To the Graduate Council:

I am submitting herewith a thesis written by Roxanna Ganji entitled "Automated Testing Facility for Television Industry." I have examined the final copy of this thesis for form and content and recommend that it be in partial fulfillment of the requirements for the degree of Masters of Science, with a major in Electrical Engineering.

Daniel B. Koch

Daniel B. Koch, Major Professor

We have read this dissertation
and recommend its acceptance:

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Accepted for the Council:

Associate Vice Chancellor and
Dean of the Graduate School

Automated Testing Facility

for Television Industry

A Thesis

Presented for the

Master of Science

Degree

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DEDICATION

I am dedicating this thesis to my parents, Mrs. Fatemeh Afkhami and Mr. Gholamali Ganji, for their guidance and encouragement , to my brother, Armin, and my sister, Azita, for their friendship, and to my husband, Hamid Babaei, for his love and support.

ACKNOWLEDGMENT

I would like to thank Dr. Daniel B. Koch for his guidance and support during this research work. I also thank Dr. Paul B. Crilly and Dr. Michael. J. Roberts for serving on my thesis committee. I would like to express my appreciation to all of the ATF team members for their great job. Also Thanks to Mr. Mostafa Rahbar for his help in editing this thesis.

ABSTRACT

This thesis is the result of a research project on an Automated Testing Facility (ATF) for the television industry. The purpose of this project is to provide the industry with an automatic system for measuring television performance from different points of view. Manual methods for measuring television performance have been used for years, and they have become standard industrial practice. However, manual processes limit the volume and consistency of the measurements. Therefore, the ATF project converts the manual procedures to automated ones using the LabVIEW graphical programming language. This thesis reviews the background of the ATF project and studies the benefits of the automatic system. It presents the diagnostic software developed for the ATF system. It then discusses the instrument driver for the CA-100 CRT Color Analyzer that communicates with the instrument through a GPIB bus. It also describes the code developed for the color temperature test on a direct-view TV as an example of the automated tests. This study demonstrates that the productivity and consistency of the automated tests are substantially better than manual measurements.

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CHAPTER 1

INTRODUCTION

1.1 Problem statement and motivation

In our competitive industrial world, most companies and corporations are making an effort to improve the quality of their products in order to survive and succeed. It is crucial to surpass all competitors' technology to lead the competition for better quality and pricing. Therefore, it is of great importance that companies plan their future investments with detailed predictions based on up-to-date and reliable market information. Taking the wrong direction in product enhancements leads to increased cost without improvement in sales. Competitive analysis provides the needed information for the strategic product design decisions.

In the television industry, competitive analysis translates television behavior profiles into qualitative measures of product performance. These performance measures are the basis for investment decisions.

To complete a performance profile for a television, competitive analysis performs a variety of tests on the television. As will be demonstrated, there are many different pieces of equipment involved in testing televisions. For each test, the operator is supposed to configure all the test equipment properly, do necessary calculations, and record the results. When the test is performed, environmental factors, such as cable losses must be taken into account.

Manual completion of a profile is a time-consuming task and there is always the possibility for mistakes to be made during the different steps of manual testing. Manual processes limit the volume and consistency of the tests.

By automating the performance tests, their reliability increases dramatically. Automated tests can be repeated with fewer mistakes and the operator has a greater assurance that all equipment has been set properly and all calculations are being done accurately. Automated tests are much faster. Each year manufacturers produce many new models of televisions. Manual completion of the performance profiles for all of them is a difficult task. Automated testing systems increase the number of televisions that can be tested for a given manpower and time. Automation provides speed and accuracy in performing the tests and recording their results.

1.2 Thesis outline

This thesis consists of six chapters. Chapter 2 gives an overview of the Automated Testing Facility (ATF) project, layout of the test area, equipment rack, and general software architecture.

Chapter 3 describes the Built In Test (BIT). The chapter first explains the philosophy of the BIT and then presents its software, including the self diagnostic tests for the equipment and level measurements for the modulator output.

Chapter 4 introduces the Color Temperature Test for Direct-view TV as an example of a test. The chapter discusses the measurement theory for the Color Temperature Test. Then it presents the test procedure and explains the front panel and block diagram of the program.

Chapter 5 discusses the driver for Minolta CA-100 CRT Color Analyzer. This chapter explains the CA-100 operations, the driver features, and the front panel and the block diagram of the driver.

Chapter 6 summarizes the research, and draws conclusions about the employed method and the achieved results.

CHAPTER 2

BACKGROUND

2.1 History of the ATF project

During the 1980s, the television industry initiated a comprehensive program to improve international competitiveness. Better product performance through modern quality improvement techniques became the primary tool in achieving greater market share and lowering production cost.

Manufacturers developed corporate quality standards consistent with applicable television measurement practice[1]. Quality standards prescribe the methods for measuring performance and provide the means for monitoring performance trends over time. Analysis of the quality measurements provides management with a gauge of relative product strength.

In the television industry, skilled personnel measure television performance. A technician may work a whole day or more to manually compile a full set of measurements. As mentioned in the previous chapter, manual processes cannot reasonably address a growing demand for competitive product information.

In 1993, the Communications, Information, and Signal Processing (CISP) group, University of Tennessee, Knoxville, began the Automated Testing Facility project in cooperation with members of the television and test equipment industry. The ATF project expands upon accepted measurement methods by applying automatic test equipment techniques to the measurement process. The ATF project seeks to improve the consistency and efficiency of television measurement. ATF project goals are to:

- Reduce the labor required for a performance profile.
- Increase the compilation rate for measurement profile.
- Improve the accuracy of receiver measurements.
- Insure compliance with recognized measurement standards.
- Facilitate automate competitive analysis.

The project combines computer-controlled test equipment, signal sources, switching matrices, and systematic measurement methods to achieve increased measurement productivity.

2.2 Layout of the test area

Typically, manufacturers collect television measurements in a dedicated facility consisting of three test rooms. An RF-free measurement room provides an area isolated from external RF emissions. This room is needed because certain tests that either measure RF levels or require that the RF level be within a specific tolerance cannot be accurately performed otherwise. An evaluation room, equipped with appropriate ambient lighting and acoustics, creates a setting for observing video and audio quality. The evaluation room is used to demonstrate different characteristics and performance levels of varying models of televisions being tested to outside parties interested in such data. Technicians perform internal television measurements using an equipment rack and work benches found in an exploratory test room referred to as the equipment room. Physical layout of the ATF test area is shown in Figure 2.1.

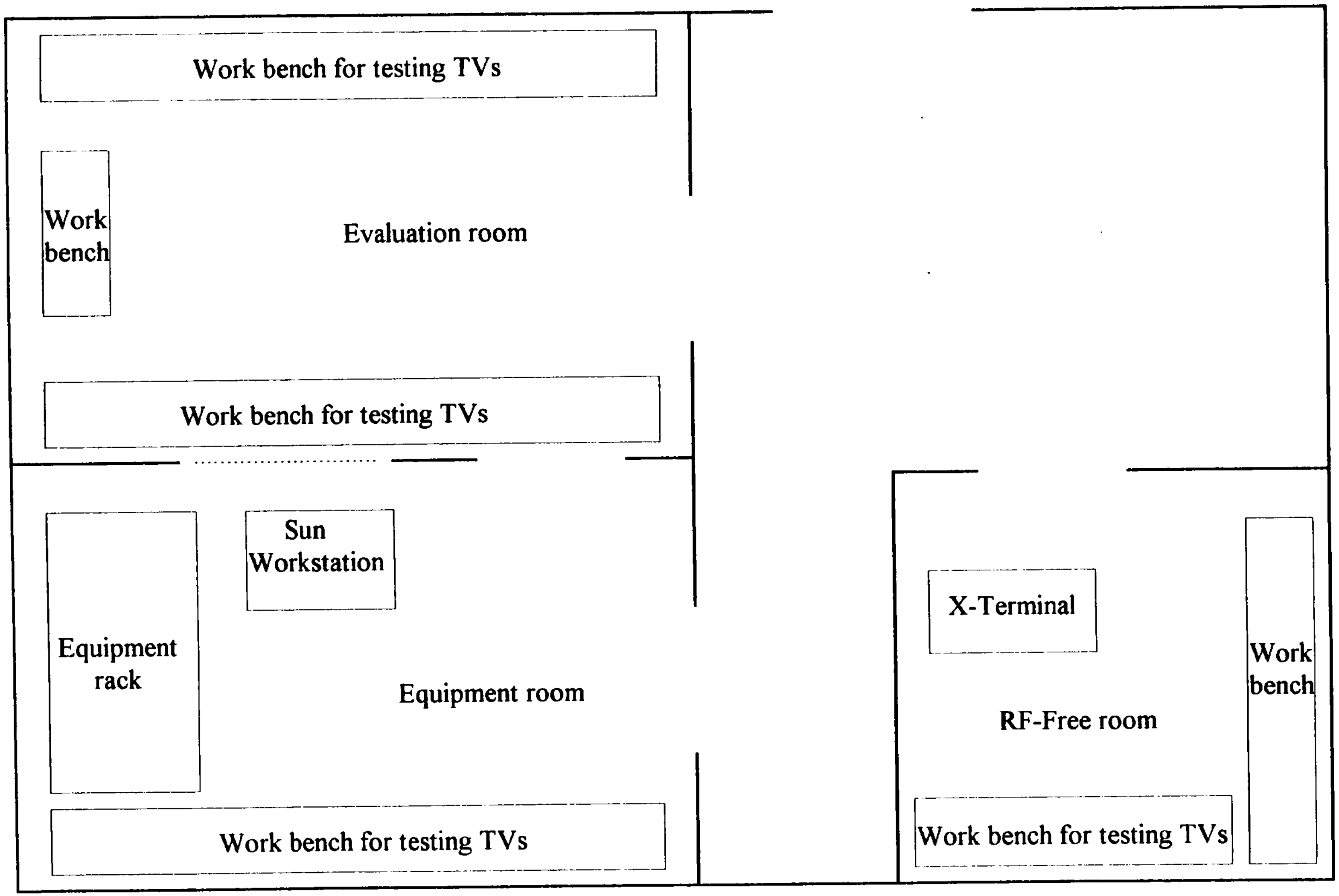

Figure 2.1 Layout of the test area

2.3 Equipment rack

Television system performance is evaluated by sending test signals with known characteristics through the signal path. The signals are then observed at the RF outputs, to determine the quality of the televisions connected to those outputs. To perform these tasks, two basic types of television test and measurement equipment are needed. Test signal generators provide the stimulus and specialized measurement instruments provide displays for evaluating the response.

Television signal generators provide a variety of test signals and synchronization signals ranging from black burst to more complex signals designed for evaluation of specific distortions. Each generator model offers a different selection of signals. Therefore, to do all of the different standard tests on a television, usually several analog and digital signal generators are needed. Generator performance is critical to accurate system testing. Operators need to be confident that any distortions observed on the television are introduced by the system being tested and not by the generator itself.

The instruments used to evaluate a system's response to test signals make up the second major category of television test and measurement equipment. Some measurements can be performed with a general purpose analog or digital oscilloscope. There are other measurements that need a spectrum analyzer, or a waveform monitor, or a vectorscope.

Modern spectrum analyzers are powerful tools available for television performance analysis. They provide the ability to measure a wide range of system parameters, from simple carrier level checks to in-depth analysis of system performance that includes all of the RF proof-of-performance measurements. In addition, spectrum analyzers simplify complicated test procedures by automating many of the instrument setups and by logging the resulting data.

Waveform monitors provide TV triggering capabilities and video filters that allow the user to separately evaluate the chrominance and luminance portions of the signal. Most waveform monitor models also have a line selector for observing the signal on individual lines[7].

A vectorscope which demodulates the video signal and displays R-Y versus B-Y is another important test and measurement tool. Vectorscopes allow the user to accurately evaluate the chrominance portion of the signal.

Figure 2.2 illustrates the ATF equipment rack for television performance testing. A schematic of the system equipment and interconnectivity of control and data lines is shown in the Figure 2.3.

A crosspoint router with sixteen inputs and sixteen outputs connects the baseband test signals coming from one of the different signal sources, to the proper modulator. Computer controlled attenuators adjust the modulated signal level. A test interface system channels signals from source to the destination by controlling attenuators, switches, and relays. This way, the operator can have the desired signal at the end of a path which can be a measurement instrument or one of the RF outlets mounted on the walls of the testing areas.

A programmable power control system in conjunction with a power analyzer guarantees stable power supply for the system. A Sun SPARCstation 10 controls all the test equipment via an IEEE-488 General Purpose Interface Bus (GPIB). A remote X-terminal located on a mobile cart enables technicians to do the tests in different areas.

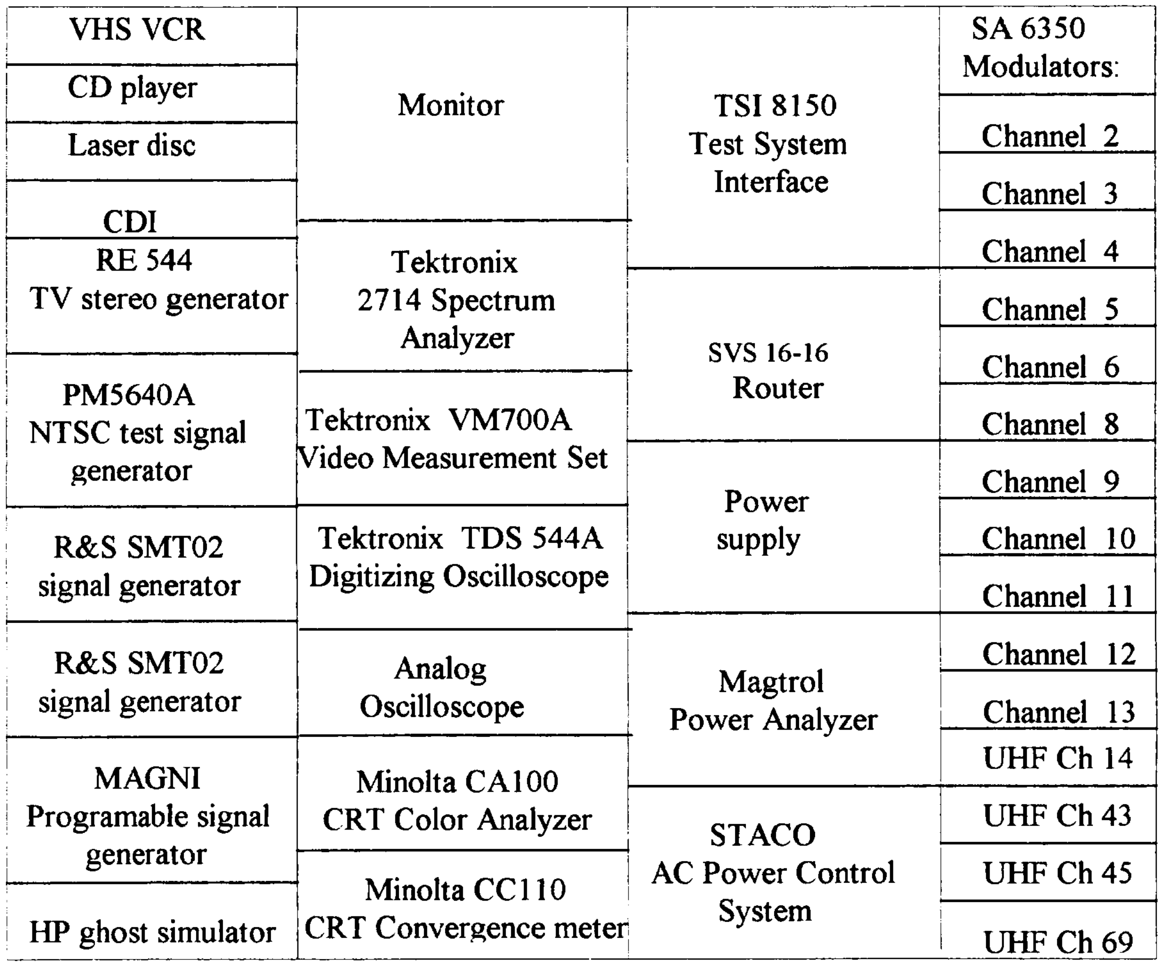

Figure 2.2 ATF rack equipment

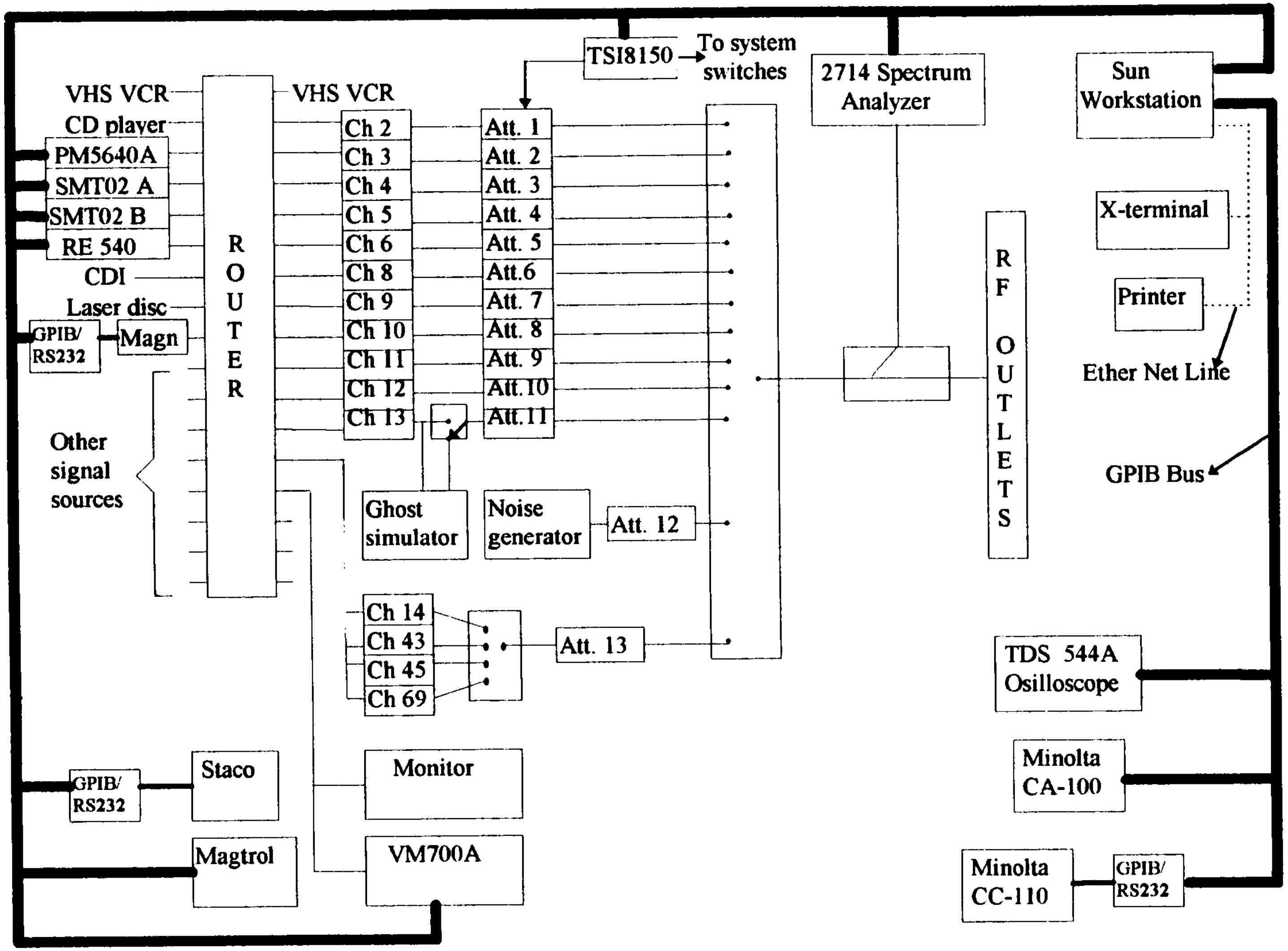

Figure 2.3 Block diagram of the ATF system

The Automated Testing Facility utilizes the IEEE-488 GPIB bus to interconnect all of its equipment and the controller. An extender is placed between the host controller and the rest of the bus to provide low impedance driving power to the bus to handle the additional capacitance and inductance of bus cabling when more than the recommended 2-meter distance between devices is required. The system also uses several IEEE-488.2/RS232 converter boxes to communicate with the serial instruments.

2.4 ATF software

ATF software written in the National Instrument Laboratory Virtual Instrument Engineering Work bench, LabVIEW language, is the most complex part of the project effort. The ATF project addresses development complexity by adopting the cleanroom software engineering methodology as described in [2]. Cleanroom methods promote software quality through a rigorous design process and comprehensively defined user requirements through iterative productivity by virtually eliminating design rework. The ATF project adapts the cleanroom process and box definition methods to the LabVIEW visual programming language.

2.4.1 LabVIEW language

LabVIEW is a powerful and flexible instrumentation and analysis software system. LabVIEW departs from the sequential nature of traditional programming languages and features a graphical programming environment and all of the tools needed for data acquisition, analysis, and presentation. With this graphical programming language, called G, the user can program using a block diagram approach, the natural design notation of scientists and engineers.

LabVIEW programs are called Virtual Instruments, or VIs. A VI consists of a front panel, block diagram, and icon/connector. The front panel with knobs, switches, graphs, and so on, specifies the inputs and outputs and features the user interface requires for interactive operation. The actual executable program, the block diagram, is located behind the front panel. The components of a block diagram, icons, represent lower-level instruments and program control structures. The programmer wires the icons together to indicate data flow in the block diagram. The icon/connector is the programmer's means of turning a VI into an object that can be used in the block diagram of other VIs as if it were a subroutine. The icon graphically represents the VI in the block diagram of other VIs. The connector terminals determine where to wire the inputs and outputs of the icon. The terminals are analogous to parameters of a subroutine. An example of a front panel, a block diagram, and an icon/connector for a VI is shown in Figure 2.4.

2.4.2 ATF software development discipline

Successful design of a large and complex software effort such as the ATF demands the test design engineers to work as team following a development discipline called a methodology. The ATF project is a new and evolutionary creation. System requirements change during system development reflecting an increased understanding of the business problem, increased user sophistication, and business paradigm shifts. Due to its dynamic nature, the ATF project adopts a software engineering methodology called cleanroom[3,4]. Cleanroom methods promote language independent designs, increase design productivity, reduce design test failures, reduce design upkeep costs, adapt to evolving system requirements, and create design correctness through quality

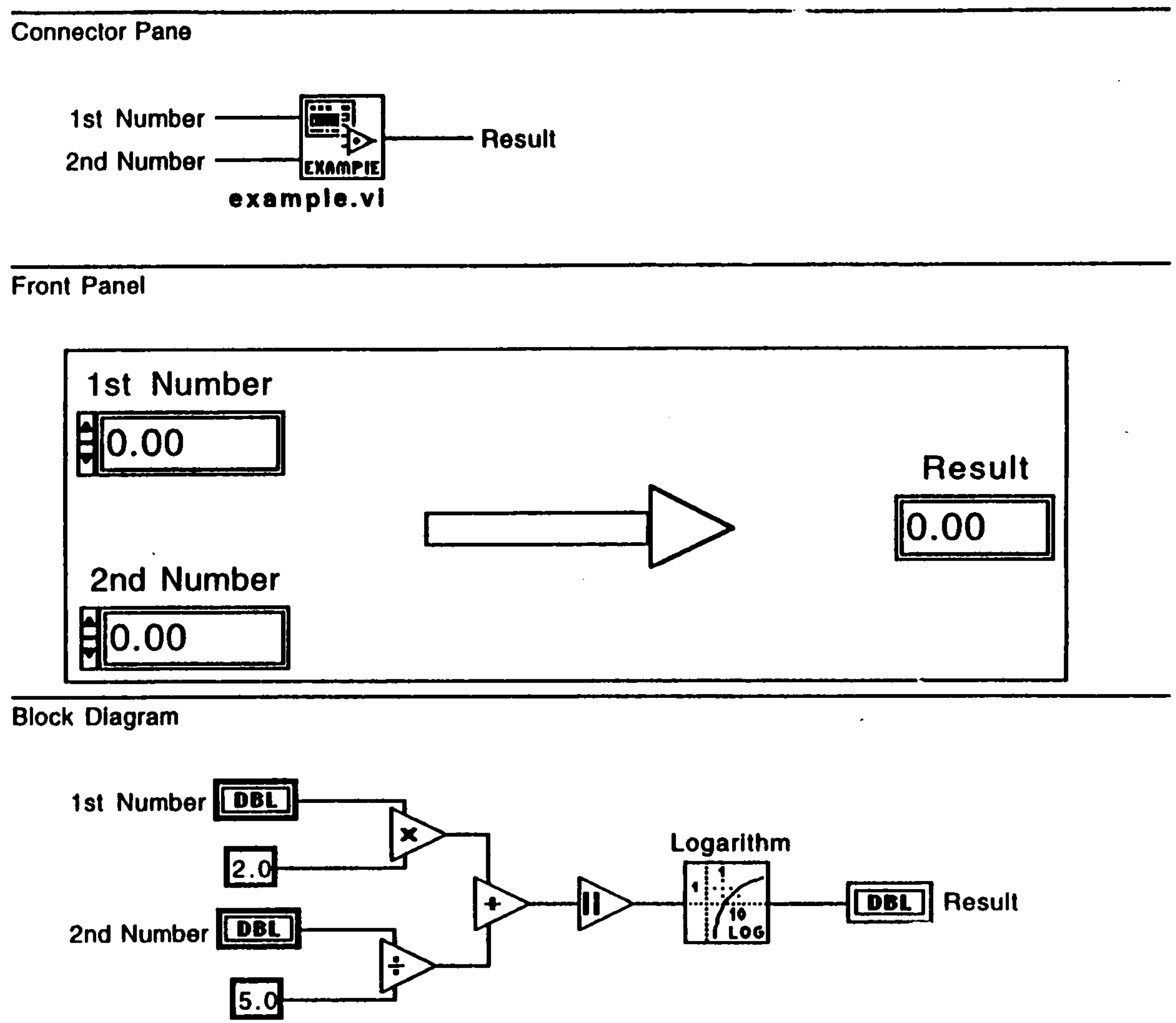

Figure 2.4 An example of icon/connector, front panel, and block diagram for a VI

controls. All of these benefits are important to ATF development success.

