable, 120 ohms or none **Connector:** DE9
External 1 PPS*:	1 microsecond timing accuracy (uses external event input port)
Error Bypass:	Factory set to three frames

Table A.3 True Time GPS-PCI Stand-Alone Generator Mode Specifications

STAND-ALONE GENERATOR MODE	
GENERAL SPECIFICATIONS	Allows the user to preset, start and stop the GPS-PCI over the PCI bus.
IRIG B Serial Code Output (Analog):	**Amplitude:** Adjustable, 0.5-10 Vpp into 600 ohms **Ratio:** Fixed, 3:1 **Connector:** BNC
IRIG B Serial Code Output (RS-422):	**Amplitude:** RS-422 levels **Connector:** DE9
Oscillator:	**Accuracy:** $5x10^{-8}$ (when disciplined to IRIG code or GPS input) **Stability:** 2.5 PPM, 0°C to +50°C, unlocked
1 PPS Pulse Rate Output:	**Amplitude:** 0-5 Vdc** **Timing:** Positive edge on time **Duty Cycle:** 50% **Connector:** DE9
Programmable Pulse Rate Output:	**Rates:** 1 PPS, 10 PPS, 100 PPS, 1 kPPS, 10 kPPS **Outputs:** Interrupt and pulse **Amplitude:** 0-5 Vdc** **Connector:** DE9
External Event Occurrence Input:	**Resolution:** Microseconds-years **Output:** Interrupt and time/event capture **Event Input:** Positive edge of 2-5 Vdc pulse **Impedance:** Approximately 2k ohms **Connector:** DE9
Time Compare Output:	**Resolution:** Microseconds-years **Outputs:** Interrupt and pulse at compare time **Amplitude:** 5 Vdc** on compare **Connector:** DE9

Table A.4 True Time GPS-PCI Mechanical and Environmental Specifications

MECHANICAL/ENVIRONMENTAL	
Receiver:	**Power:** <5 W **Size:** PCI short card **Operating Temperature:** 0°C to +50°C **Storage Temperature:** -17°C to +85°C **Humidity:** To 95%, non-condensing
Antenna:	**Size:** 2.625" x 1.5" (6.67 cm x 3.8 cm) **Weight:** .55 lb. (.25 kg) **Operating Temperature:** -40°C to +70°C **Storage Temperature:** -55°C to +85°C **Humidity:** 100%, condensing
Certification:	CE pending, GPS WNRO, Year 2000

A.3 Landmark Data File

Landmark	Des	Latitude N			Longitude W		
Pad 17	"+	28	26	50	80	33	56
Pad 36	"+	28	28	17	80	32	15
Pad 39a	"+	28	36	28	80	36	15
Pad 39b	"+	28	37	36	80	37	16
Pad 40	"+	28	33	43	80	34	37
Pad 41	"+	28	35	0	80	34	58
Lighthouse	"^	28	29	0	80	31	30

A.4 Map Data File

Area	Latitude			Longitude		
R-2932/3	28	41	40	80	35	0
R-2932/3	28	39	20	80	42	40
R-2932/3	28	34	0	80	39	30
R-2932/3	28	25	0	80	38	0
R-2932/3	28	25	0	80	30	30
R-2932/3	28	27	30	80	28	0
R-2932/3	28	41	40	80	35	0
0	0	0	0	0	0	0
W-2934	28	49	10	80	50	45
W-2934	28	51	15	80	47	15
W-2934	28	51	15	80	42	20
W-2934	28	41	40	80	35	0
W-2934	28	39	20	80	42	40
W-2934	28	34	0	80	39	30
W-2934	28	25	0	80	38	0
W-2934	28	25	0	80	41	45
W-2934	28	25	0	80	43	50
W-2934	28	38	0	80	47	2
W-2934	28	49	10	80	50	45
0	0	0	0	0	0	0
W-2935	28	47	20	81	5	0
W-2935	28	58	0	80	47	0
W-2935	28	51	15	80	42	40
W-2935	28	51	15	80	47	15
W-2935	28	49	10	80	50	45
W-2935	28	38	0	80	47	2
W-2935	28	31	20	80	43	50
W-2935	28	25	0	80	41	45
W-2935	28	25	0	80	30	30
W-2935	28	19	0	80	33	30
W-2935	28	19	0	80	46	30
W-2935	28	47	20	81	5	0
0	0	0	0	0	0	0
W-497a	28	41	40	80	35	0
W-497a	29	0	0	79	30	0
W-497a	28	22	75	79	30	30
W-497a	28	0	0	80	38	0
W-497a	28	27	30	80	28	0
W-497a	28	41	40	80	35	0
0	0	0	0	0	0	0

A.5 VI Modules Supplied with True Time Card

A.5.1 True Time Get Device Info.vi

This function returns static information about the board associated with the handle provided. This function is available in all modes and requires FILE_SHARE_READ access. This module was supplied by True Time Incorporated and was not used [8].