Cleanroom procedures follow an iterative process that responds to an evolving understanding of system requirements. Each iteration, called a "design increment", captures new information about the ATF system. Successive increments expand upon prior understanding increasing the sophistication of each increment. New increments build upon the correctness of prior increments resulting in the reuse of earlier designs.

The process begins with the collection of information through user interaction, story board design trials, examination of current business processes, and experimentation. Designers consolidate their findings into a System Requirements Specification. System users and designers revise the specification until its content achieves a consensus. With each increment, new System Requirements Specifications develop reflecting the increased experiential understanding gained through user interaction with an evolving system. Thus, cleanroom development is a dynamic, highly responsive process reflecting the latest thinking of designers and users. A more detailed description of cleanroom methodology and ATF software development discipline can be found in [9].

2.4.3 General software architecture

ATF software consists of four main groups: BIT, drivers, utilities, and tests. The BIT group contains those functions related to Built In Test. Chapter 3 of this thesis will discuss the Built In Test in detail. The ATF team has put forth considerable effort to develop drivers for all instruments involved in television performance tests. Each driver communicates with one instrument and controls it remotely. All of the VIs for each driver are put in a folder named after the corresponding instrument under the drivers folder. There are some global variables, and test or driver template VIs that are commonly used by different tests; these are collected under the utilities folder. Finally the tests folder contains six folders, audio tests, video tests, raster series, power consumption, RF series, and PTV tests. These six folders correspond to six different types of standard performance tests for television, and each one having several folders named after each test and containing all files related to those tests. Figure 2.5 illustrates the hierarchy of the folders in the ATF software.

The ATF software is a menu-based software. The user starts from the Top Menu which sits at the top of hierarchy and manages the flow of control through the lower-level menus and VIs.

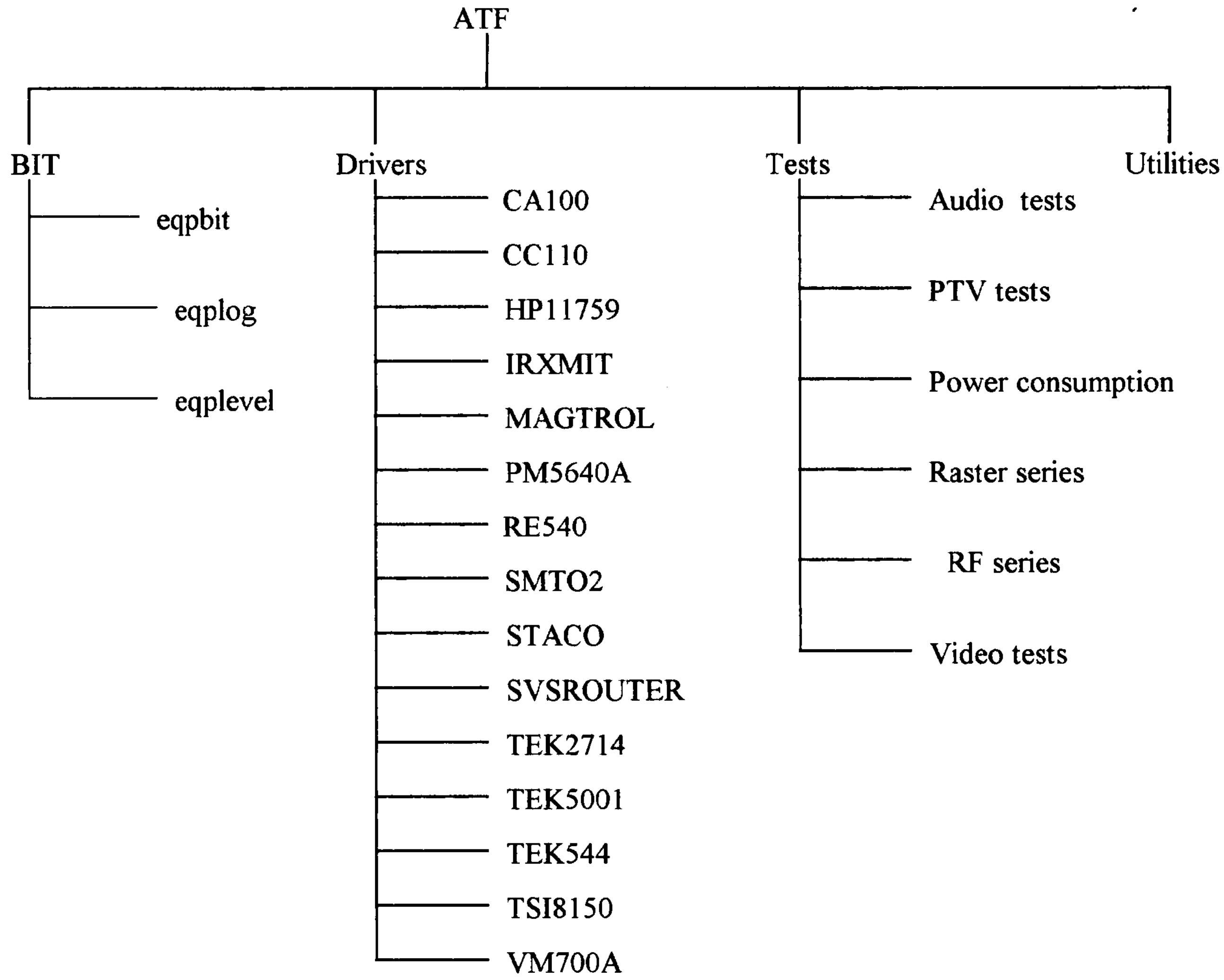

Figure 2.5 Hierarchy of the main folders in the ATF software

Figure 2.6 shows the Top Menu as an example and Figure 2.7 illustrates the hierarchy of the menus in the ATF software. The Top Menu divides the whole software to four suites, competitive analysis, engineering, diagnostics, and manual control. This thesis covers the diagnostics suit and a part of the competitive analysis suite. Next chapter discusses the diagnostics software in details.

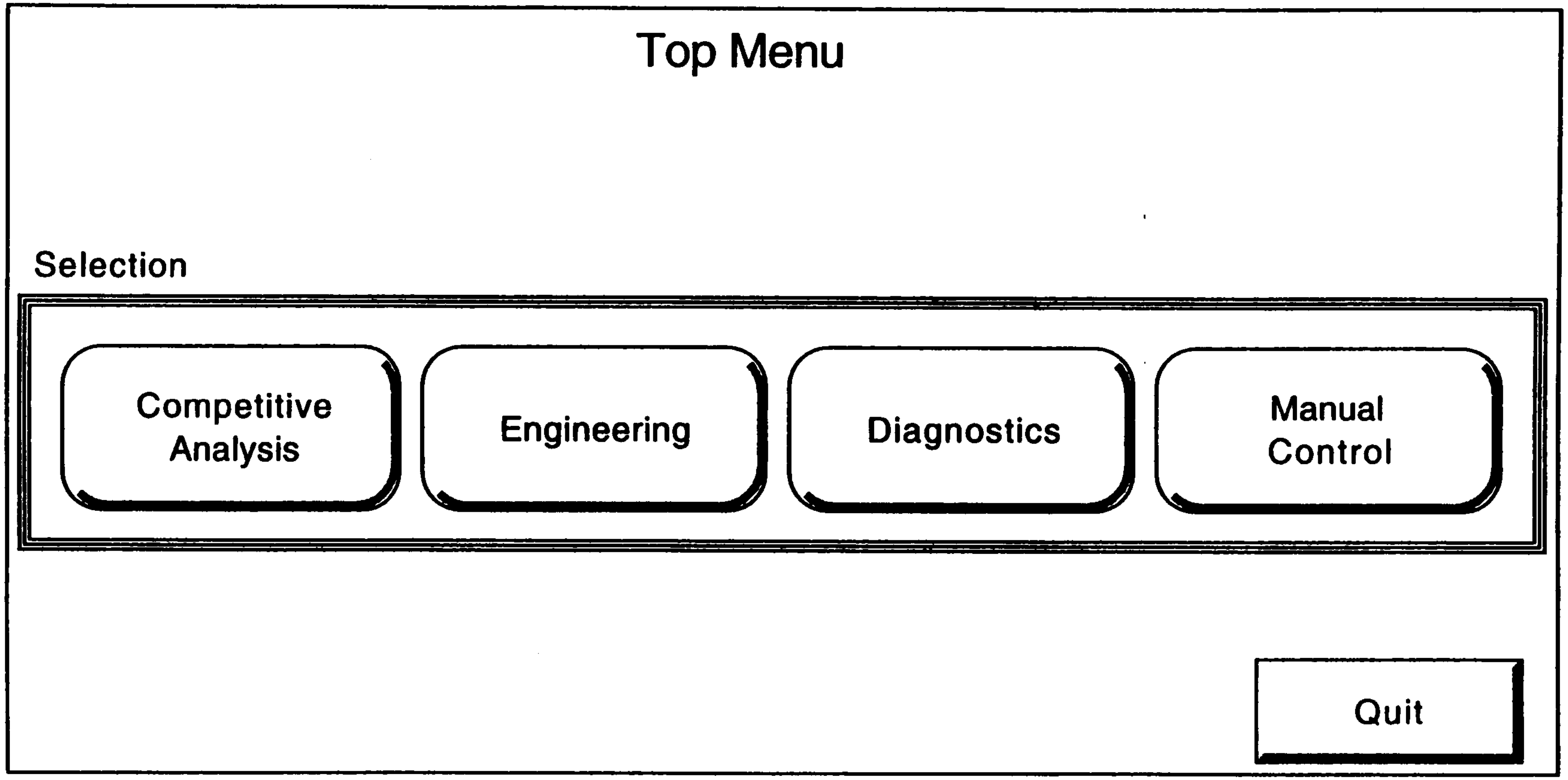

Figure 2.6 Top Menu

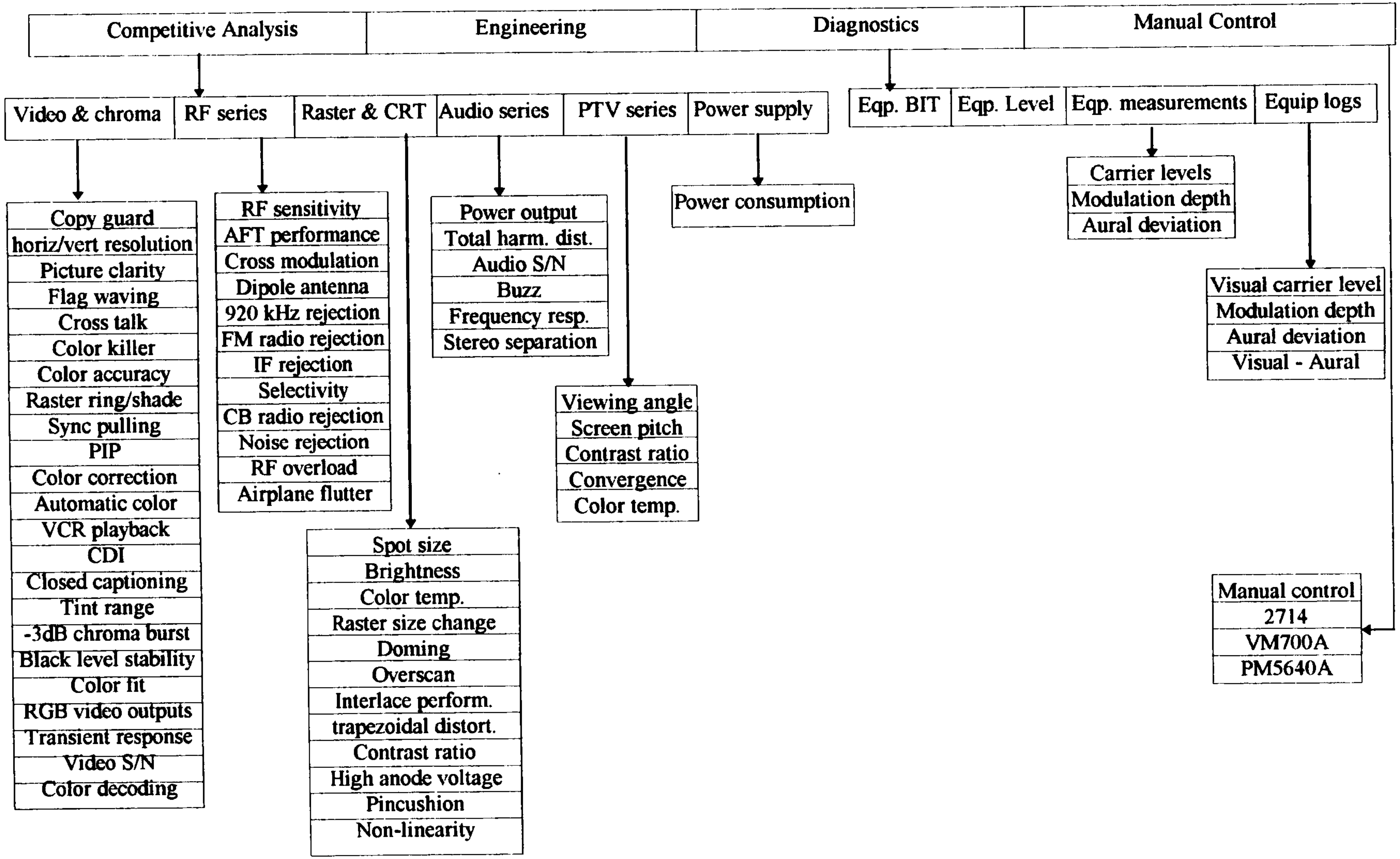

Figure 2.7 Hierarchy of the menus in the ATF software

CHAPTER 3

BUILT-IN TEST

3.1 Philosophy

As mentioned in Chapter 2, there is a variety of instruments involved in testing televisions. In manual testing, the operator makes the connections and sets each instrument properly. The operator also checks all instruments to make sure that they all work in proper order. In automatic testing, the software is supposed to perform this check and provide up-to-date information about the functionality of the test equipment. The reason is that It would be a waste of time if in the middle of a test, it turns out that one or more of the test instruments are malfunctioning.

Also in many tests it is necessary to provide a certain signal level for the television being tested. Signal generators produce baseband video signals. For each test the desired baseband signal pattern goes to one of the television modulators which have several modules. The video modulator module amplitude modulates a 45.75 MHz continuos wave (CW) carrier with a baseband video signal to generate the video IF. The double sideband AM signal then goes to the vestigial sideband filter. A sample of the CW carrier goes to the broad band audio modulator to help derive the sound IF. The broad band audio modulator module processes the baseband and the 4.5 MHz external subcarrier signals to generate the sound IF signal centered at 41.25 MHz for the vestigial filter module. The vestigial filter module combines the sound IF signal with a vestigial sideband filtered video IF signal to produce the composite IF signal. The local oscillator module generates the local oscillator (LO) signal used by the output converter module to generate the final RF output signal. The output converter module mixes the composite IF signal with the LO signal to generate the RF output signal [8].

Television testing standards define an RF modulator output to have stable characteristics. According to these standards, the visual carrier level of the RF signal should not deviate more than 3dB around its nominal value. The depth of modulation is expected to be 87.5% with a maximum tolerance of 2.5%. The aural deviation should be 25 kHz and the visual aural carrier level ratio should be 12dB. Table 3.1 shows the allowed range for the modulator's RF output parameters.

Table 3.1 Allowed range for RF modulators' outputs

Parameter	Limit
Visual Carrier Level	Nominal Carrier Level +/- 3dB
Modulation Depth	87.5% +/- 2.5%
Aural Deviation	25kHz +/- 1kHz
Visual Aural Carrier Level Ratio	12dB +/- 3dB

Unfortunately, the modulator output stage is not stable and there is a slight drift in different characteristics of the RF signal. The drifting problem increases with temperature and with the use of the modulator in high output power mode.

The fact is that RF outlets are located in different testing areas and there are many splitters along the way from the modulators to the RF outlets. Each splitter decreases the signal level 7 dB. Therefore, to have enough signal at all the RF outlets, it is necessary to drive the modulator in full output power mode, which causes more drift in the output.

The modulators' drift is an undesired situation in the television testing system. When a test needs, for example, one milivolt RF signal level, the software should have access to the information about the exact signal level at the desired outlet to adjust the attenuation in order to decrease the RF signal level to 1 milivolt. When the modulator has drift, the software has to update the signal level information file more frequently.

All of the problems stated in the previous paragraphs require that the ATF software should have a group of VIs to perform a diagnostic test for the system itself. The group of VIs which does this important task is named Built-In Test (BIT) software. There is a diagnostic button on the Top Menu which lets the user to have access to the BIT software.

3.2 BIT software

The Built-In Test software checks the functionality of the ATF equipment and informs the user if there is any problem. It also checks if the modulators' outputs remain within specified limits and alerts users depending on the rate of change of the RF levels.

All the VIs in the BIT software have two different modes, a manual mode and an automatic mode. The manual mode lets the user initiate any portion of the software at any time. The automatic mode makes it possible to run the BIT automatically once a day during off-hours and updates the information files and reports the possible errors.

The following list describes the main tasks of the BIT. A more detailed description of each task and the method used for it can be found in sections 3.2.1 to 3.2.8.

1. Checking the functionality of the ATF equipment and updating the Pass/No pass table

2. Checking the RF output level on each modulator and updating the level table on a daily basis
3. Checking the video modulation depth of each modulator
4. Checking the Aural deviation of each modulator
5. Checking the Visual-Aural carrier ratio of each modulator
6. Reporting possible errors when the user presses any button on the Top Menu

Figure 3.1 illustrates the hierarchy of the menus in the BIT software. Figure 3.2 shows the hierarchy of corresponding VIs and spread sheet files. The user has access to these menus from the Top Menu. Figure 3.3 illustrates the Diagnostic Menu, which lets the user to initiate one of the four major branches of the BIT in manual mode. When the Top Menu is running, at a certain time during off-hours, BIT starts automatically and executes the following sequence of the VIs.

1. power_up.vi
2. Carrier_level.vi
3. Level_table.vi
4. Modulation.vi
5. Deviation.vi

When the above measurements are done, check_limits.vi starts if the user presses any button on the Top Menu. This VI

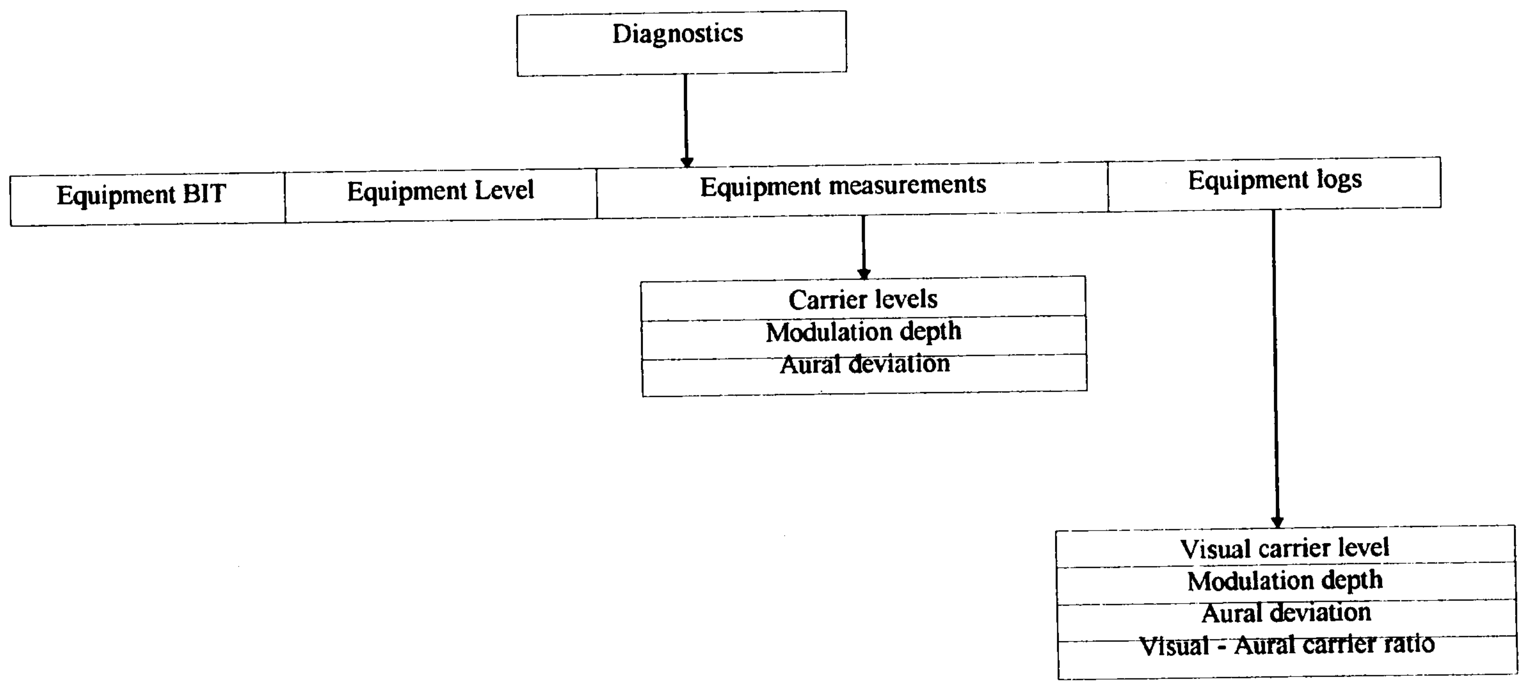

Figure 3.1 Hierarchy of the menus in the BIT software

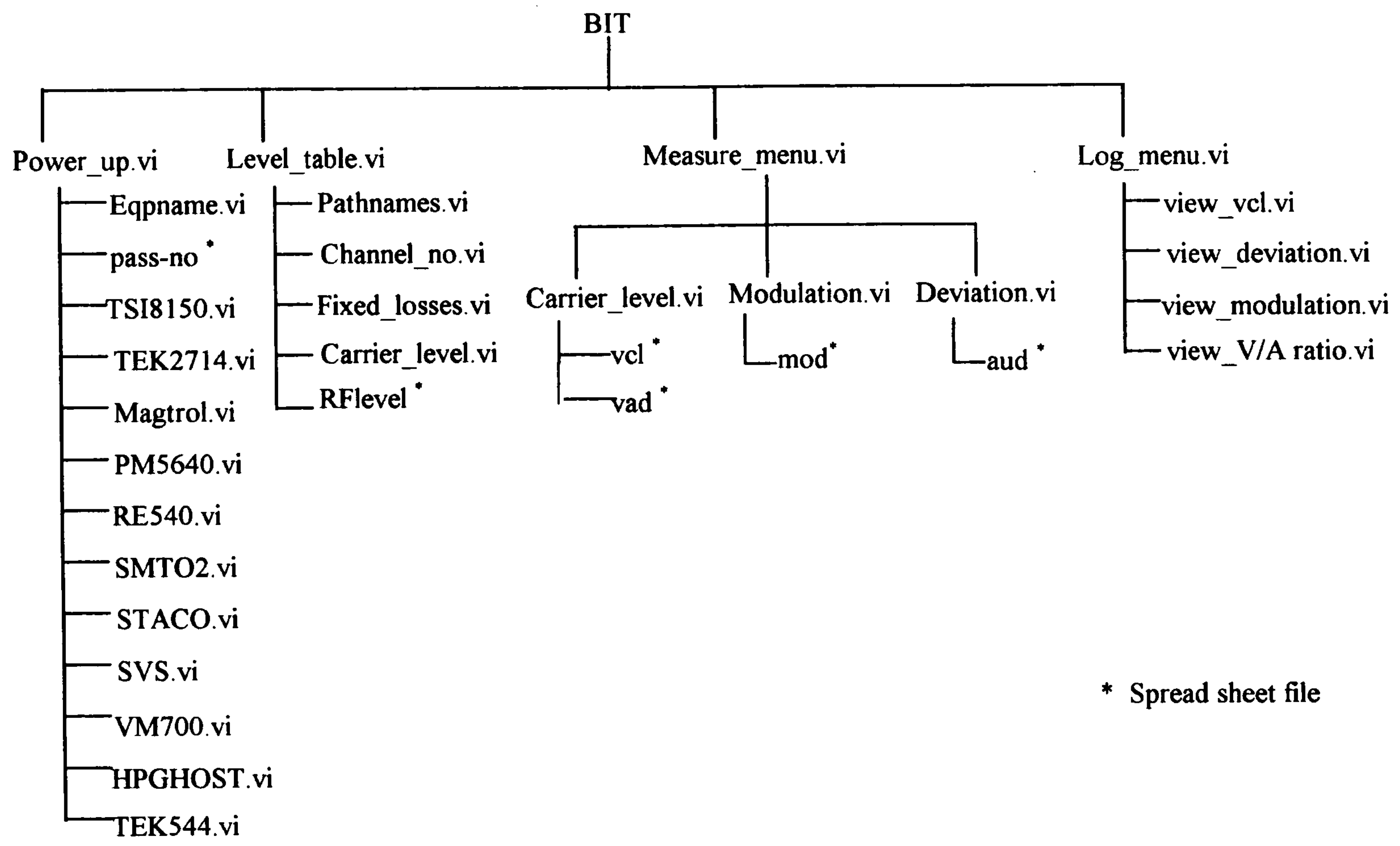

Figure 3.2 Hierarchy of the VIs in the BIT software

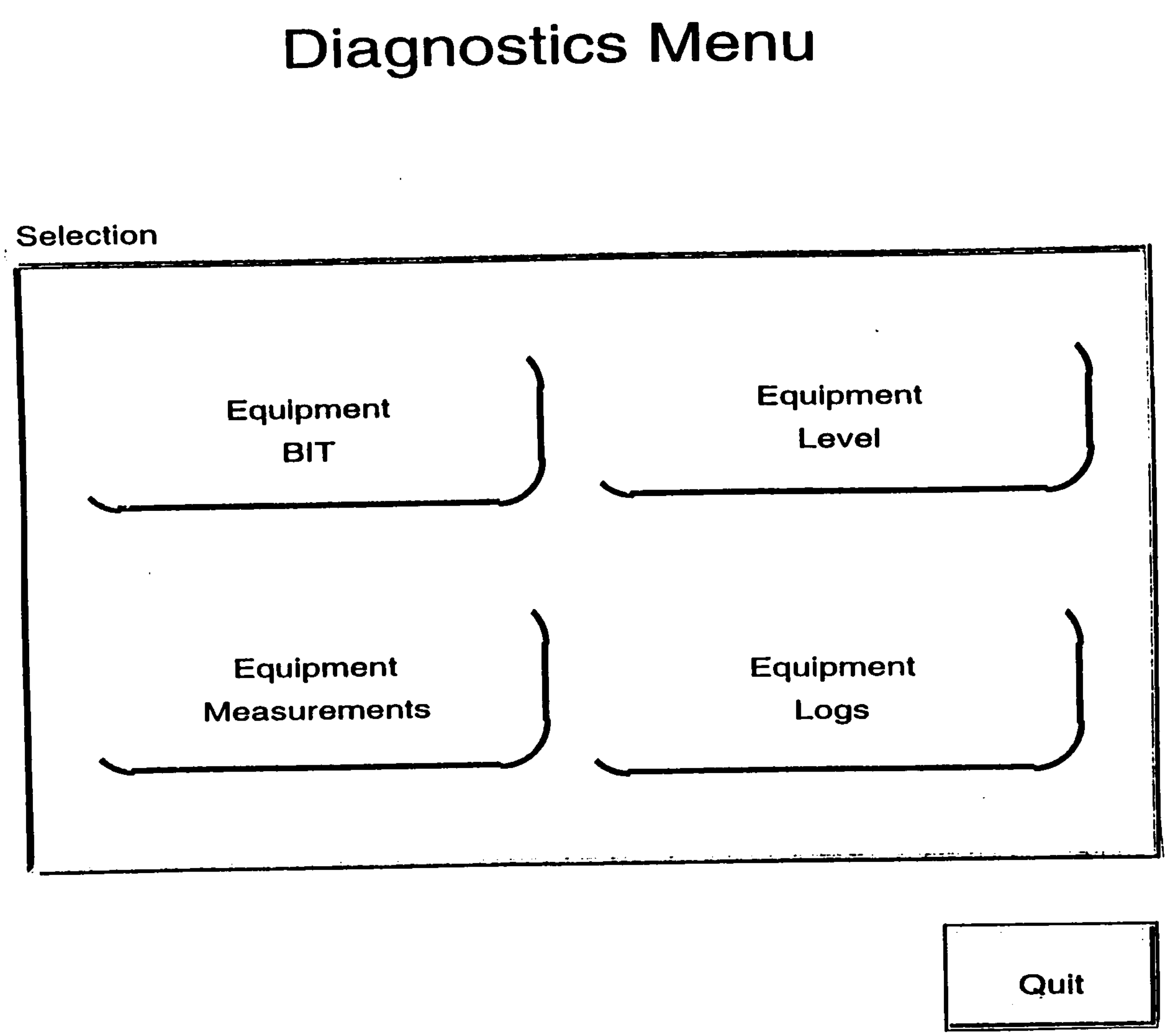

Figure 3.3 Diagnostic menu

compares the result of the most recent measurements of modulators RF output parameters with the expected values. If any parameter is outside the allowed range, a pop-up error message informs the user.

AT this point the reader should have a general idea about the BIT. The rest of this chapter explains all of the VIs used in the BIT in detail.

3.2.1 Power_up.vi

This VI checks the functionality of the ATF equipment and updates the Pass/No-pass table. There are two different types of instruments in the ATF rack. Some instruments have built-in self-diagnostic tests or initialization routines. For this type of instrument power_up.vi runs the built-in routine and reports any errors. Other instruments do not have such a built-in test. Therefore, power_up.vi clears the GPIB interface for those devices to return them to a known operating state. Again, if power_up.vi detects any errors, it reports them.

The front panel of power_up.vi is shown in Figure 3.4. It has a one-dimensional array of equipment names and another array of clusters where each cluster has three elements: response, message,

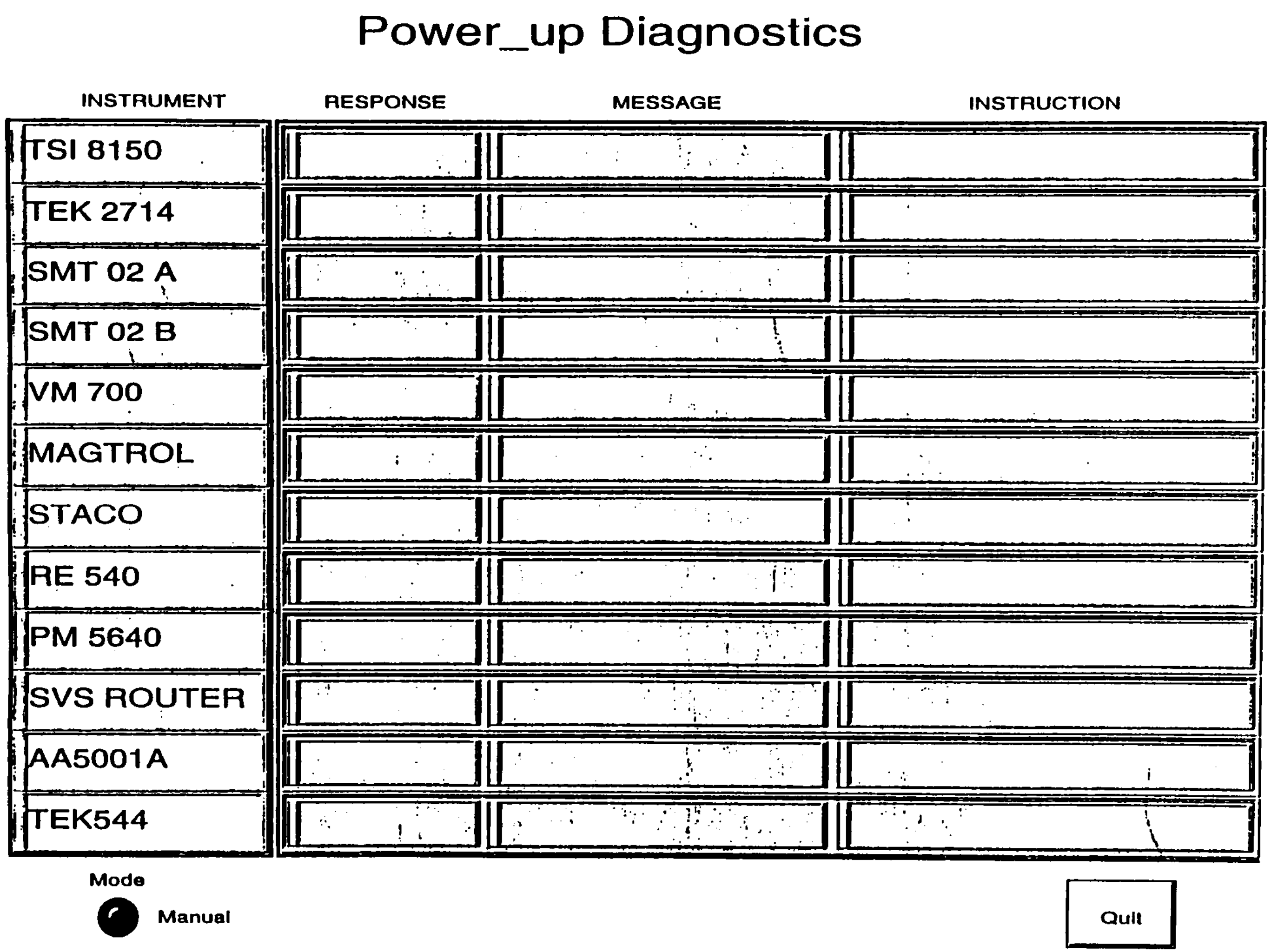

Figure 3.4 Front panel of Power_up.vi

and instructions. Response can be PASS or NO-PASS. Message and Instruction fields are used to provide the user with more information on the status of each instrument.

This VI has two different modes, the manual mode and the automatic mode. In the automatic mode, the front panel closes after populating the arrays and saving the Pass/No pass information. In the manual mode, the front panel remains on the screen until the user presses the *Quit* button.

Figure 3.5 shows the block diagram of power_up.vi. This VI has 12 subVIs, each one of which initiates one instrument and returns the results. As it was mentioned earlier, the initialization routine is different for each instrument and depends on the instrument type and complexity of the driver. This thesis does not go further into the details of each driver since these drivers have been designed by other members of the ATF team. Figures 3.6, 3.7, and 3.8 show the block diagram of three of the subVIs as examples. Each of the subVIs uses the corresponding driver and translates the reported responses.

Figure 3.6 shows the block diagram of the TSI8150.vi. This VI calls the driver for the TSI8150 Test System Interface and runs function number 7 which is the initialization and self-test. If the event code is

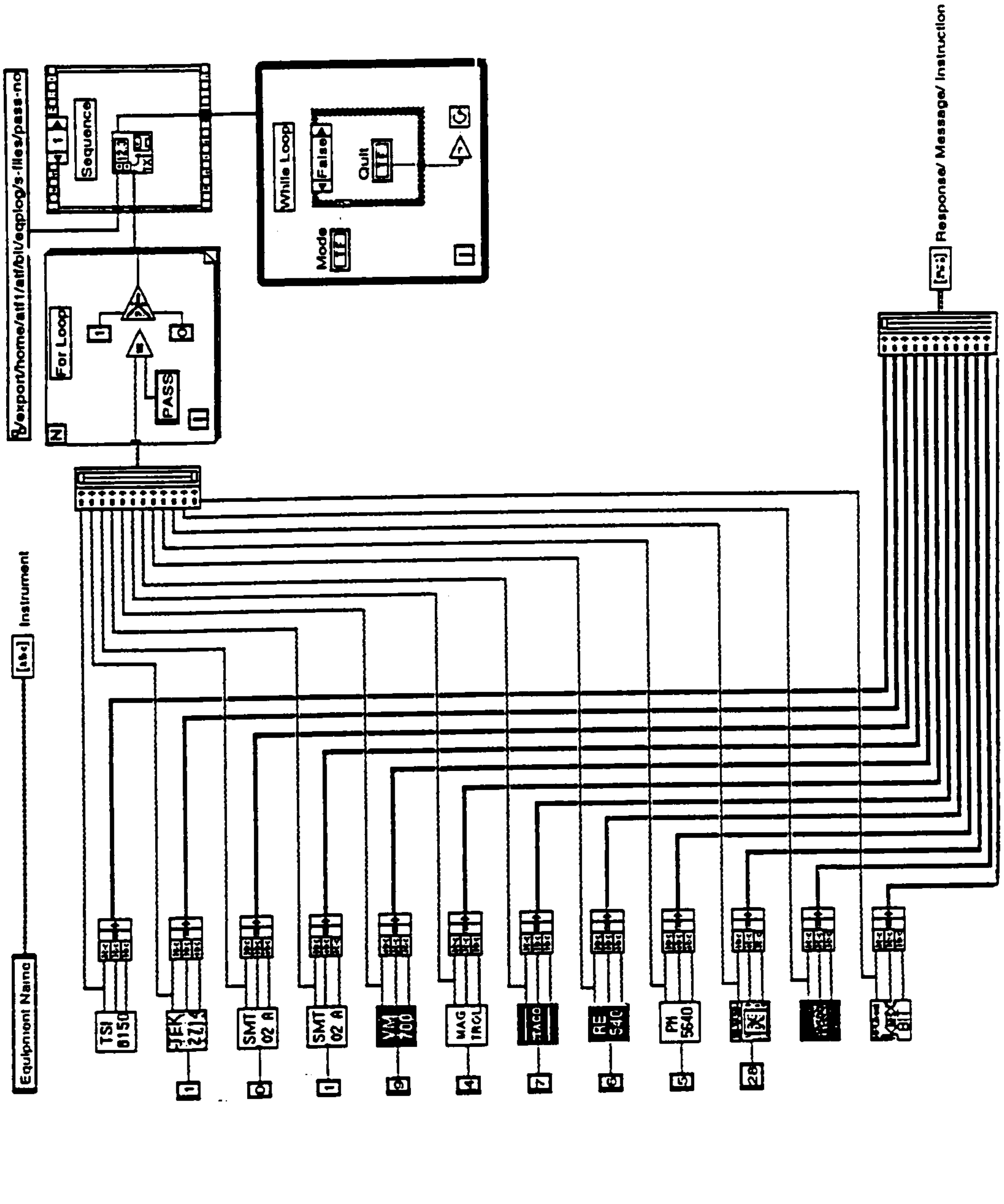

Figure 3.5 Block diagram of Power_up.vi

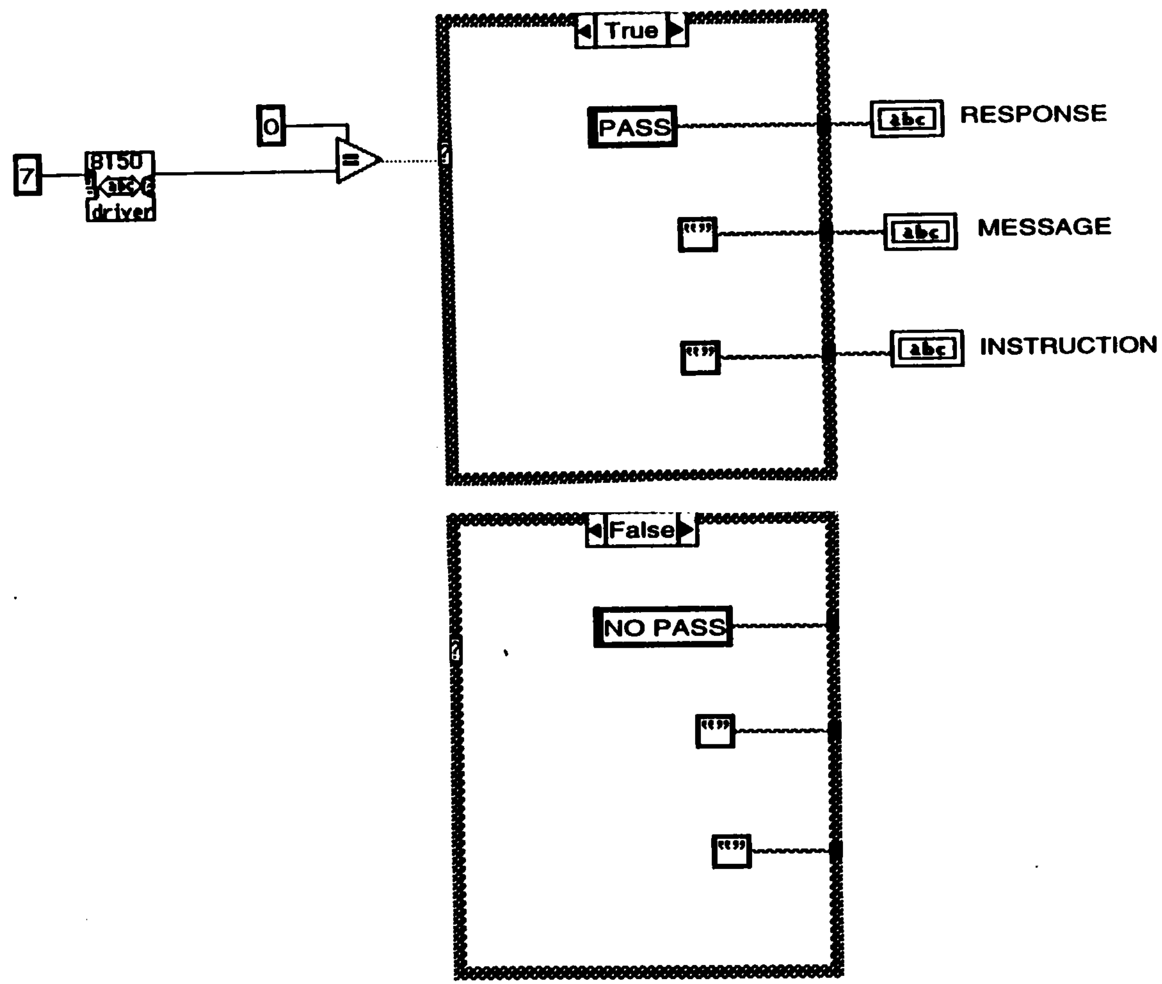

Figure 3.6 Block diagram of *TSI8150.vi*

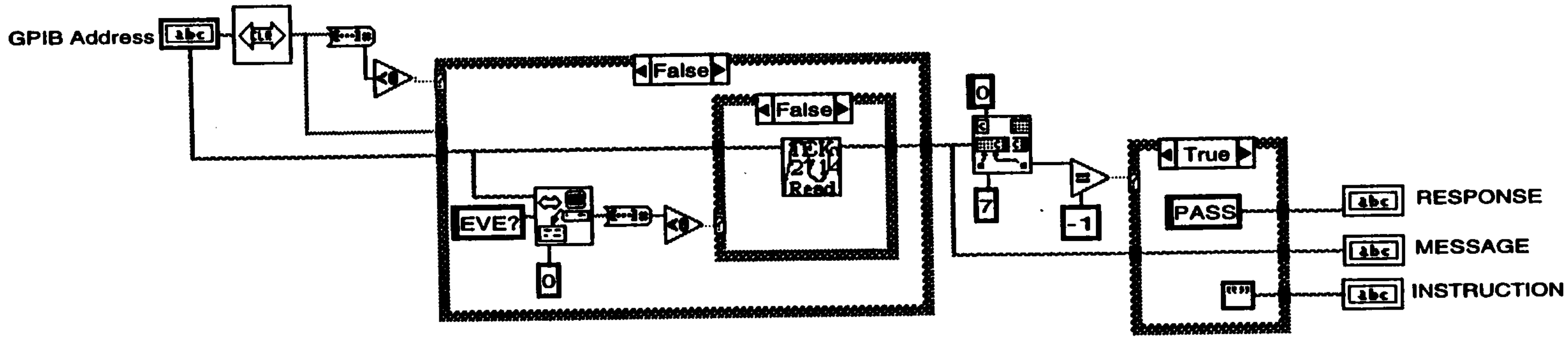

Figure 3.7 Block diagram of *TEK2714.vi*

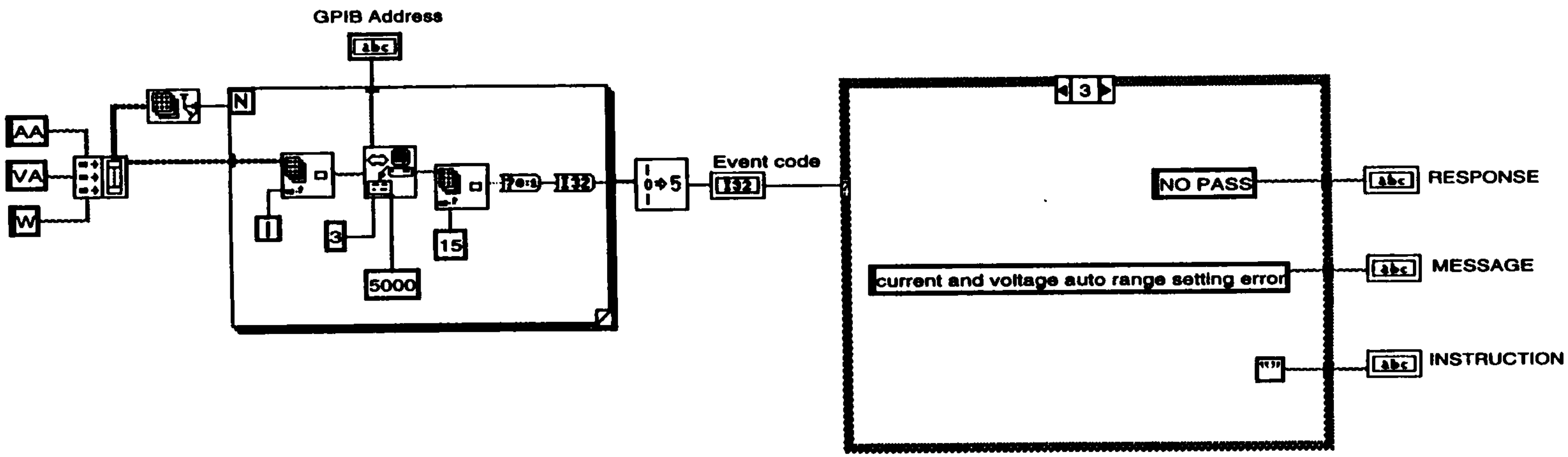

Figure 3.8 Block diagram of *Magtrol.vi*

not equal to zero, it means an error has occurred and TSI8150 has not passed the self-test. In this case TSI8150.vi reports NO PASS and a message which has been retrieved from the *error-out* cluster of the driver. TSI8150 driver does not provide any instructions so the instruction string remains empty. If the TSI8150 passes the self-test the event code will be zero and TSI8150.vi will report PASS.

Figure 3.7 shows the block diagram of tek2714.vi as an example of those instruments whose driver does not have an initialization routine.

This VI returns the spectrum analyzer to a known state, clears any prompts, and terminates any measurement in progress by clearing the GPIB interface. It then reads the code for the last event. The spectrum analyzer is ready for use if the code is equal to -1. The only information that this VI returns to the power-up.vi is the PASS or NO PASS response.

Figure 3.8 shows the block diagram of magtrol.vi. This VI performs the function of initialization for the MAGTROL power analyzer and reports the errors.

Other subVIs of the Power-up.vi are very similar to one of these three examples. Power-up.vi receives the results from all of its subVIs and populates the array of clusters, response/message/instructions.