A.5.2 True Time Get Leap Second.vi

This function returns the current status of the hardware to add a leap second at the end of the current day. This function requires FILE_SHARE_READ access and is available in 1 PPS mode. This module was supplied by True Time Incorporated and was not used [8]. This module was supplied by True Time Incorporated and was not used [8].

A.5.3 True Time Get Phase Compensation.vi

Gets the current phase compensation for the device. When the Synchronized Generator is using amplitude-modulated time code as the reference, there are inherent delays caused by signal distribution amplifiers or transmission media. The reference code is input to the automatic gain control (AGC) circuit and then to the zero crossing detector. Both of these circuits can contribute small delays (less than 40 microseconds). The phase compensation value will be used to offset fixed phase errors, either positive or negative. This function requires FILE_SHARE_READ access, and is only available in Timecode Synchonization mode. This module was supplied by True Time Incorporated and was not used [8].

A.5.4 True Time Get Rate Generator.vi

This function obtains the current generator event settings. This function requires FILE_SHARE_READ access and is available in all modes. This module was supplied by True Time Incorporated and was not used [8].

A.5.5 True Time Get Time Compare.vi

This function returns the current settings for the time compare event. This function requires FILE_SHARE_READ access and is available in all modes. This module was supplied by True Time Incorporated and was not used (Figure A-51) [8].

A.5.6 True Time Set Rate Generator.vi

This function enables/disables the rate generator event. If a callback has been registered (TT_RegisterCallback), it will be called at the requested rate. This function requires FILE_GENERIC_WRITE access and is available in all modes. This module was supplied by True Time Incorporated and was not used (Figure A-60) [8].

A.5.7 True Time Set Time Compare.vi

This function enables/disables the time compare event. If a callback has been registered (TT_RegisterCallback), it will be called at the requested times. This function requires FILE_GENERIC_WRITE access and is available in all modes. This module was supplied by True Time Incorporated and was not used (Figure A-61) [8].

A.5.8 True Time System Time External to File Time.vi

This function converts a system time to 64-bit file time format. The *wDayOfWeek* member of the SYSTEMTIME_EX structure is ignored. This module was supplied by True Time Incorporated and was not used [8].

A.5.9 True Time Preset Time.vi

This function sets the current time in the device, converting the supplied time as specified by *eConvertFlag*. In Timecode mode, this function is used to set the year since year information is not encoded in the time code reference. Year data is necessary to handle end of year rollover correctly for leap years. Year information is saved in EEPROM and automatically increments at the end of each year. This function requires FILE_GENERIC_WRITE access and is available in Generator, 1 PPS, and Timecode modes. This module was supplied by True Time Incorporated and was not used (Figure A-52) [8].

A.5.10 True Time Read Diagnostic Register.vi

This function returns the error and oscillator values from the diagnostic register. This module was supplied by True Time Incorporated and was not used (Figure A-53) [8].

A.5.11 True Time Set External Event.vi

This function enables/disables the external input event. If a callback has been registered (TT_RegisterCallback), it will be called at the external event. This function

requires FILE_GENERIC_WRITE access and is available in all modes. This module was supplied by True Time Incorporated and was not used (Figure A-56) [8].

A.5.12 True Time Set Leap Second.vi

This function enables/disables the hardware to add a leap second at the end of the current day. This function requires FILE_GENERIC_WRITE access and is available in 1 PPS mode. This module was supplied by True Time Incorporated and was not used (Figure A-57) [8].

A.5.13 True Time Set Mode.vi

This function sets the current operating mode, which is maintained by the hardware in non-volatile memory. Since the hardware is pre-configured by the factory, it is not necessary for any application to call this function. However, it is available for situations where the factory settings must be changed. This function requires FILE_GENERIC_WRITE access. This module was supplied by True Time Incorporated and was not used (Figure A-58) [8].

A.5.14 True Time Set Phase Compensation.vi

Sets the phase compensation for the device. When the Synchronized Generator is using amplitude-modulated time code as the reference, there are inherent delays caused by signal distribution amplifiers or transmission media. The reference code is input to the automatic gain control (AGC) circuit and then to the zero crossing detector. Both of these circuits can contribute small delays (less than 40 microseconds). The phase compensation value will be used to offset fixed phase errors, either positive or negative.