It also updates the array of the instrument names from a global variable that keeps them. Finally, this VI builds a binary array which contains zero if the corresponding instrument in the equipment name global variable has not passed its power-up test. Otherwise, it contains a one. Then the VI deletes the previous results and saves the current results in a spread sheet file called PASS-NO.

The while loop in the block diagram keeps running in the manual mode until the user presses the *Quit* button. Other tests and VIs receive information on the status of each instrument by reading the PASS-NO file.

3.2.2 Carrier_level.vi

Figure 3.9 shows the front panel of the Carrier_level.vi. The VI has two modes of operation. In the automatic mode, the VI performs the visual and aural carrier level measurements for all the channels and saves the results. In the manual mode, the VI waits for the user to specify the channels and to press the *Run* button. Then, it performs the carrier level measurements for the specified channels and waits for the user to press the *Quit* button. The user can avoid any measurement by just pressing the *Cancel* button. If the user

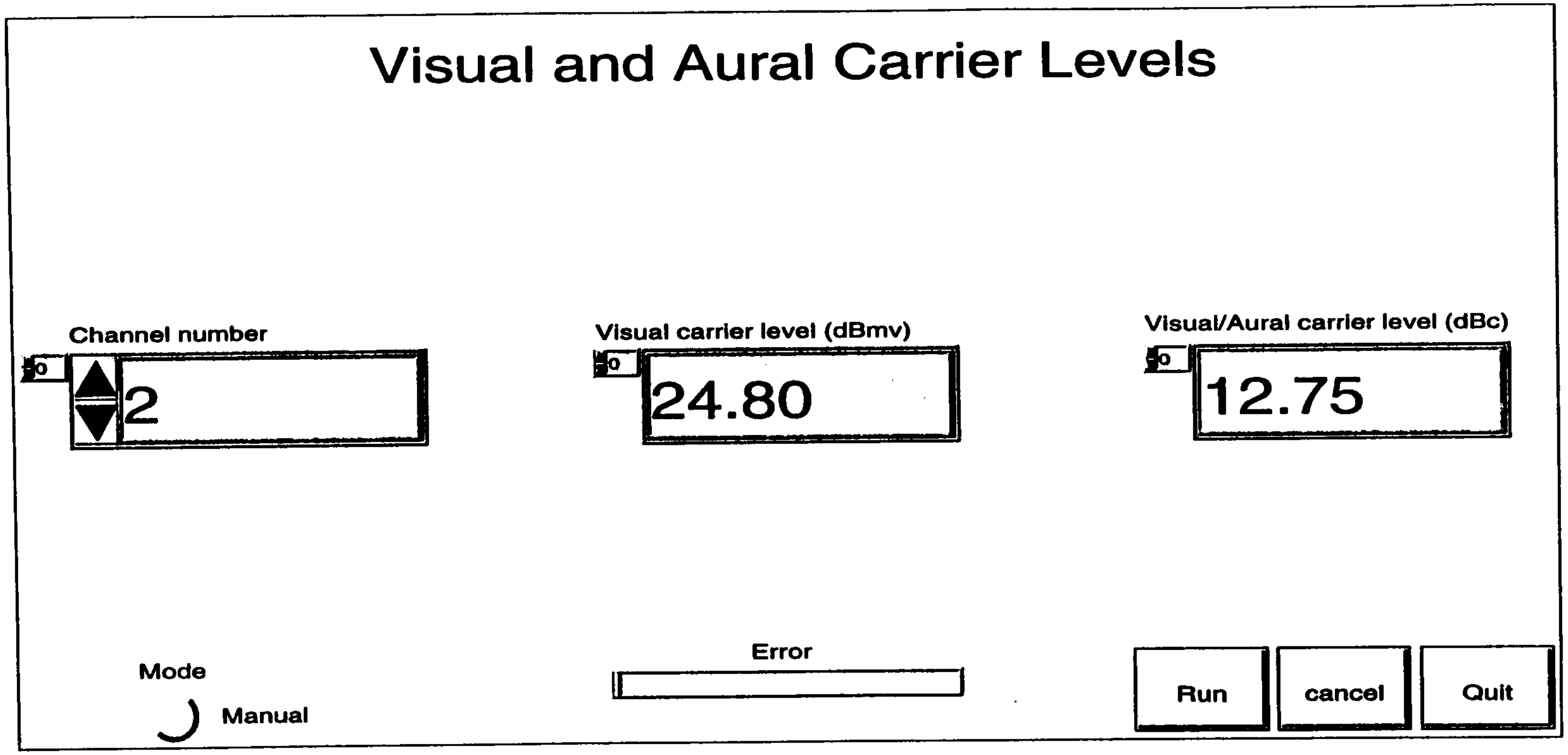

Figure 3.9 Front panel of *Carrier_level.vi*

selects an invalid channel number, an error message will appear inside the error box.

Figure 3.10 shows the block diagram of the VI. There are three main case structures where the middle one does the actual measurement and the two others determine the situation for canceling or quitting the measurement.

To perform the carrier level measurements, this VI first sets the TSI8150 to the ATF default configuration, which means all attenuators are fully attenuated and all switches are set to their default position. Then it uses the driver for the PM5640 (NTSC video test signal generator) to generate a 100 IRE flat field video signal.

Subsequently, the VI checks the channel numbers and compares them to the contents of the channel number global variable to make sure all specified channels point to a valid channel. At this point the VI starts the measurement sequence. In sequence zero, it routes the PM5640 video output to the proper modulator for each channel and sets the attenuation level to zero. In sequence one, the spectrum analyzer is set to the appropriate channel. In sequence two, a request for performing carrier level measurements is sent to the spectrum analyzer and the result is read. The rest of this vi finds the visual carrier level and Visual/Aural carrier ratio

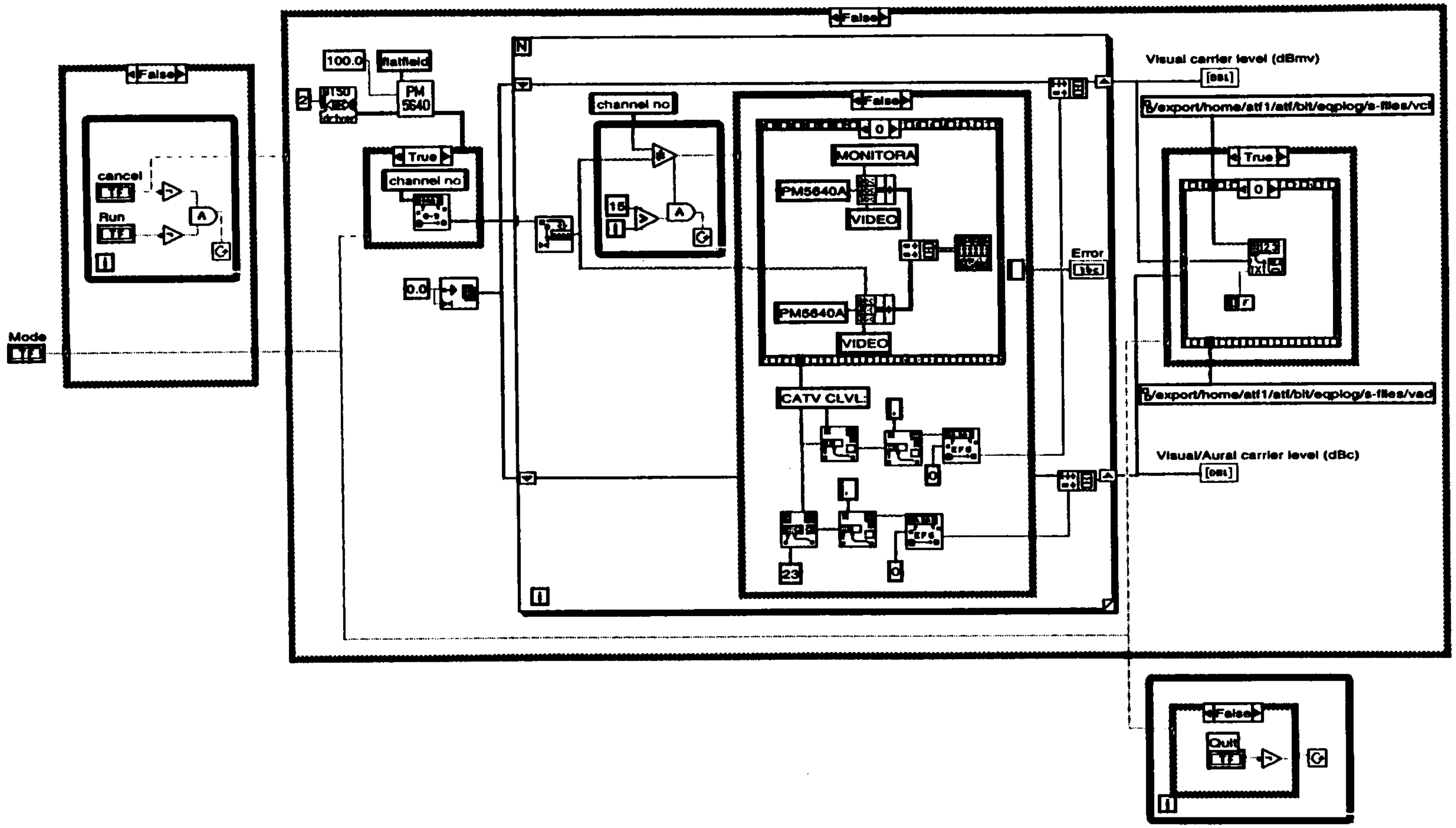

Figure 3.10 Block diagram of *Carrier_level.vi*

measurement results in the 2714 response and saves them in the vcl and vad spreadsheet files for future reference.

3.2.3 Modulation.vi

This VI works similar to the Carrier_level.vi. Figure 3.11 shows the front panel and Figure 3.12 shows the block diagram of this VI. The only difference is that this VI sends a different measurement request to the spectrum analyzer and saves the results in a spread sheet file called **mod.**

3.2.4 Deviation.vi

The front panel of this VI is shown in Figure 3.13 and the block diagram is in Figure 3.14. Compared with the last two VIs, this measurement needs some additional settings. After setting the TSI8150 to the ATF default configuration, the SMT02 driver is used to generate an audio signal at 1kHz frequency with one volt amplitude. Then the PM5640 generates a 100 IRE flat field video signal. After that, the duration for the aural deviation test interval on the TEK2714 is set to one minute.

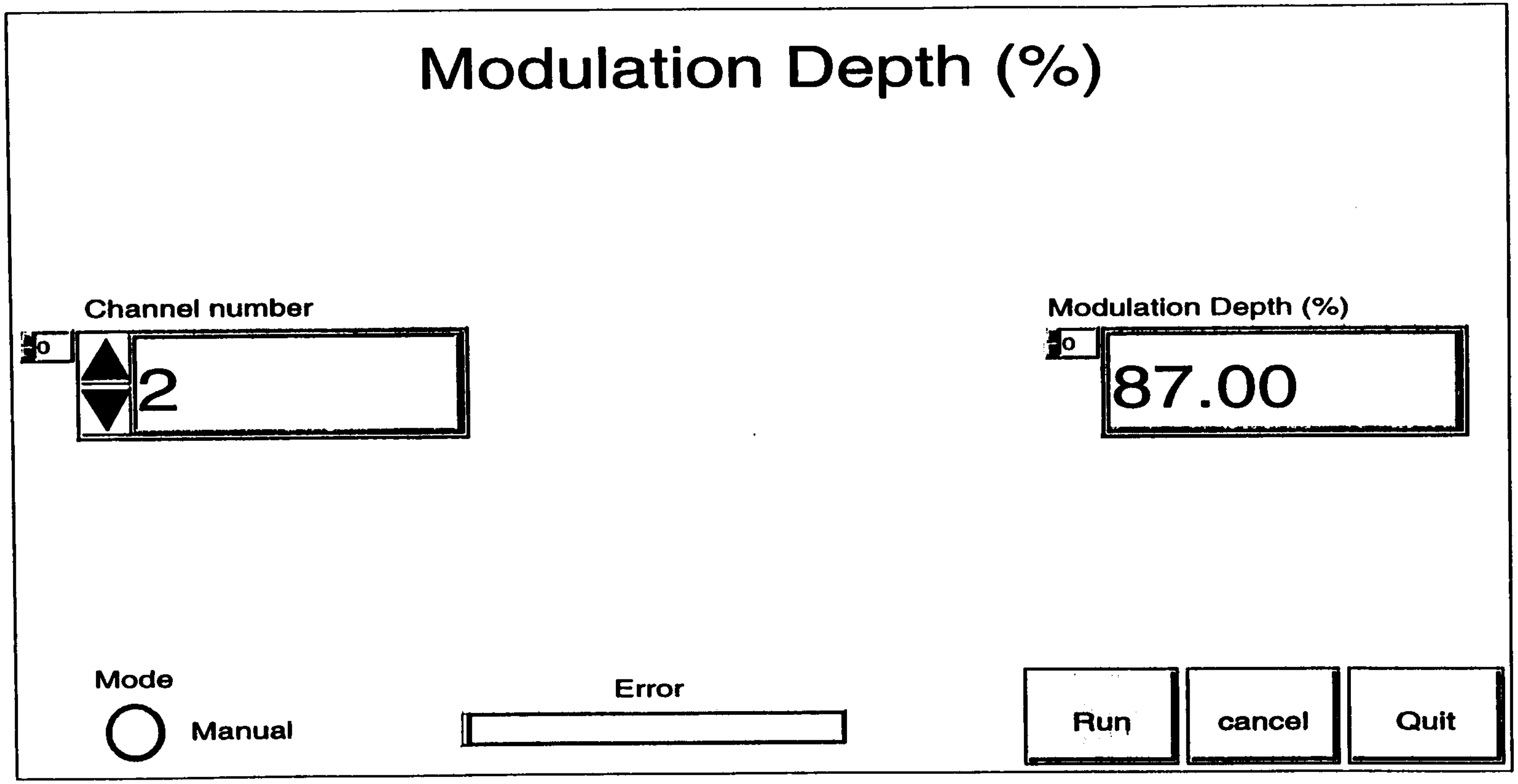

Figure 3.11 Front panel of *Modulation.vi*

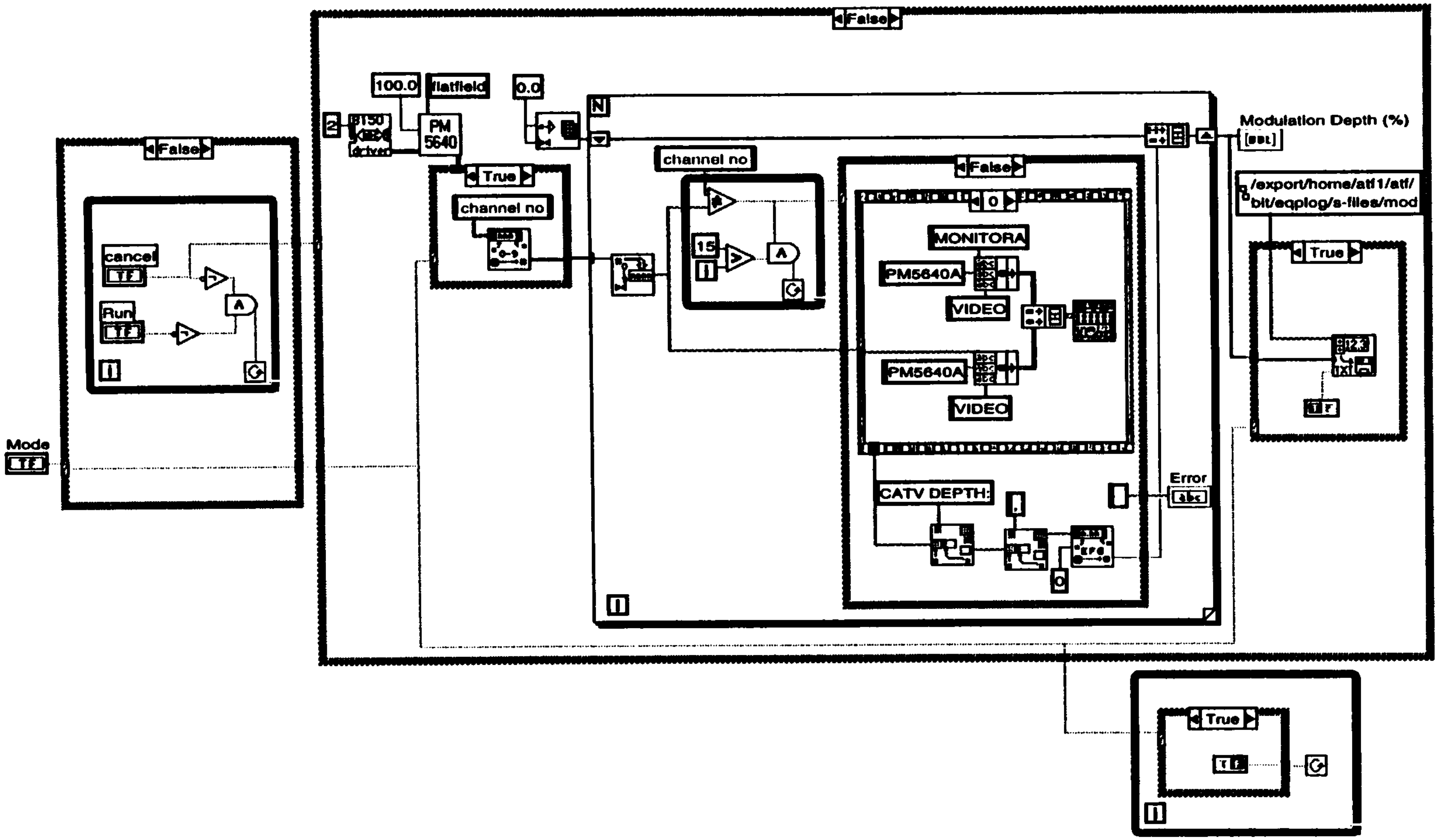

Figure 3.12 Block diagram of *Modulation.vi*

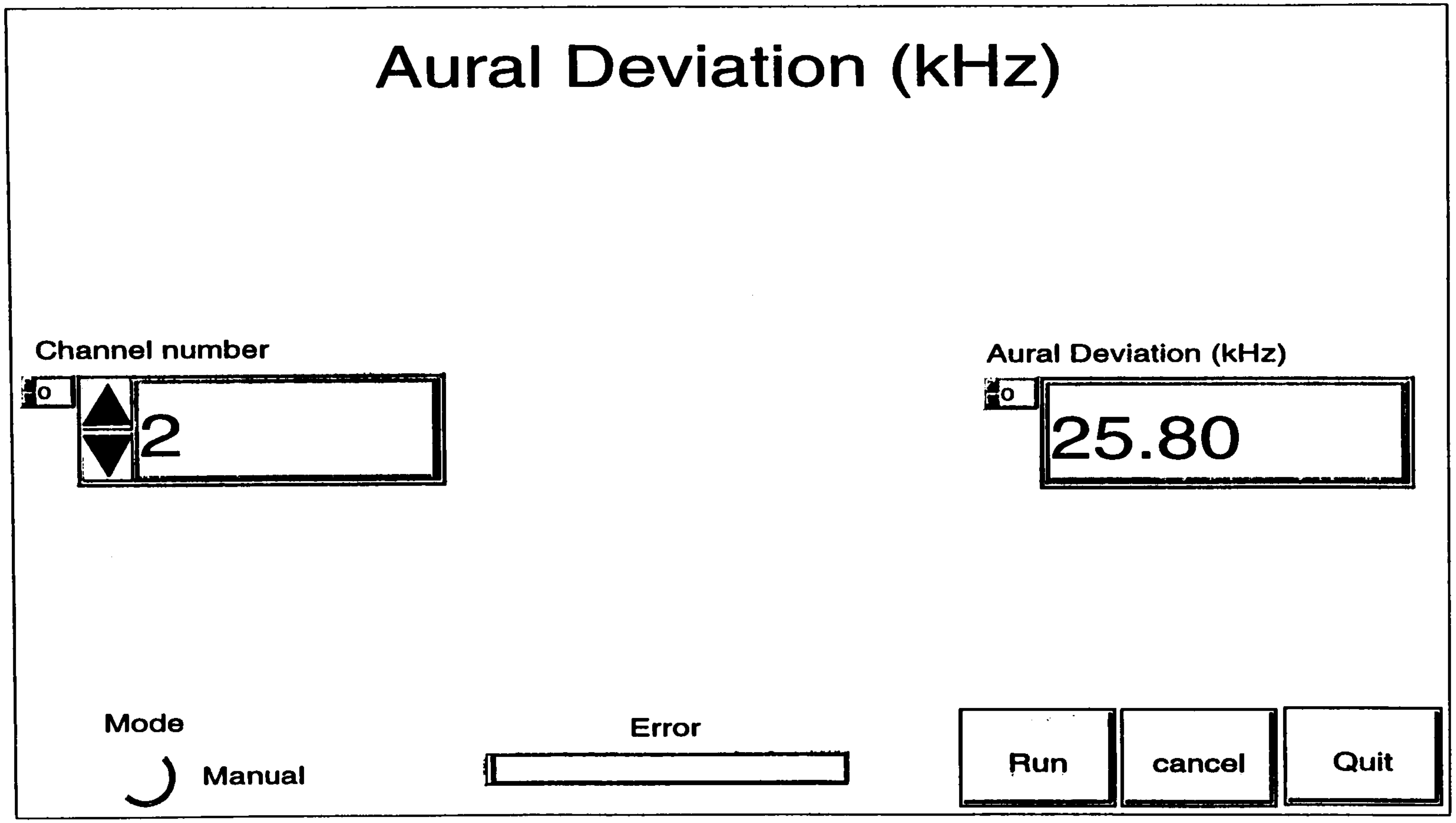

Figure 3.13 Front panel of *Deviation.vi*

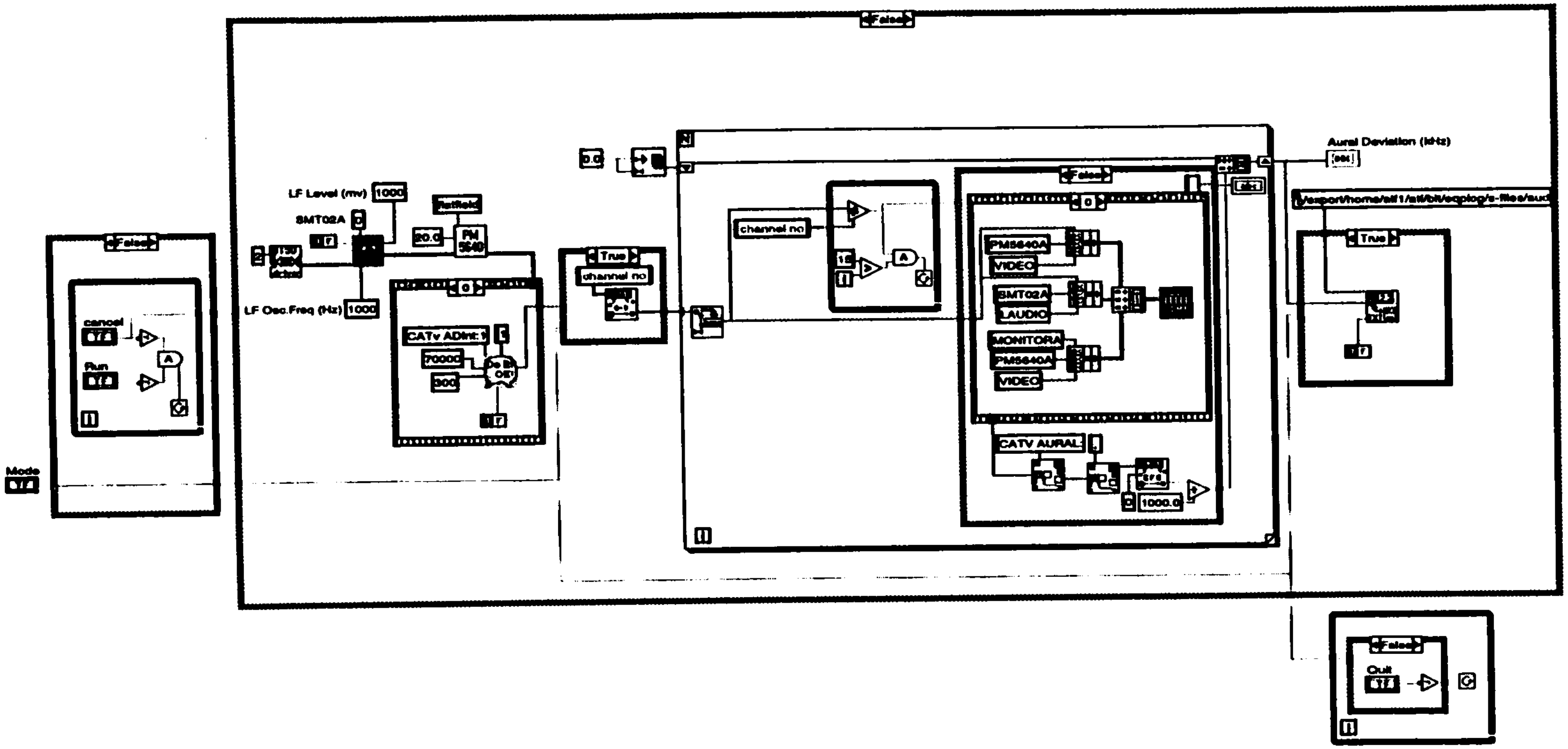

Figure 3.14 Block diagram of *Deviation.vi*

The rest of this VI is similar to the Carrier_level.vi and Modulation.vi except that a 10-second delay is needed in sequence 3, and a different measurement request is sent to the spectrum analyzer. The result is also saved in a spread sheet file called aud.

3.2.5 Level_table.vi

The test technicians may choose to perform a test in one of three different testing areas. Inside each area there are several RF outlets. They need to know the exact signal level at each outlet. Current configuration of testing areas results in different paths for the signal from the modulator to the RF outlets, and each path has its own fixed loss. These losses have been measured manually and are recorded in a global variable called fixed_losses.vi.

This VI runs the Carrier_level.vi to measure the visual carrier level and subtracts the fixed losses for each path to populate the level table which contains the signal level at the end of each path. The result is also saved in a spread sheet file(RF level) to be used later during different television performance tests.

Figures 3.15 and 3.16 show the front panel and the block diagram of Level_table.vi. In the automatic mode, the VI does its

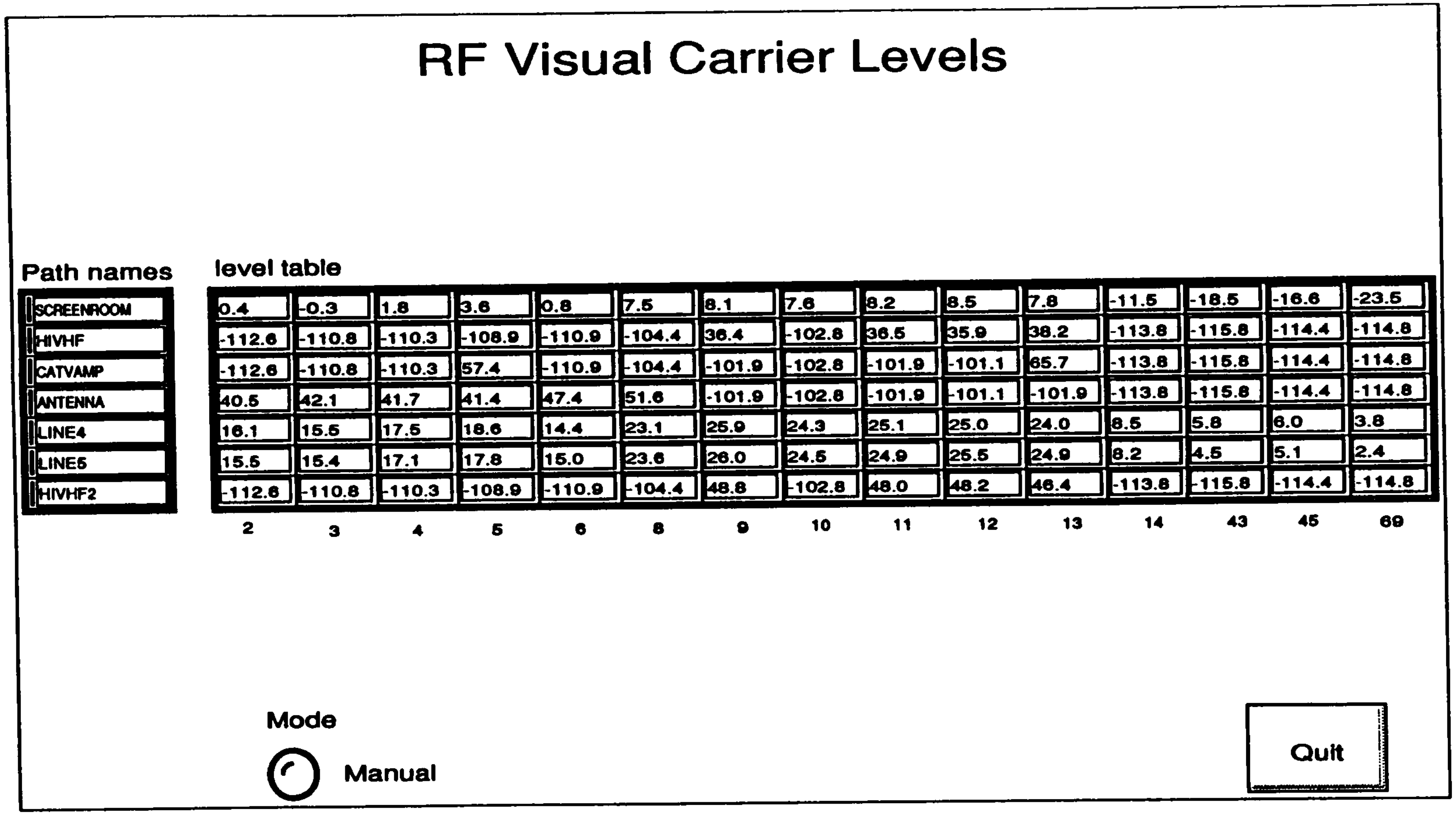

Figure 3.15 Front panel of *Level_table.vi*

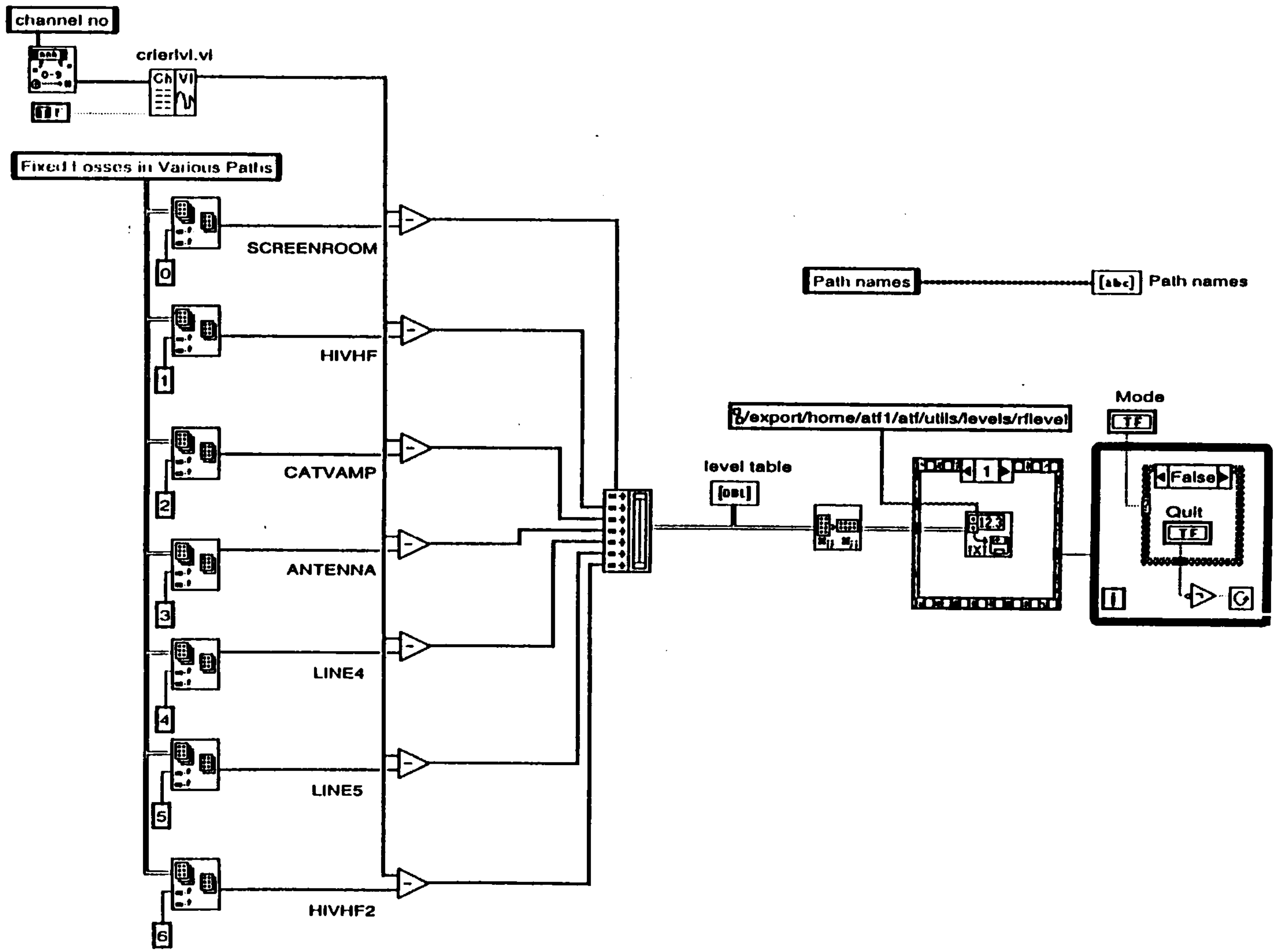

Figure 3.16 Block diagram of Level_table.vi

job and quits. In the manual mode, the front panel remains on the screen until the user presses the *Quit* button.

3.2.6 Check_limits.vi

This VI starts running each time a user presses any button on the Top Menu screen of the ATF system. Figure 3.17 shows the block diagram of this VI. It first reads the expected value of the modulator's parameters from a global variable. Then, it reads the results of the last measurements of the visual and aural carrier levels, modulation depth, and aural deviation from the appropriate spreadsheet file. Then, if the measured value is outside the specified range for any parameter and any channel, an error line is added to the error message. At the end, it displays a dialog box that contains the error message. The user has the choice to print the error message or to cancel it.

3.2.7 Log_menu.vi

This VI, as its front panel in Figure 3.18 shows, lets the user view the measurement log for any of the RF signal parameters. It has four

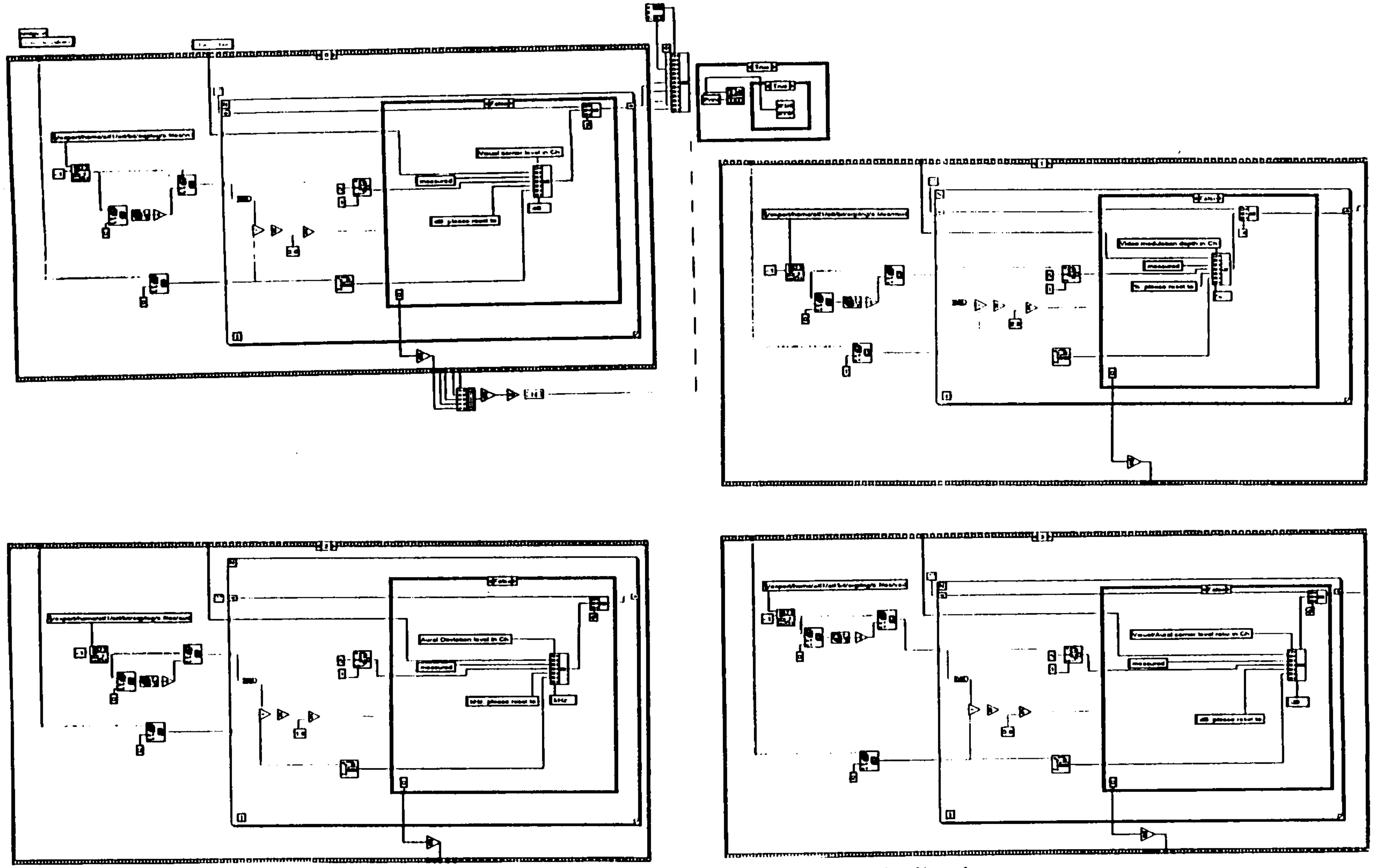

Figure 3.17 Block diagram of Check_limits.vi

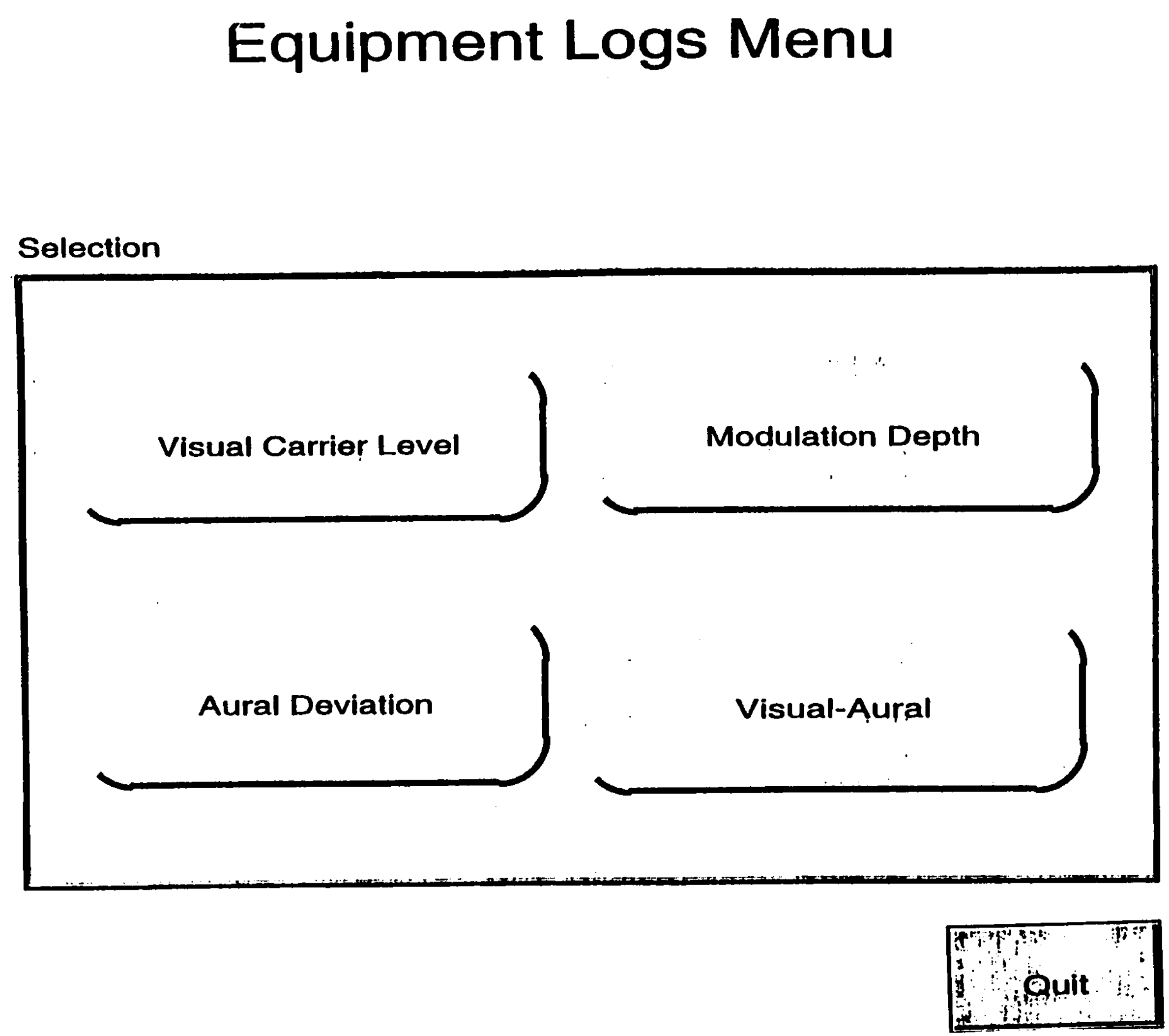

Figure 3.18 Front panel of Log_menu.vi

subVIs, view-vcl, view-modulation, view-deviation, and view-V/A ratio. View-vcl reads the last 30 measurements of the visual carrier level from the vcl file and displays a graph of them for all the channels. It also displays another graph for the visual carrier level for the screen room or RF free room, which is of great importance to the users. The block diagram and front panel of **view_vcl.vi** are shown in Figures 3.19 and 3.20. The other three subVIs are very similar to this one and display the measurement log for their corresponding parameters. Their front panels are shown in Figures 3.21, 3.22, and 3.23.

3.2.8 Measure_menu.vi

This VI lets the user to perform one of the following measurements: carrier levels, modulation depth, or aural deviation. Figure 3.24 illustrates the front panel of this VI.

After completing the BIT software, a new driver for the Minolta CA-100 CRT Color Analyzer was developed and will be discussed in the next chapter.