This function requires FILE_GENERIC_WRITE access, and is only available in Timecode Synchronization mode. This module was supplied by True Time Incorporated and was not used (Figure A-59) [8].

GLOSSARY

Active Track: The track referring to an aircraft in currently monitored part of an airspace.

Aerospace Control Officer (ACO): The military person responsible for ensuring the Eastern Range's (ER) restricted and warning airspaces are cleared of all aircraft

Air Traffic Clearance: An authorization by air traffic control, for the purpose of preventing collision between aircraft, for an aircraft to proceed under specified traffic conditions within controlled airspace.

Air Route Traffic Control Center: A facility established to provide air traffic control services to aircraft operating on IFR flight plans with controlled airspace (such as the Positive Control Air) and principally during the en route phase of flight. When equipment capabilities and controller workload permit, certain advisory/assistance service may be provided to VFR aircraft.

Airport Traffic Control Tower: A terminal facility which through the use of air/ground communications, visual signaling, and other devices, provides ATC services to airborne aircraft operating in the vicinity of an airport and to aircraft operations on the movement area.

Altimeter Setting The barometric pressure reading used to adjust a pressure altimeter for variations in existing atmospheric pressure or to the standard altimeter setting (29.92).

Altitude: The height of a level, point or object measured in feet above ground level (ACL) or from Mean Sea Level (MSL).

Altitude Readout: An aircraft's altitude transmitted via the mode C transponder feature, that is visually displayed in 100 foot increments on a radar scope heaving readout capability.

Approach Control: A terminal facility that provides ATC service for arriving and departing VFR/IFR aircraft.

- TRACON - An FAA Terminal Radar Approach Control Facility.
- RAPCON- A USAF Terminal Radar Approach Control Facility.
- ARAC - A US Army Terminal Radar Approach Control Facility.
- RATCF - A US Navy Radar Air Traffic Control Facility.

ATC Assigned Airspace (ATCAA): Airspace of defined horizontal and vertical limits, assigned by ATC, for the purpose of separating certain military training activities being conducted within the assigned airspace from other IFR traffic. ATCAA's established within or outside PCA over water or land and are not charted. VFR traffic may he encountered in ATCAA's outside of PCA. ATCAAs are published only in letters of agreement between ARTCCs and military flying and/or control organizations.

Automated Spacelift Training for Range Operators (ASTRO): An independent simulator used to train range operators in support of launch operations.

Beacon Code: A unique numeric identifier that only one aircraft can havein a particular Center's airspace at any given instant.

Cardinal Altitudes/Flight Levels: "Odd" or "Even" thousand foot altitude or flight levels; e.g., 6000, 7000, FL 250, FL 260, FL 270.

Ceiling: The height above the earth's surface of the lowest layer of clouds or obscuring phenomena that is reported as "broken", "overcast", or "obscuration"; and not classified as "thin" or "Partial".

Common Reference Points: Reference points on radar display at both Military Radar Unit (MRU) and the ATC facility Allowing easy radar identification of aircraft prior to transfer of control.

Control Responsibility in ATCAA: When FAA releases aircraft to region's control in ATCAA, the military command assumes responsibility for separation of their aircraft within the area. FAA requires the controlling agency to keep aircraft within assigned airspace and place's responsibility for remaining in airspace on both the air controller and pilot.

Control Sector: An airspace areas of defined horizontal and vertical dimensions for which a controller or group of controllers, has air traffic control responsibility, normally within air route traffic control center or an approach control facility.

Controlled Airspace: Designated airspace within which some or all aircraft may be subject to air traffic control.

Discrete Code/Discrete Beacon Code: As used in the air traffic control radar beacon system, any one of 4096 selectable mode 3/A aircraft transponder codes except those ending in zero zero e.g., discrete codes: 0010, 1201, 2317, 77771 non-discrete codes: 0100, 1200, 7700.

DME Fix: A geographical position determined by reference to a navigational aid which provides distance and azimuth information. It is defined by a specific distance in nautical miles and a radial or course in degrees magnetic from that aid.

Department of Transportation (DOT): An executive department of the US Government that develops and promotes national transportation policies and programs. It coordinates programs that provide save, economical, and efficient transportation on the land, sea and in the air.

Distance Measuring Equipment (DME): Equipment (airborne and ground) used to measure, in nautical miles, the slant range distance of an aircraft from the OME navigational aid. DME operates on frequencies in the UHF spectrum between 962 MHz and 1213 MHz. Aircraft equipped with TACAN equipment will receive distance information from a VORTAC automatically, while aircraft equipped with VOR must have a separate DME airborne unit.