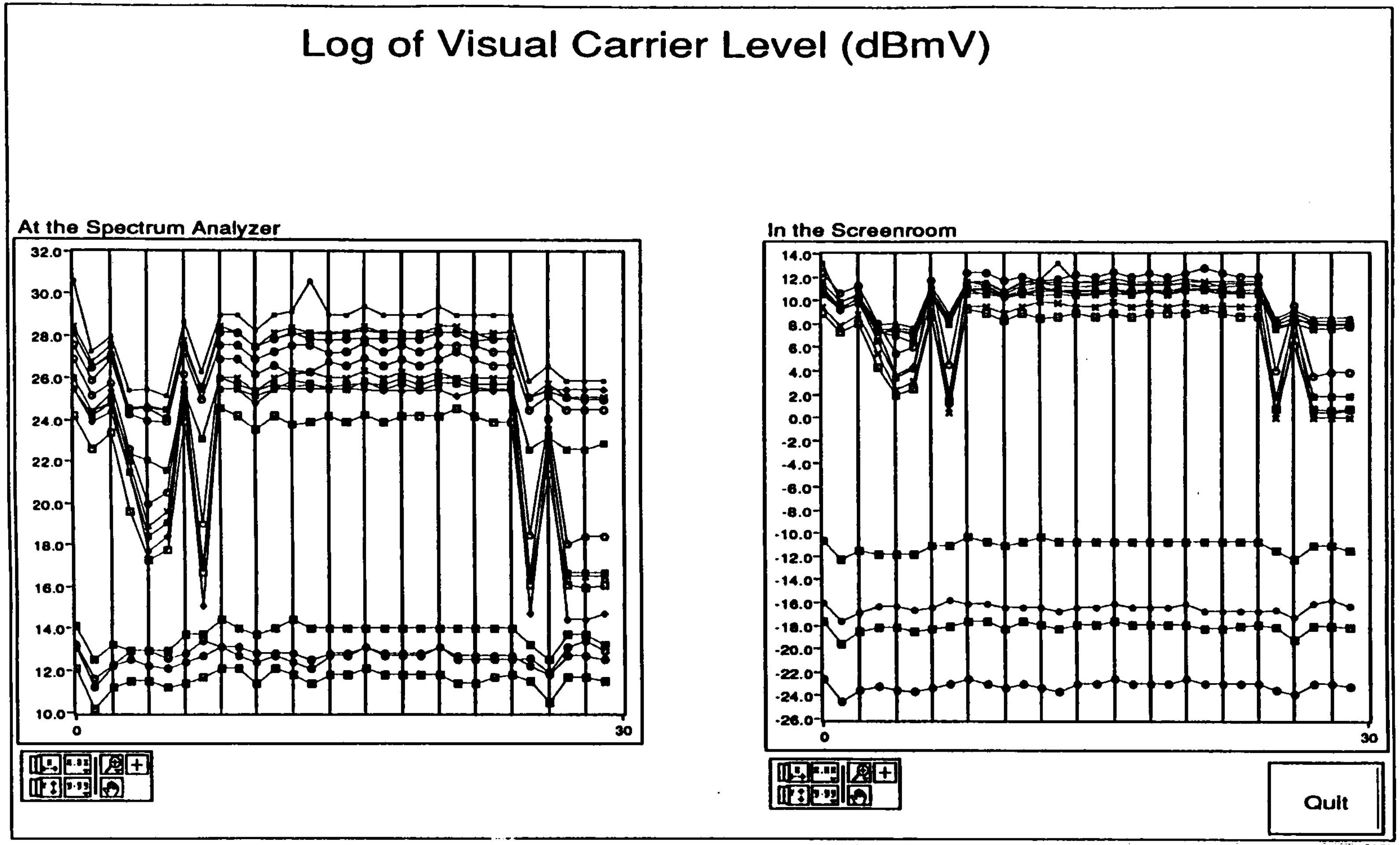

Figure 3.19 Front panel of View_vcl.vi

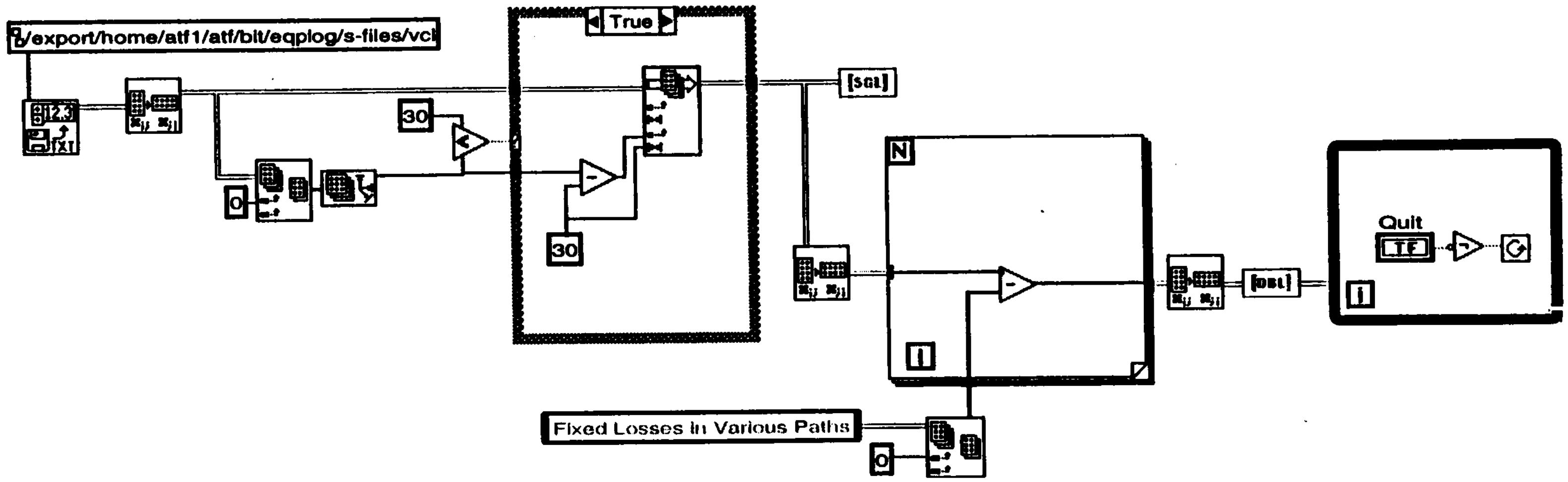

Figure 3.20 Block diagram of *View_vcl.vi*

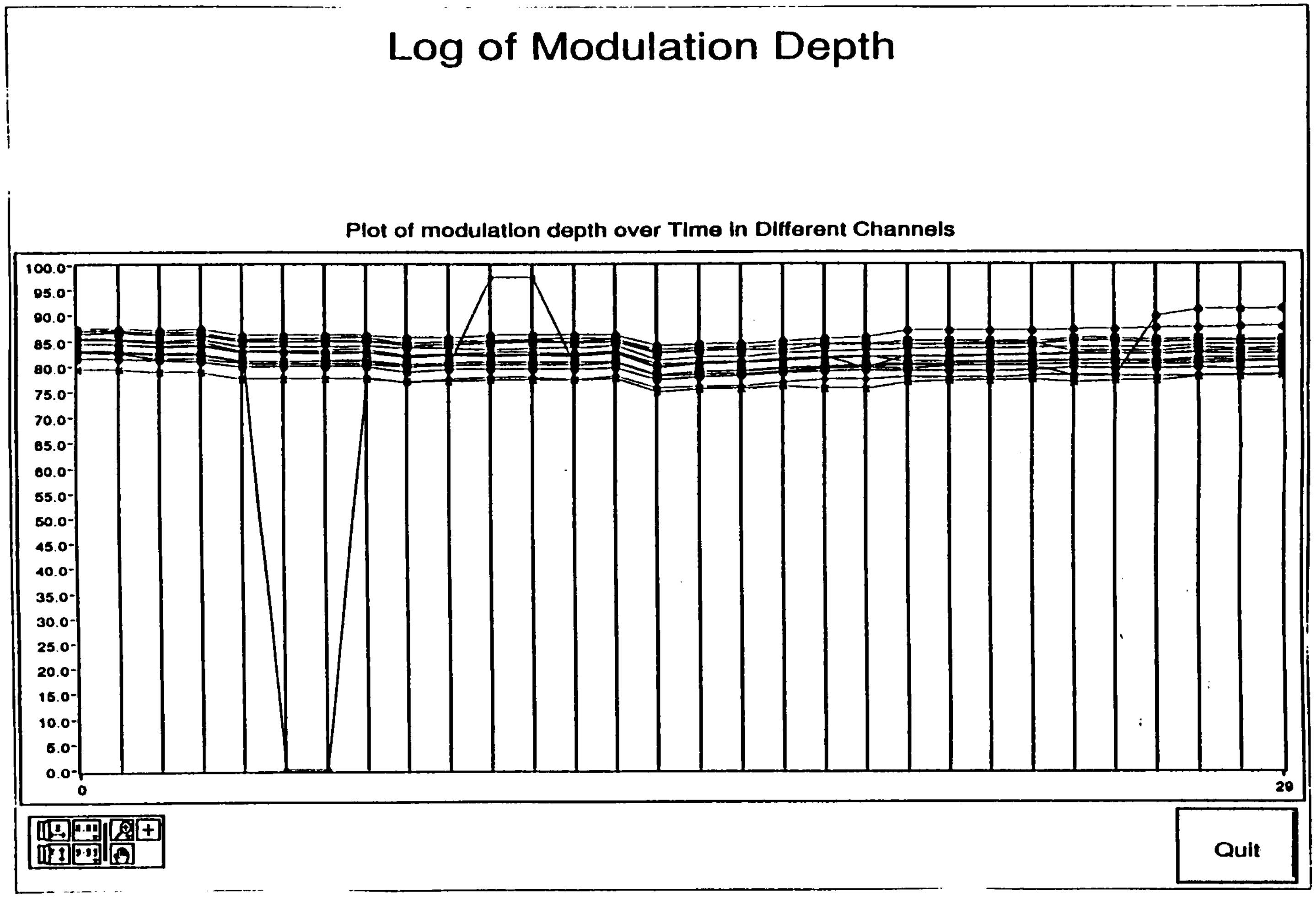

Figure 3.21 Front panel of View_modulation.vi

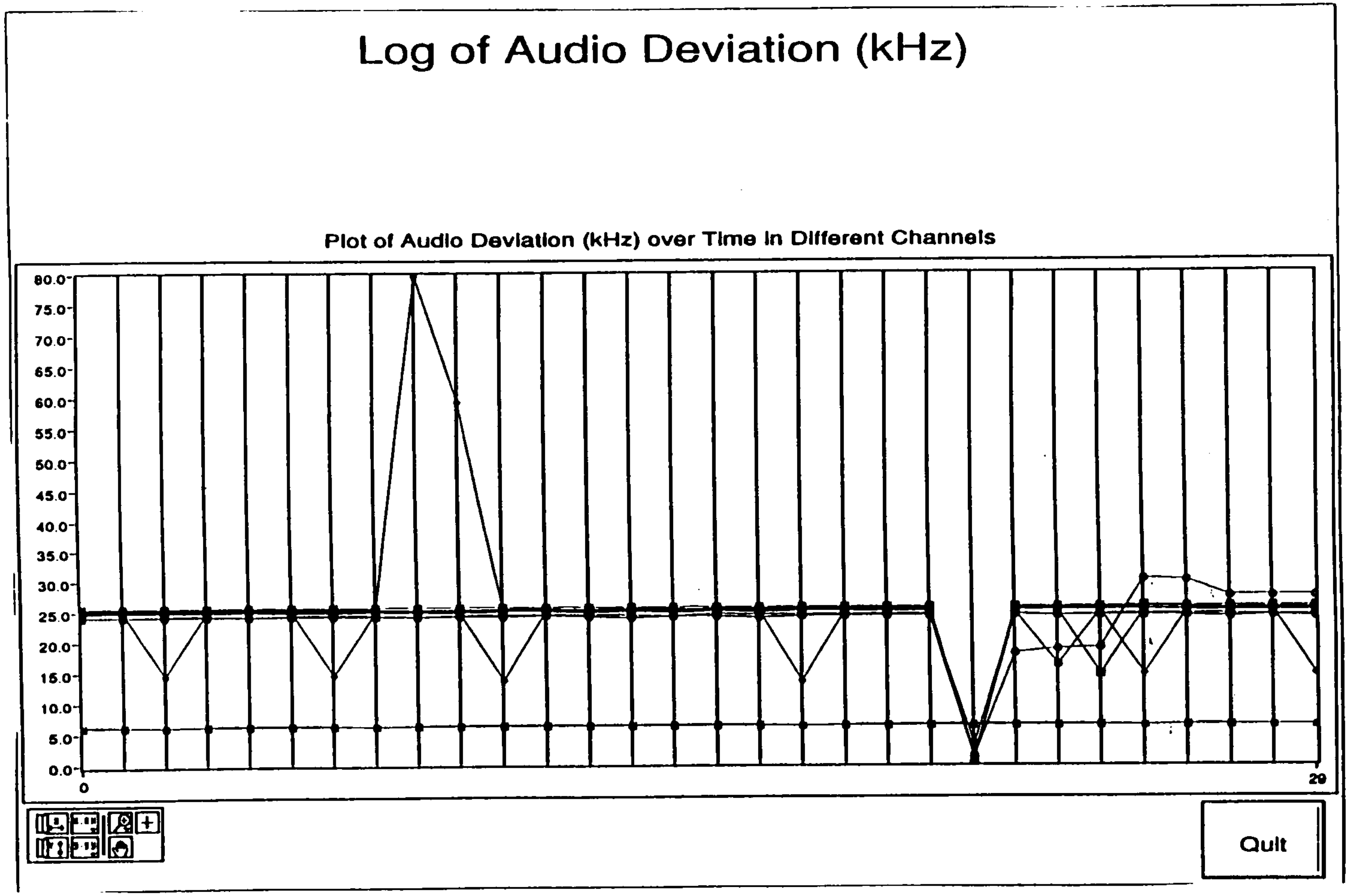

Figure 3.22 Front panel of View_deviation.vi

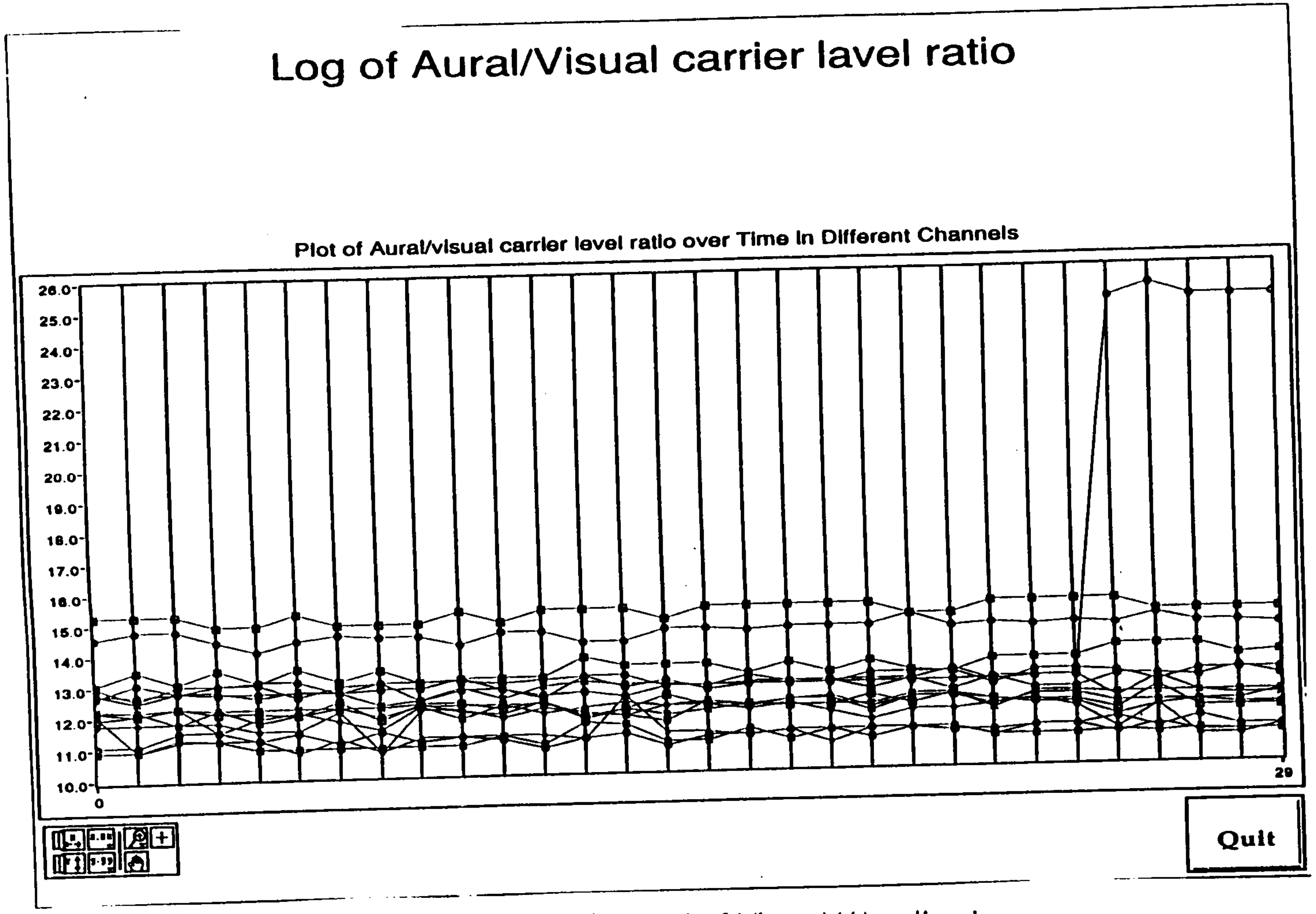

Figure 3.23 Front panel of View_V/A ratio.vi

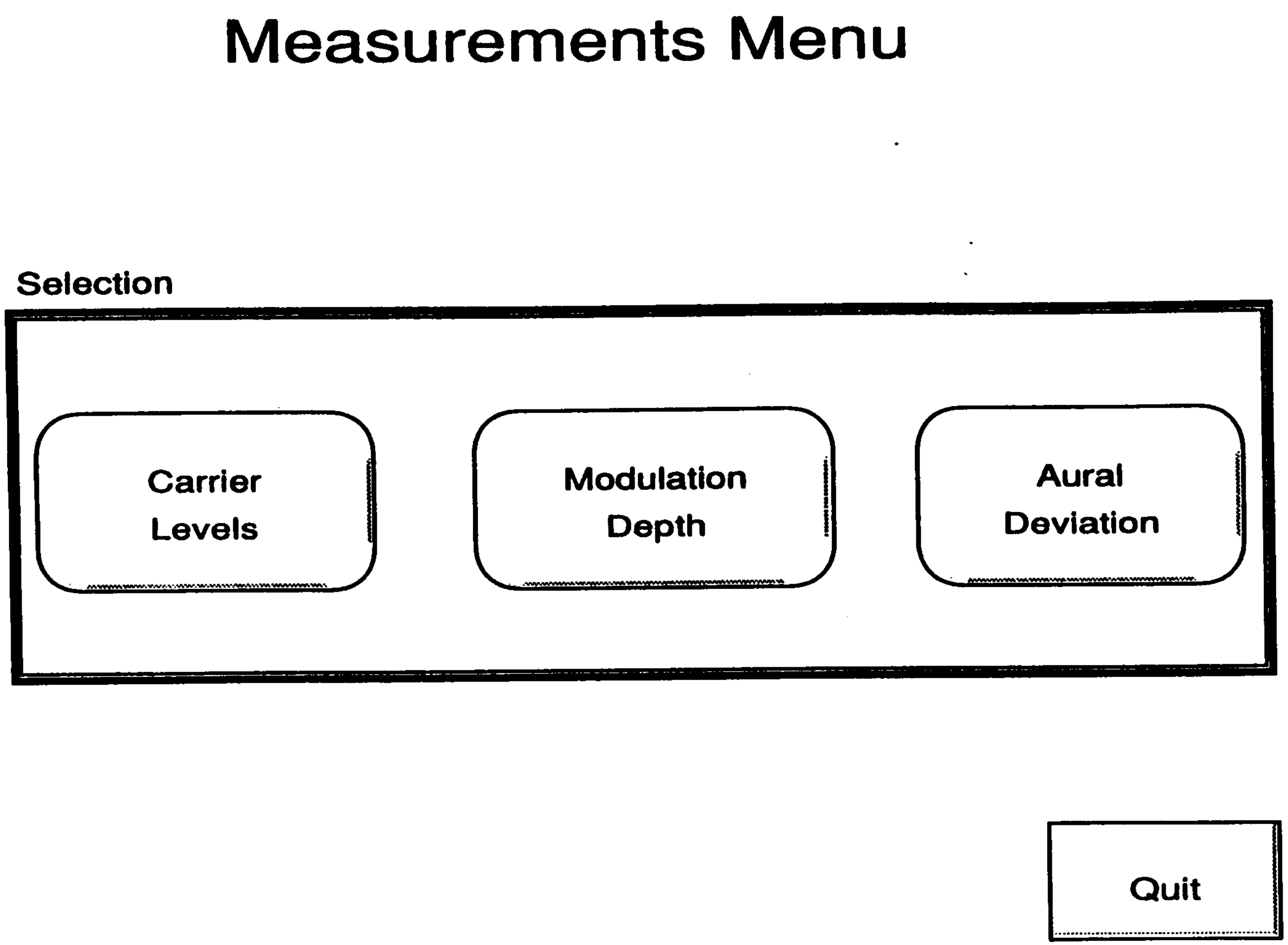

Figure 3.24 Front panel of *Measure_menu.vi*

CHAPTER 4

INSTRUMENT DRIVER

In order to automate the television tests, it is necessary to control all the instruments involved in each test remotely. LabVIEW VIs must be developed to communicate with each instrument, send them different commands, and receive their responses. These VIs are called instrument drivers. The writer has developed drivers for the MINOLTA CA-100 CRT Color Analyzer and the Tektronix VM700A Video Measurement set. Each driver controls its respective instrument from the Sun SPARCstation 10. The driver for the MINOLTA CA-100 will be discussed thoroughly in this chapter.

4.1 Measuring Principle

A CRT screen is equipped with phosphors to emit red, green, and blue light. When the electron beam inside the CRT strikes these phosphors, the phosphors emit their respective colors, and these colors are combined on the CRT screen to form an image.

In 1931, the International Commission on Illumination (known by the French initials CIE (Commission Internationale de l'Eclairage) defined a set of color-matching functions and a coordinate system that have remained the predominant international standard method of color specifying ever since. The CA-100 uses sensors filtered to closely match the CIE 1931 color-matching functions to measure the energy of the light emitted by the CRT phosphors. The measured values are then displayed as x, y, Y, or T, duv, Y values. Figure 4.1 illustrates the relative sensitivity of the CA-100 in comparison with the CIE 1931 color-matching functions.

Measurements are performed as follows:

1. The red, green, and blue light emitted by the CRT phosphors entering the receptor area of the measuring probe passes through spectral-response correction filters and strikes the light sensors, which convert the light into currents proportional to the intensity of the light. These currents are then converted into proportional voltages (output values X_2, Y, and Z).
2. At the same time, a temperature sensor outputs a current proportional to the temperature of the measuring probe. This current is then converted into a proportional voltage (output value T).

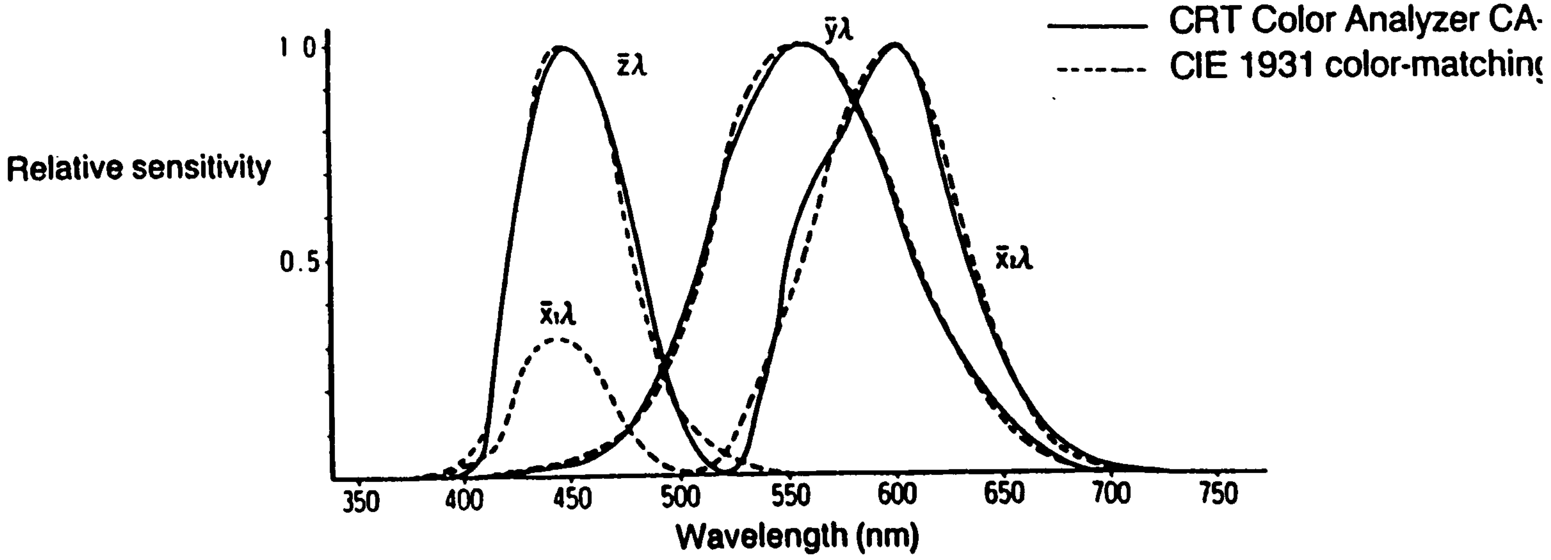

Figure 4.1 Relative sensitivity of the CA-100 in comparison to CIE color matching standards [6]

3. The voltages obtained in step 1 and step 2 are passed through analog-to-digital converters and are changed according to the selected SYNC mode to operate at the proper time for measurement.
4. The resulting digital values are sent to the CPU of the main unit. The CPU performs calculations according to the present measuring conditions (display mode, SYNC mode, etc.) set using the keys and switches.
5. The results of the calculations are shown in the display and output via the GPIB interface board.

4.1.1 xyY display mode

When the xyY display mode is set on the main unit, the digital displays show the x, and y chromaticity coordinates of CIE color space, and luminance Y. The values are calculated according to the following formulas:

$$x = X / (X+Y+Z)$$

$$y = Y / (X+Y+Z)$$

$$Y = Y$$

Where X is determined from the measured X_2 value and Z,

$X = 0.1672Z + X_2$

4.1.2 TduvY mode

When TduvY display mode is set on the main unit, the digital displays show the correlated color temperature (T), color difference from blackbody locus (duv), and luminance (Y).

The color temperature of a light source is used to apply the general idea of color temperature to those colors that are close to but not exactly on the blackbody locus. The correlated color temperature is measured by determining the isotemperature line on which the color of the light source is positioned. As Figure 4.2 shows, isotemperature lines are straight lines for which all colors on the line appear visually equal. The correlated color temperature of any color on the isotemperature line is equal to the color temperature at the point where the isotemperature line intersects the blackbody locus.

Since all colors on an isotemperature line have the same correlated color temperature, it is also necessary to specify the difference from the blackbody locus (duv) to completely describe a color. A positive value of duv indicates a color which is above the

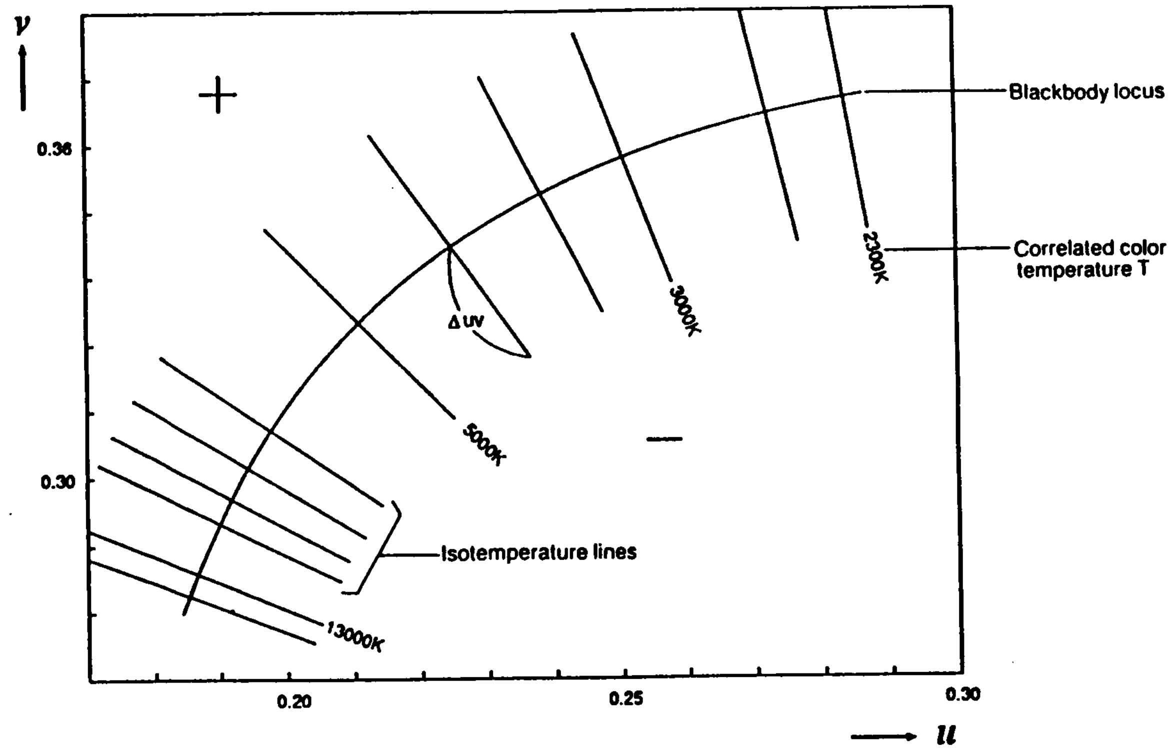

Figure 4.2 Relation between color temperature and duv [6]

blackbody locus, and a negative value indicates a color which is below the blackbody locus[6].

4.2 CA-100 functions

Figure 4.3 shows the front panel and measuring probe of the CA-100. Some of the switches are not used during the automated television tests. Those switches that are important for the ATF project are described below.

4.2.1 0-cal (zero calibration)

Zero calibration must be performed before any measurements can be taken after the POWER switch has been set to ON or after the Remote control mode has been initiated. Zero calibration determines the output of the measuring probe's receptor when no light is incident on the receptor, providing a reference point for measurement. Zero calibration must be repeated if the ambient temperature changes after zero calibration has been performed. Furthermore, when measuring CRTs of low luminance, zero

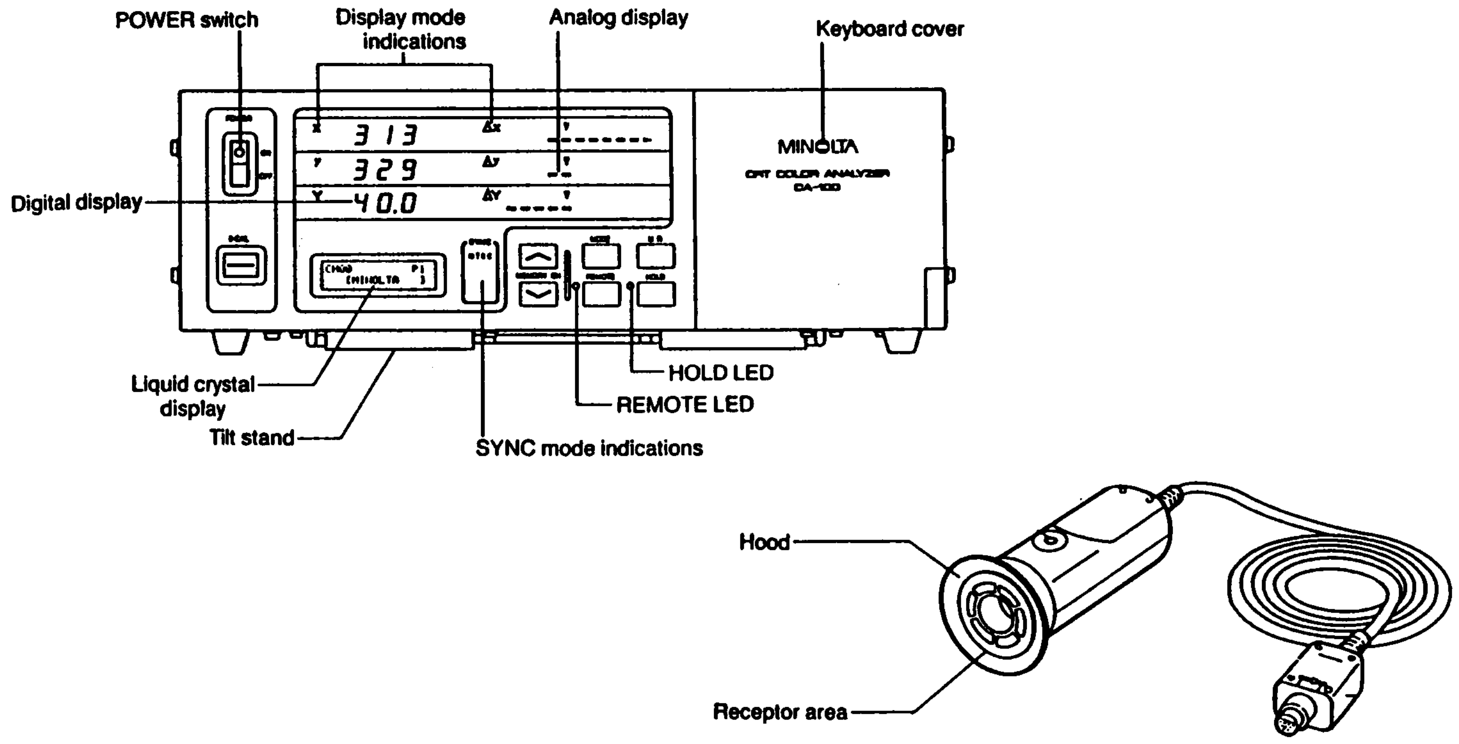

Figure 4.3 MINOLTA CA-100 CRT Color Analyzer [6]

calibration should be performed approximately once an hour to ensure accuracy.

4.2.2 SYNC

The SYNC switch selects the measurement synchronization mode to NTSC, PAL, EXT, or UNIV. The selected SYNC mode is one of the factors involved in determining the rate at which calculations and updating of displayed and output data can be performed. Other factors involved are the luminance of the CRT being measured, and the display mode.

4.2.3 Mode

CA-100 is equipped with two standard display modes. In the xyY mode, digital displays show chromaticity coordinates x and y and luminance Y. In the TduvY mode, digital displays show the correlated color temperature T, the difference from blackbody locus duv, and luminance Y.

4.2.4 The luminance-unit selector switch

This switch on the rear surface of the CA-100 selects the luminance unit to be cd/m^2 or fL.

4.2.5 Taking measurements

After all preparations have been made measurements can be taken by just placing the receptor area of the probe flat against the surface of the CRT to be measured. Measurements will be started immediately, and the measured data will be shown in the digital and analog displays according to the selected display mode.

4.3 CA -100 driver

The MINOLTA CA-100 driver lets the user initialize the CA-100 and to do the measurements in two standard modes. Figure 4.4 shows the front panel of the CA-100 driver. This VI has three inputs and four outputs. The inputs are,

1. *GPIB address* for CA-100

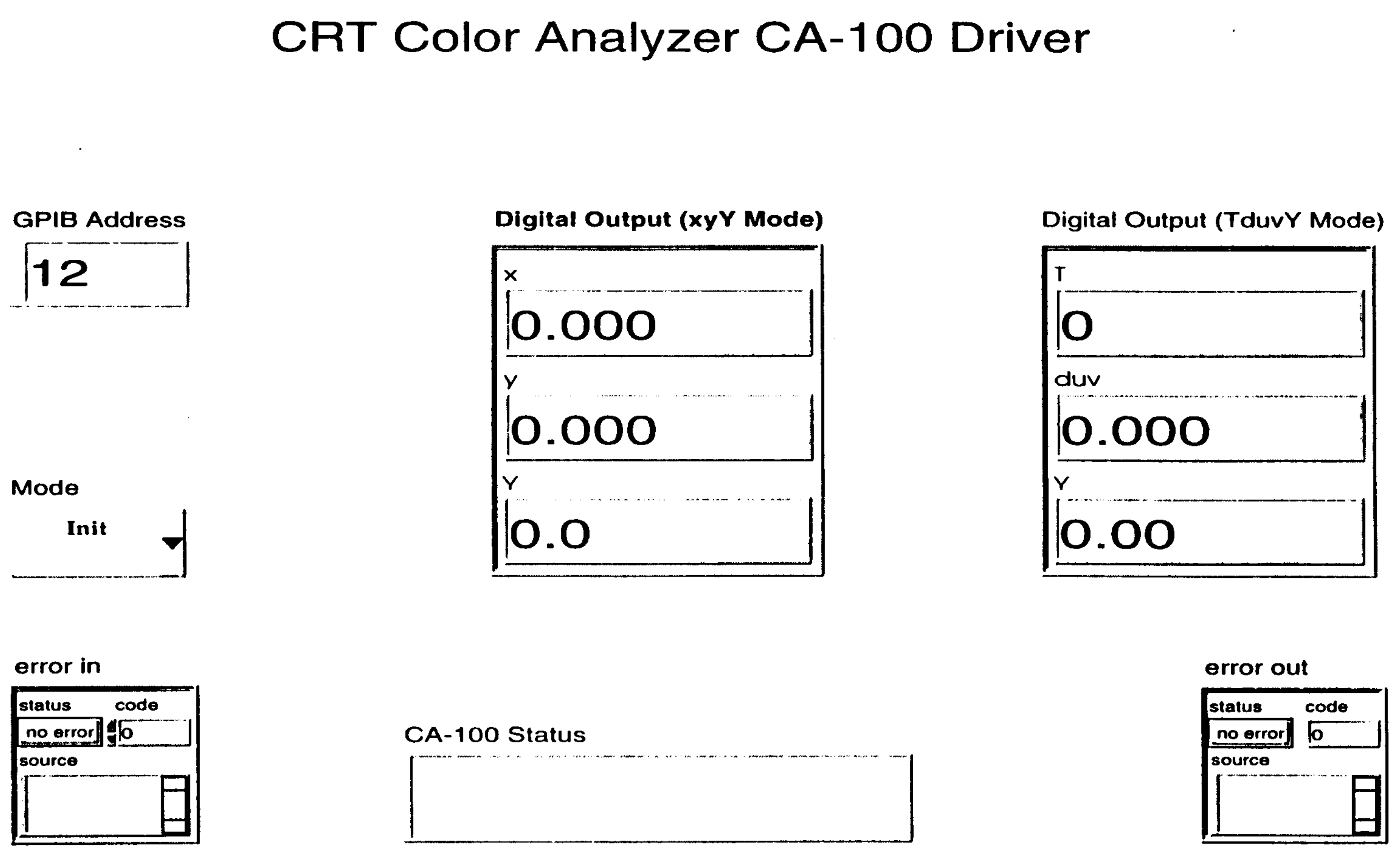

Figure 4.4 Front panel of the CA-100 driver

2. Measurement *mode* that can be *Init* mode, *xyY* mode, or *TduvY* mode, In the Init mode, the driver runs the initialization VI which is discussed in Section 4.3.1. In the other two modes, the driver performs the measurements and updates the appropriate digital output cluster.

3. *Error in*, a cluster that describes the error status before this VI executes, If *error in* indicates that an error has occurred before this VI was called, the CA-100 diver will not perform any function, and it will only pass the *error in* to the *error out* cluster. If no error has occurred, then this VI executes normally and sets its own error status in *error out* cluster. The *Error in* cluster has three elements: *Status*, *Code*, and *Source*. *Status* is TRUE if an error has occurred before this VI was called. If *Status* is TRUE, *Code* is a non-zero error code. *Source* is a string that describes the origin of the error, if any. Usually *Source* is the name of the VI in which the error has occurred.

Outputs of the CA-100 driver are,

1. *CA-100 status* that describes the present status of the CA-100
2. *Digital output (xyY mode)*, a cluster that contains the measurement data which are output by CA-100 in xyY mode

3. *Digital output (TduvY mode)*, a cluster that contains the measurement data, which are output by CA-100 in TduvY mode
4. *Error out* which describes the error status after this VI executes

Figure 4.5 shows the block diagram of the CA-100 driver. This VI first checks the *Status* of the *error in*, and if it is TRUE , this VI does nothing but pass the *error in* information to the *error out* cluster. If the *Status* of the *error in* is FALSE, one of the following cases may happen:

1. In *Init mode*, this VI calls the initialization VI, updates the *CA-100 status* string, and passes the *error in* cluster to the *error out*.
2. In the *xyY* mode, a pop-up message reminds the user to position the CA-100 probe in the center of the CRT screen. Then a command (M0) is sent to CA-100. If no GPIB error occurs, the CA-100 output is read. Then, the output is checked by the error handling VI. If it does not contain any error message, the measured values of the x and y chromaticity co-ordinates and luminance are extracted from the CA-100 output string.
3. In the *TduvY* mode, a sequence similar to that of the *xyY* mode is executed. The only differences are the measurement command,

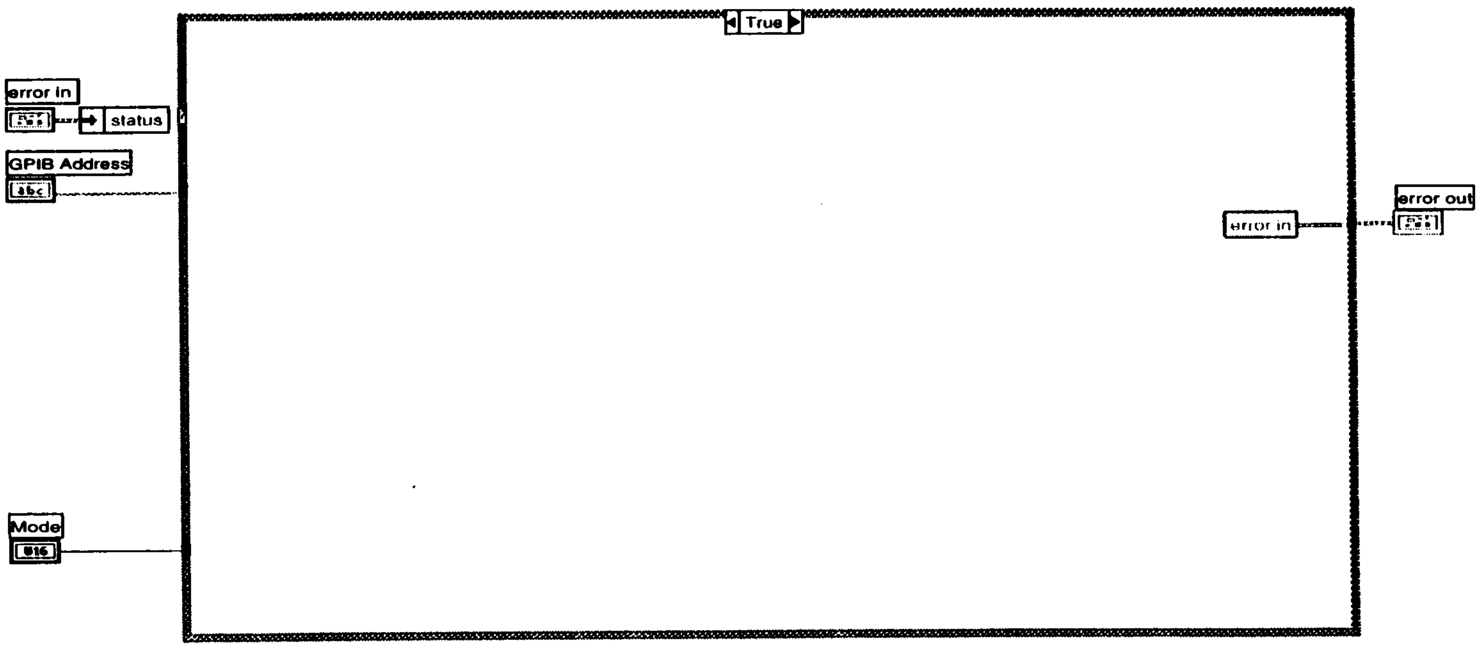

Figure 4.5 Block diagram of the CA-100 driver

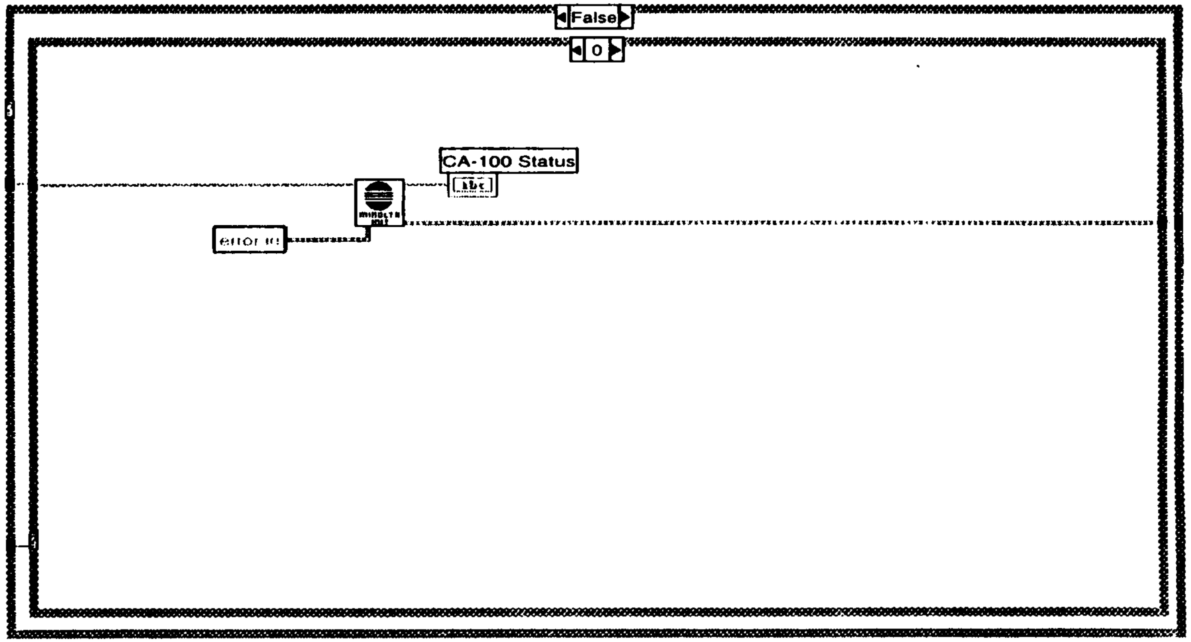

Figure 4.5 Continued

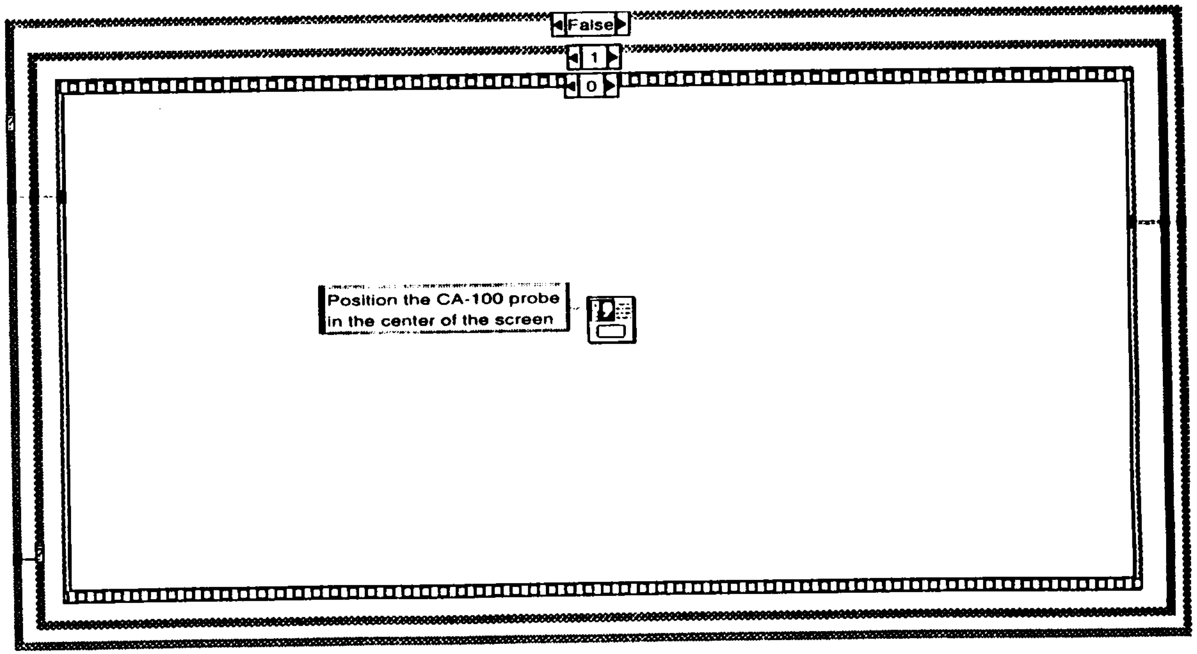

Figure 4.5 Continued

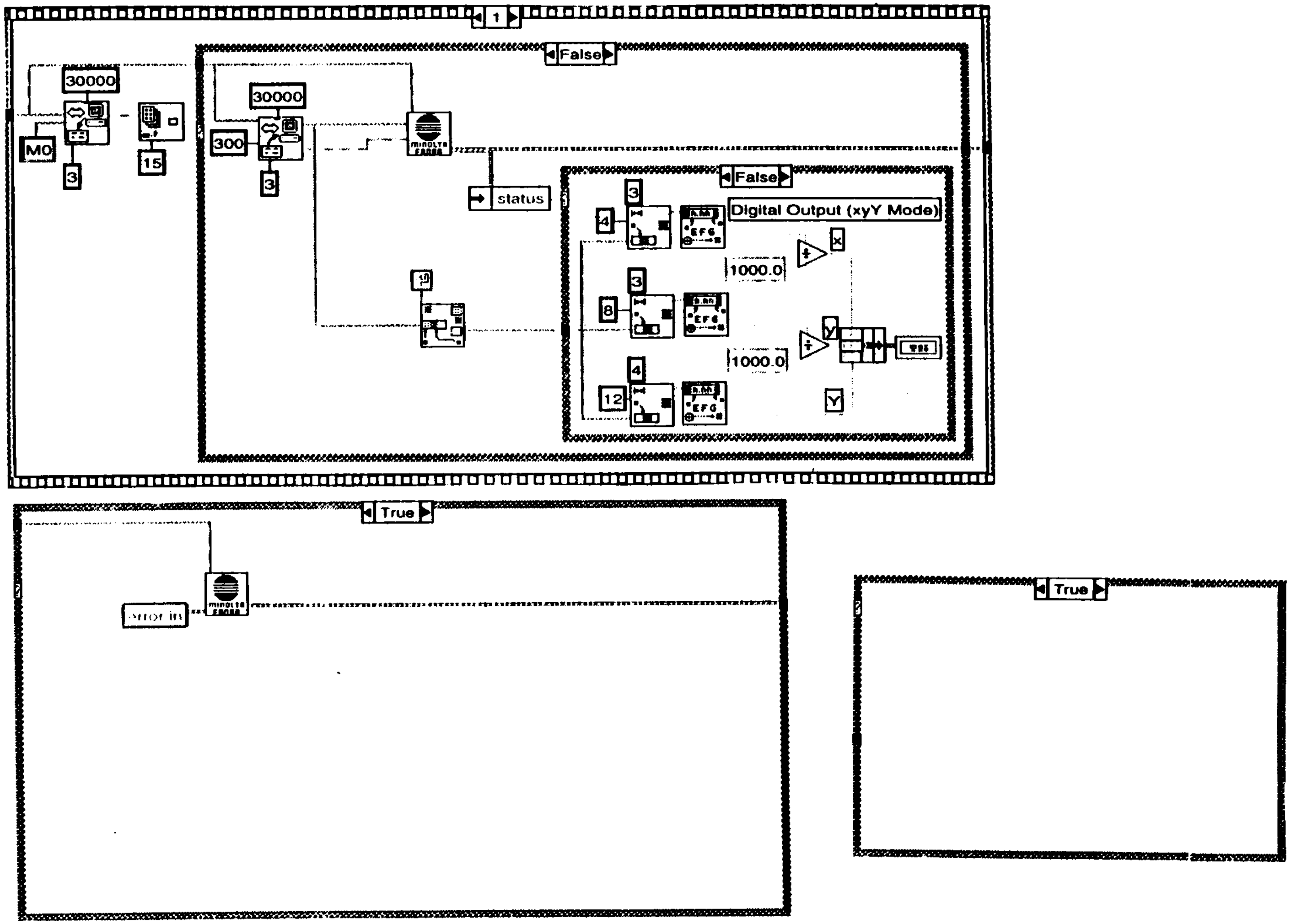

Figure 4.5 Continued

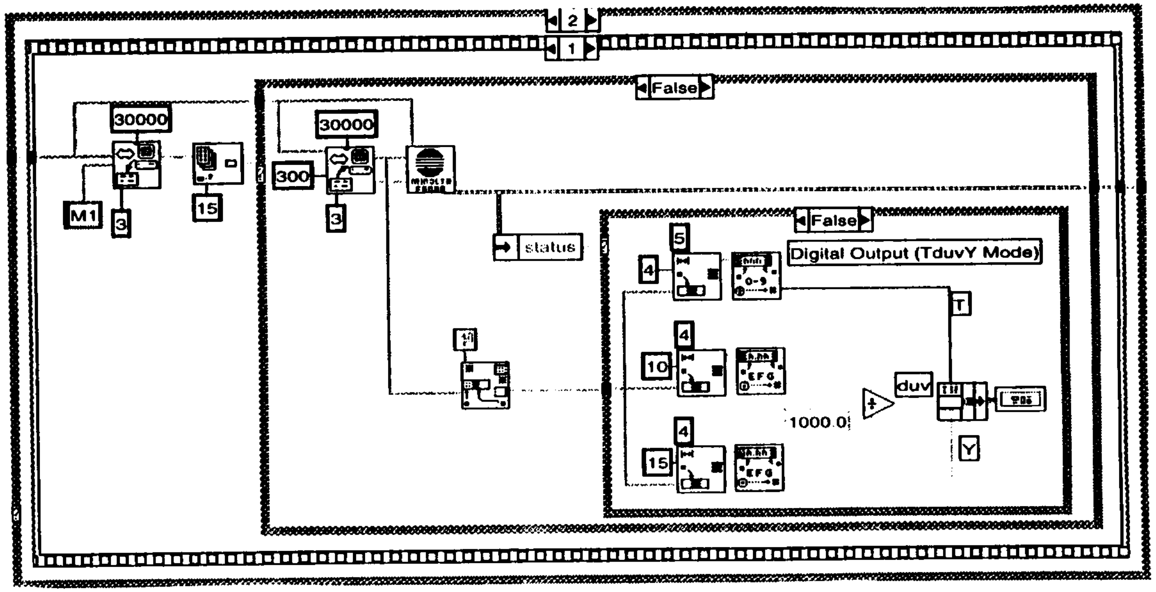

Figure 4.5 Continued

which is M1 in this case, and the output data, which are measured values in the *TduvY* mode.