En Route Descent: Descent from the en route cursing altitude which takes place along the route of flight.

Eastern Range (ER): The Wing's lineage dates back to the Air Force Division of the Joint Long Range Proving Ground, an Air Force/Army/Navy organization which was established on 1 October 1949 to manage missile testing and launch operations on the Eastern Range. Upon its activation in 1949, the Air Force Division assumed responsibility for the Joint Long Range Proving Ground Base (formerly the Banana River Naval Air Station, a World War II seaplane patrol and training base). On 16 May 1950, the Air Force Division was renamed the Long Range Proving Ground Division, and it

assumed sole responsibility for the Proving Ground. The Long Range Proving Ground Base was renamed Patrick Air Force Base in honor of Major General Mason M. Patrick on 1 August 1950. From those humble beginnings, the Division and its successors coordinated and managed the development of the Eastern Range, which soon became one of the busiest and most important missile and space support ranges in the world.

FAA Air Traffic Facilities: Air Route Traffic Control Centers, Terminal Area Facilities (Control Tower) and approach controls and Flight Services Stations engaged in promotion the safe, orderly and expeditious movement of air traffic.

Federal Aviation Administration (FAA): An agency of the Federal Government under the DOT responsible for the regulation of air commerce, the promotion, encouragement and development of civil aeronautics, control of the use of navigable airspace in the US, regulation of both civil and military operations in such airspace, consolidation of research and development with respect to air navigation facilities as well as the installation and operation and the development on operation of a common system of air traffic control and navigation for both military and civil aircraft.

Flame-out: Unintended loss of combustion in turbine engines resulting in the loss of engine power.

Flight Level: A level of constant atmospheric pressure related to a reference datum of 29.92 inches of mercury. Each is stated in three digits that represent hundreds of feet. For example, flight level 250 represents a barometric altimeter indication of 25,000 feet.

Flight Service Station (FSS): Air Traffic Service Facilities within the National Airspace System (NAS) which provide pilot briefing and enroute communications with VFR

flights, assist lost aircraft, assist aircraft having emergencies, relay ATC clearances, originate, classify and disseminate Notices to Airmen, broadcast aviation weather and NAS information, receive and close flight plans, monitor radio NAVIDS, notify search and rescue units of missing VFR aircraft, and operate the National Weather Teletypewriter System. FSS's may also provide weather observations, airport advisories, Custom and Immigration support.

Flight Plan: Specified information relating to the intended flight of an aircraft, that is filed orally or in writing with an FSS or an ATC facility. Data consisting of the following items: aircraft identification, aircraft type and equipment, beacon code, filed air speed, coordination fix, coordination time, requested altitude, and route of flight.

Ident: A request for a pilot to activate the aircraft transponder identification feature. This will help the controller to confirm an aircraft identity or to identify an aircraft.

IFR Protection in ATCAA: An ATCAA in the PCA is sterile airspace. There will be no non-participating aircraft in the airspace block. An ATCAA area over water and outside the PCAs will have no other IFR aircraft in the block. VFR aircraft is advised to avoid the areas; however, VFR aircraft could legally transit the block.

Instrument Flight Rules/IFR: Rules governing the procedures for conducting instrument flight. Also a term used by pilots and controllers to indicate type of flight plan.

Instrument Landing System (ILS): A precision instrument approach system designed to provide an approach path for exact alignment and descent of an aircraft on final approach to a runway.

Instrument Meteorological Conditions/IMC: Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling less than the minimum specified for visual meteorological conditions maintain.

1. Concerning altitude/flight level, the terms means to remain at the altitude/flight level specified. The phrase “climb and” or “descend and” normally precedes “maintain” and the altitude assignment.

2. Concerning other ATC instructions, the term is used in its literal sense; e.g., maintain VFR.

Launch Decision Authority Simulator (LDAS): A simualtor which gives the General the same information necessary to determine whether Launch Decision Authority (LDA) is a go or no-go.

Military Assumes Responsibility for Separation of Aircraft: A condition whereby the military services involved assume responsibility for separation between participating military aircraft in the ATC system. It is used only for required IFR operations which are specified in Letters of Agreement or other appropriate FAA or military documents.

Military Operations Area (MOA): Airspace defined by vertical and lateral limits established for the purpose of separating certain military training activities from IFR traffic. MOA's are established over land and below Positive Control Area. VFR traffic may he encountered while operating within a MOA. ATC will separate IFR traffic from operations within a MOA.

Military Radar Unit: Any fixed or mobile ground based unit radar the operational jurisdiction of the military services excluding commissioned ATC facilities. Military radar units shall not provide ATC services.

Minimum Fuel: Indicates that aircraft's fuel supply has reached a state where, upon reaching the destinations it can accept little or no delay. This is not an emergency situation but merely indicates an emergency situation is possible should any undue delay occur.

Mission Support Point (MSP): The predetermined safe position for range support aircraft prior to launch.

MRU Operator's Confirmation of Altitude Block: The Operator must confirm to the pilot the block altitude assigned by ATC to ensure both are familiar with vertical limits of the ATCAA for their planned mission.

Non-Directional Radio Beacon (NDB): A low or medium frequency radio that transmits non-directional signals whereby the pilot of an aircraft, properly equipped, can determine his bearing and home on the station. NDB's have 3-letter identification and are depicted on aeronautical charts.

Positive Control Area (PCA): Airspace designated in Federal Air Regulations Part 71 wherein requiring aircraft to operate under Instrument Flight Rules (IFR). Vertical extent of PCA is from FL 180 feet to and including Flight Level 600 throughout most of the US. An ATC IFR clearance requireds aircraft to operate within this airspace.

Radar: (Radio Detection and Ranging) transmit energy pulses into the atmosphere and receive pulses reflected by objects.

Radar Contact: The term a controller used to inform the transferring controller that the target being transferred is identified on his radar display.

Range Operations Commander (RCO): During launch operations the RCO is responsible for ensuring the Eastern Range (ER) is capable of supporting the launch.

Radar Hand-off: An action taken to transfer the radar identification of an aircraft from one controller to another, if the aircraft will enter the receiving controller's airspace and radio communications with the aircraft will he transferred.

Radar Point-out/Point-out: Used between controllers to indicate radar hand-off action where the initiating controller plans to retain communications with an aircraft penetrating the other controller's airspace and additional coordination in required.

RAPCON: Acroynm for Radar Approach Control which is a Military Radar Unit (MRU) located at Patrick AFB

Restricted Area: Airspace identified by an area on the surface of the earth within which flight of an aircraft, while not wholly prohibited, is subject to restrictions. Restricted areas denote the existence of unusual or often invisible hazards to aircraft such *as* artillery firing, aerial gunnery or guided missiles. Aircraft need approval from the controlling agency to enter these areas.

Roger: I have received all of your last transmission. It should not be used to answer a question requiring a yes or no answer.

Separation of Non-Participants: ATC facilities are required to provide separation between non-participation IFR aircraft cleared to transit an ATCAA. Accomplish such separation by coordinating with the MRU at least five minutes prior to ATCAA

boundary. ATC will coordinate for release of altitude(s) throughout the entire ATCAA. A point-out of non-participation aircraft will be effected with the MRU by ATC.

Tactical Air Navigation (TACAN): An ultra-high military frequency electronic air navigation aid which provides suitably equipped aircraft continuous indication of bearing and distance to the TACAN station.

Terminal Area Facilities: These facilities provide ATC service for arriving and departing IFR, VFR, Special VFR, aircraft and on occasion, enroute aircraft.

Transfer of Control: That action whereby the responsibility for the separation of an aircraft is transferred from one controller to another.

Uncontrolled Airspace: That portion of airspace not designated as controlled airspace and within which ATC has neither the authority nor the responsibility for exercising control over air traffic.

VHF Omnidirectional Range (VOR): A ground-based electronic navigational aid, transmitting very high frequency navigation signals, 360 degrees in azimuth, oriented from magnetic north. Used as the basis for navigation in the National Airspace System, the VOR periodically identifies itself by Morse code and may have an additional voice identification feature. VOR's operate within the 108.0-117.95 MHz frequency band.

VHF Omnidirectional Range/Tactical Air Navigation (VORTAC): A facility consisting of two components, VOR and TACAN, which provides three individual services: VOR azimuth, TACAN azimuth, and TACAN distance at one site.

Visual Flight Rules/VFR: Rules that govern the procedures for conducting flight under visual conditions. The term “VFR” is also used in the US to indicate weather conditions

that are equal to or greater than minimum VFR requirements. in addition, it is used by pilots controllers to indicate type of flight plan.

Visual Meteorological Conditions: Meteorological conditions expressed in terms of visibility, distance from cloud, and coiling equal to or better than specified minimal.

Warning Area: Airspace that contains hazards to non-participating aircraft in international airspace. Warning areas are established beyond the 3 mile limit over water. VFR aircraft does not need approval from the controlling agency to enter warning areas.

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