4.3.1 Initialization VI

This VI sets the CA-100 into the remote control mode. Then, it performs the zero calibration, presets the CA-100, and updates the CA-100 status information indicator. Figure 4.6 shows the front panel of this VI. The inputs of the initialization VI are,

1. *GPIB address* for CA-100
2. *Error in* cluster, which describes the error status before this VI was called

This VI has two outputs which are,

1. *CA-100 status*, which describes the present status of the CA-100
2. *Error out*, which describes the error status after executing this VI

The block diagram of this VI is illustrated in Figure 4.7. If the *Status* of the *error in* is TRUE, this VI passes the *error in* cluster to the *error out*. If the *Status* of the *error in* is FALSE, this VI sets the CA-100 into the remote control mode by clearing its GPIB interface. Then, it asks the user to place the receptor area of the measuring probe

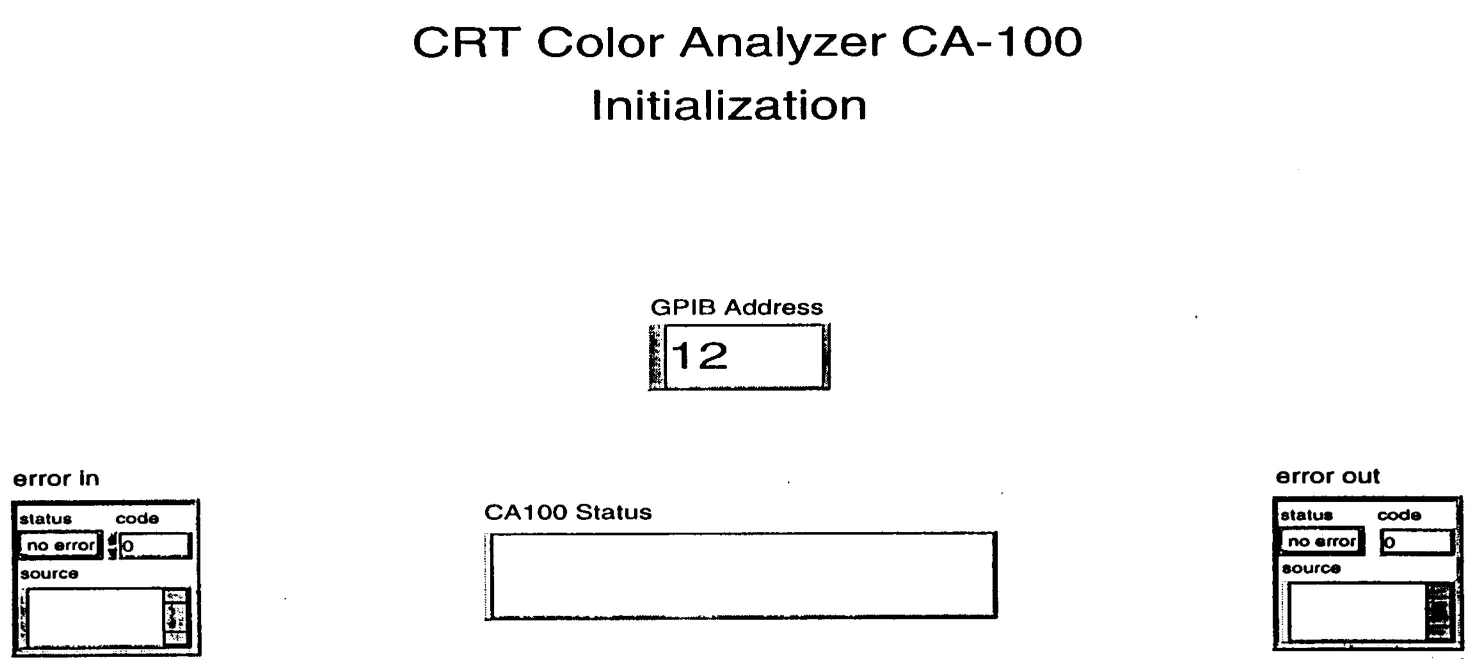

Figure 4.6 Front panel of the CA-100 Initialization VI

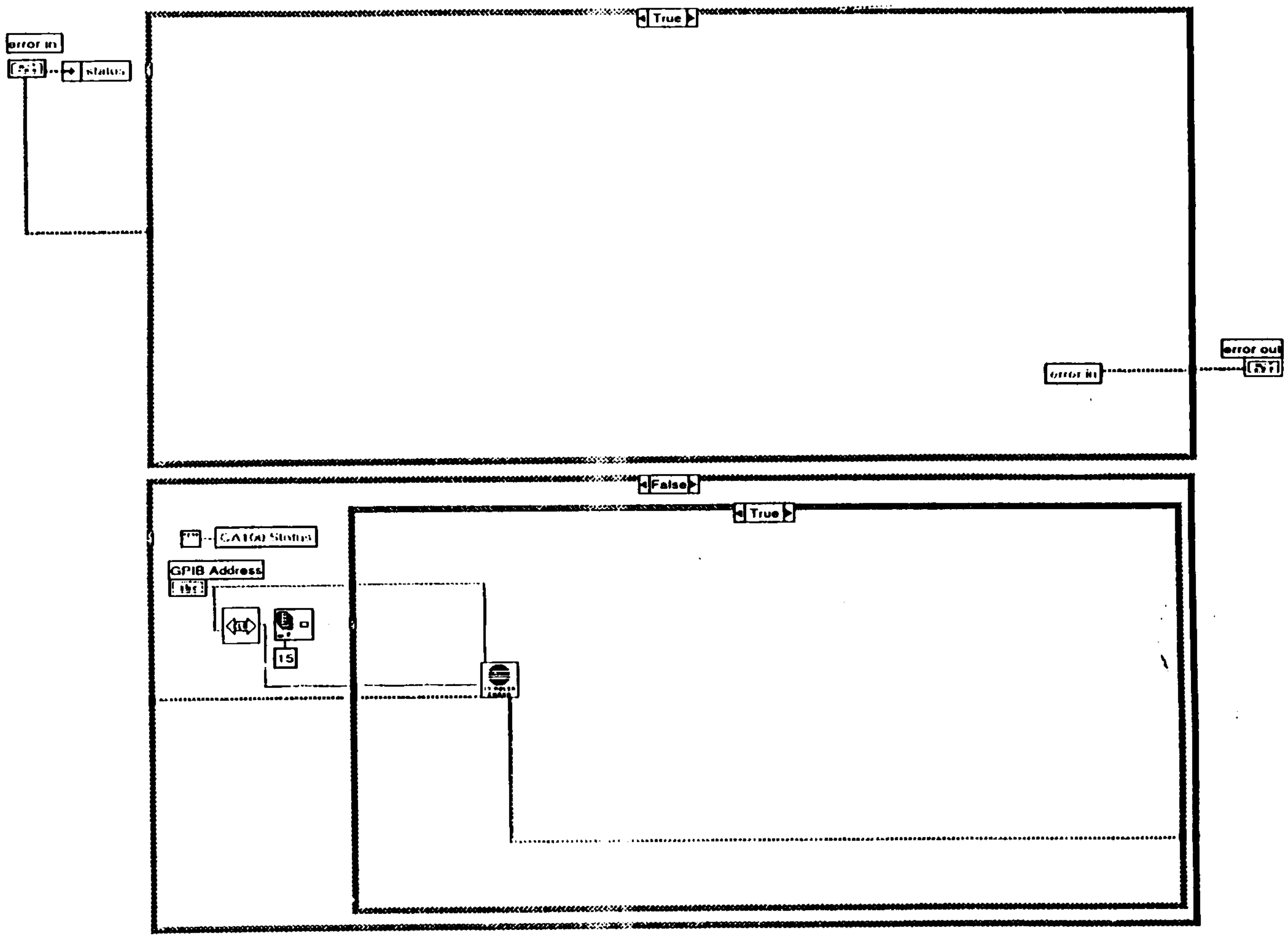

Figure 4.7 Block diagram of the CA-100 Initialization VI

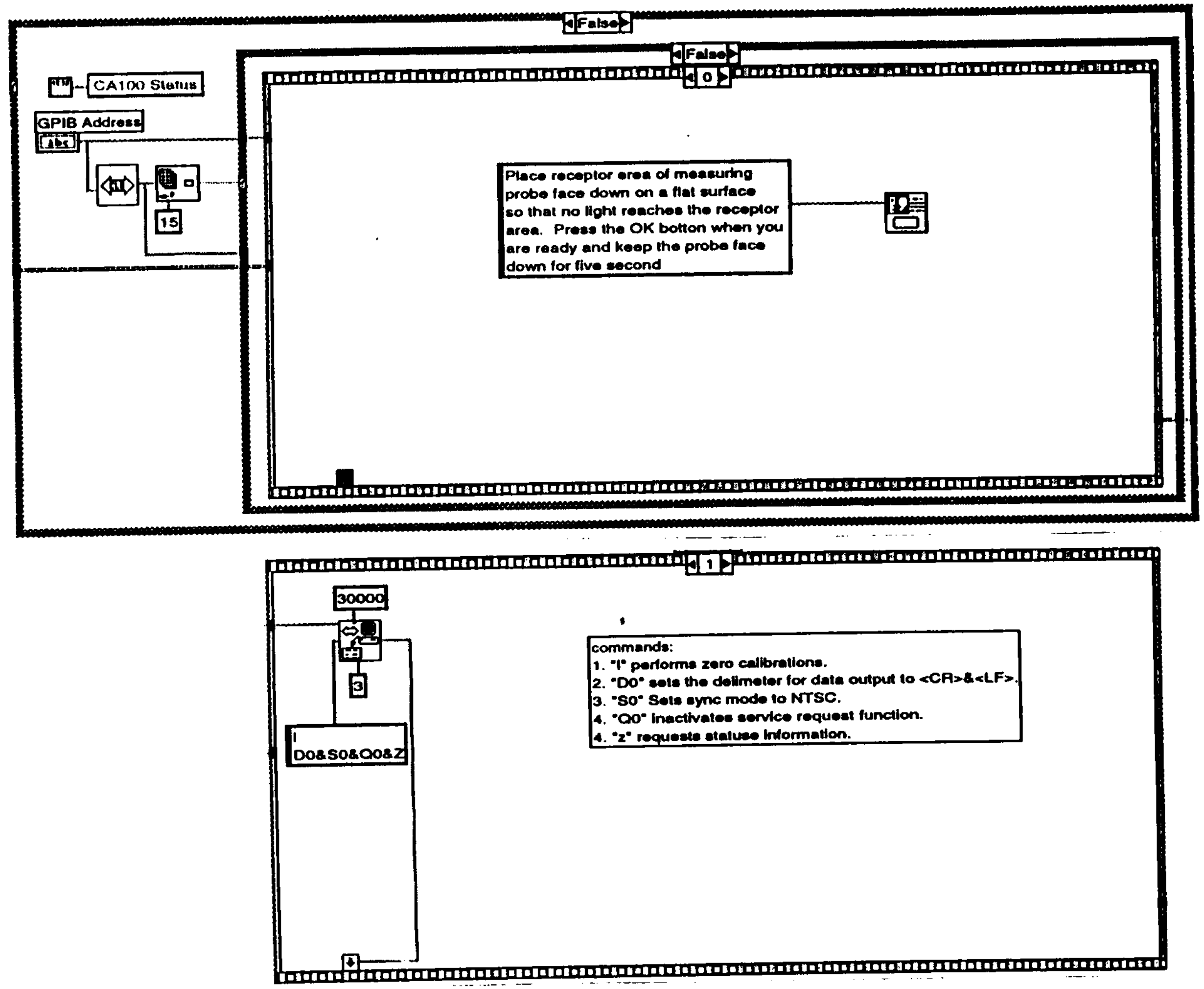

Figure 4.7 Continued

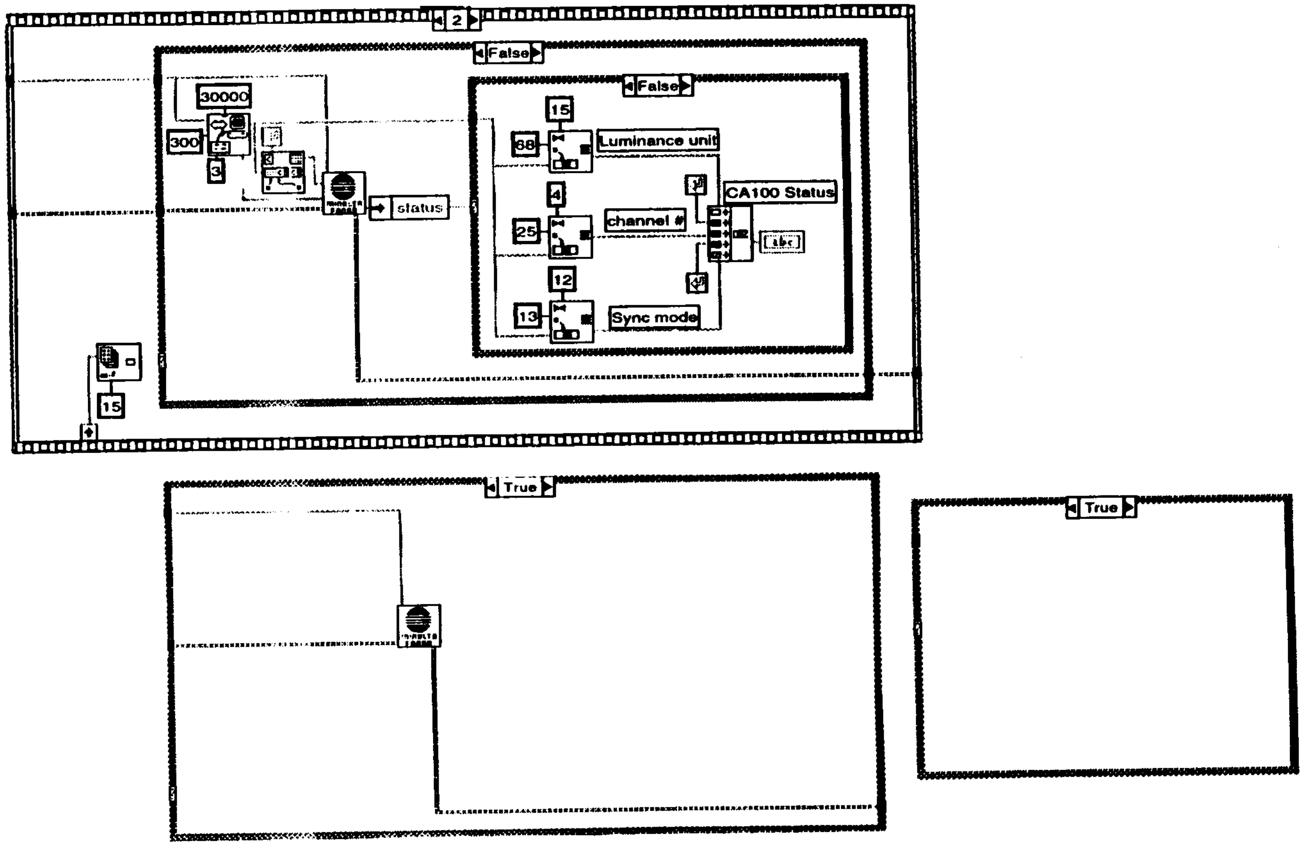

Figure 4.7 Continued

face down on a flat surface so that no light reaches the receptor area. It then sends a command string to CA-100 that executes the following functions:

1. Performs zero calibration
2. Sets the delimiter for data output to <CR>&<LF>
3. Selects the NTSC synchronization mode
4. Inactivates the service request function

Requests status information regarding the preset settings. Then this VI reads the CA-100 response string and extracts the most important status information from it.

4.3.2 Error handling VI

This VI accepts the latest response of the CA-100 and status of the GPIB controller as inputs and detects possible errors. The front panel of this VI is shown in Figure 4.8. *GPIB Status* is a 16-bit Boolean array where each bit defines a state of the GPIB controller. Bit 15 is TRUE when a GPIB error occurs. Figure 4.9 shows the block diagram of this VI. This VI examines the 15th bit of the *GPIB status* array. If it is TRUE, it sends the CA-100 address to the LabVIEW GPIB Status VI. GPIB Status VI examines the status of the GPIB controller at the input

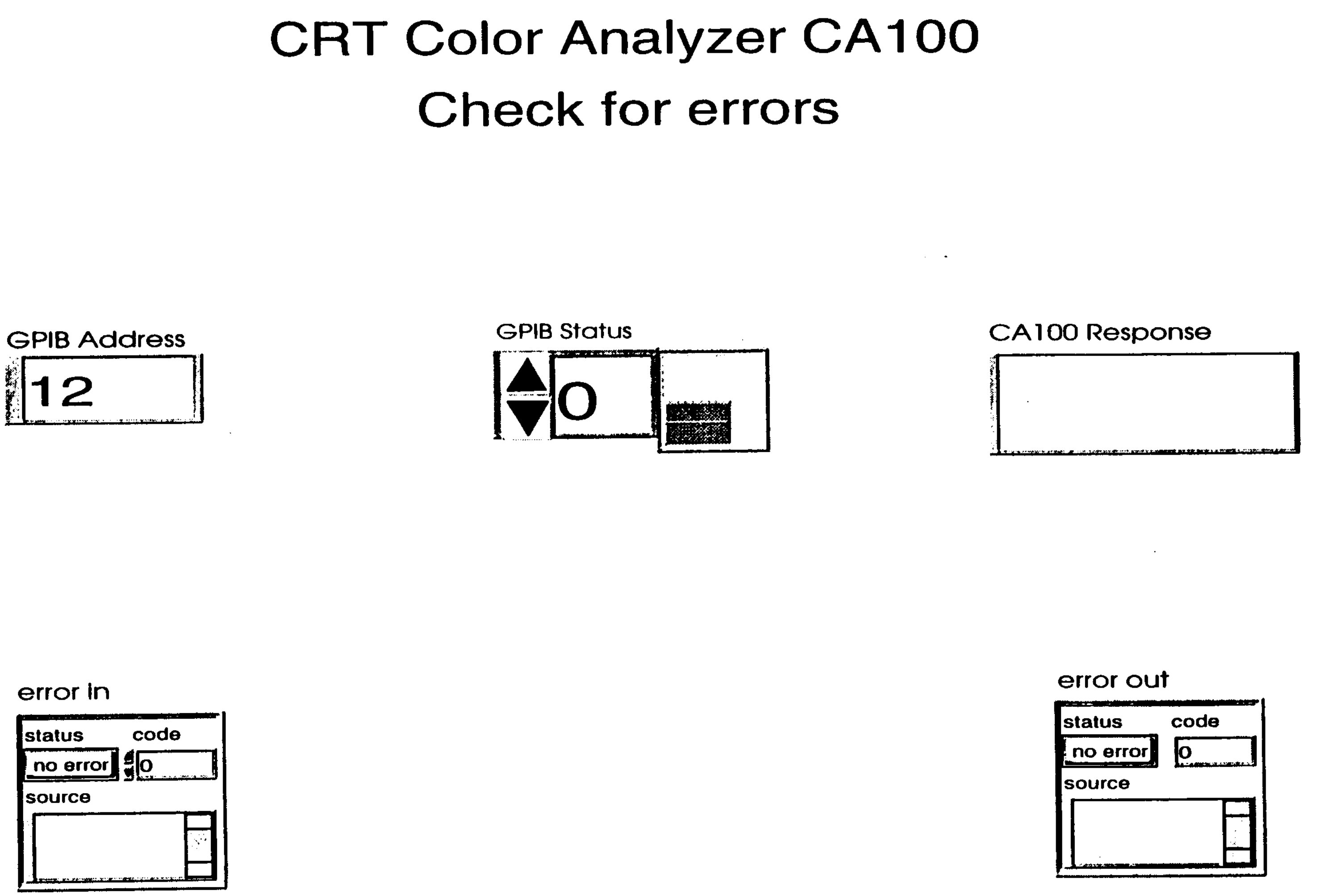

Figure 4.8 Front panel of the CA-100 error handling VI

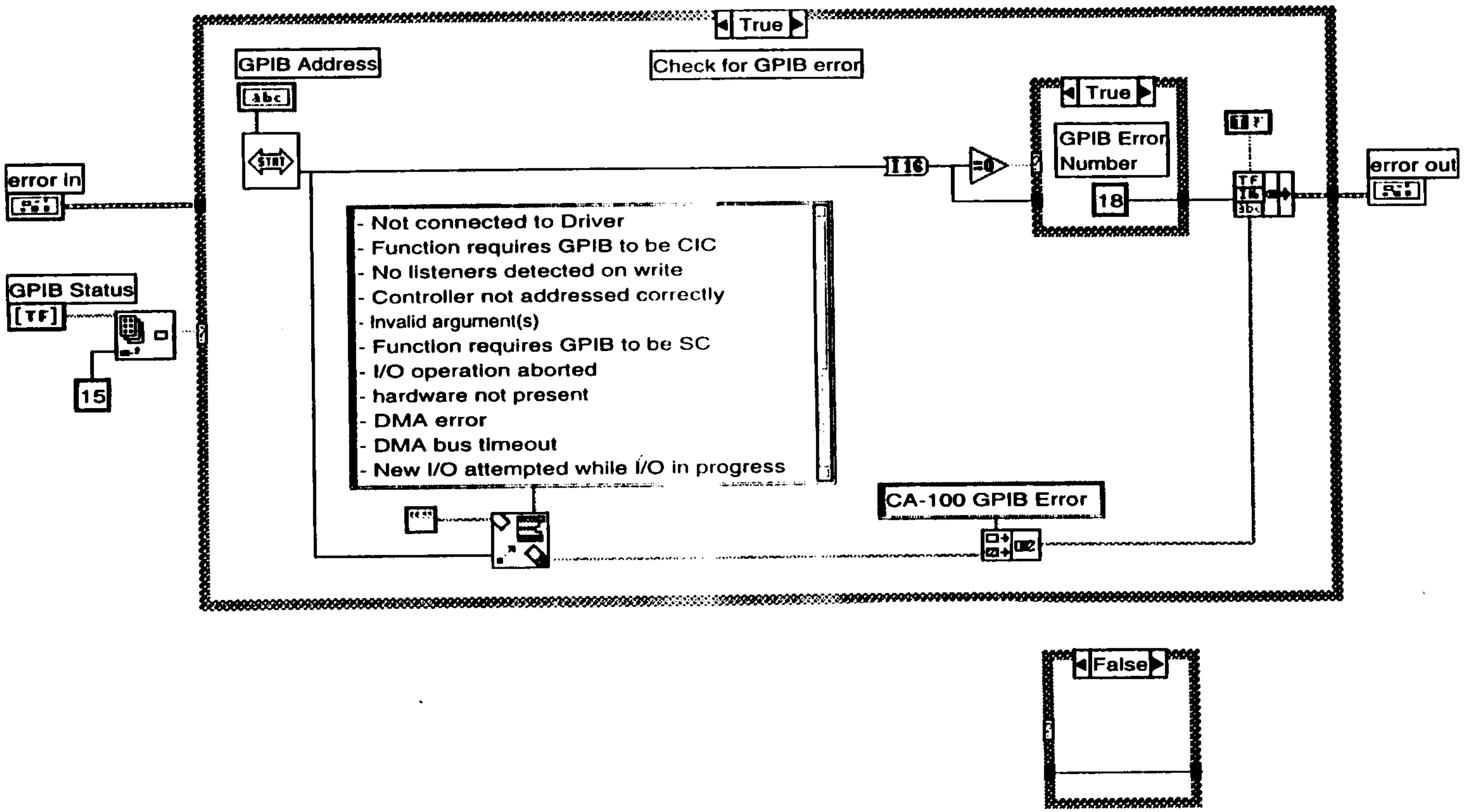

Figure 4.9 Block diagram of the CA-100 error handling VI

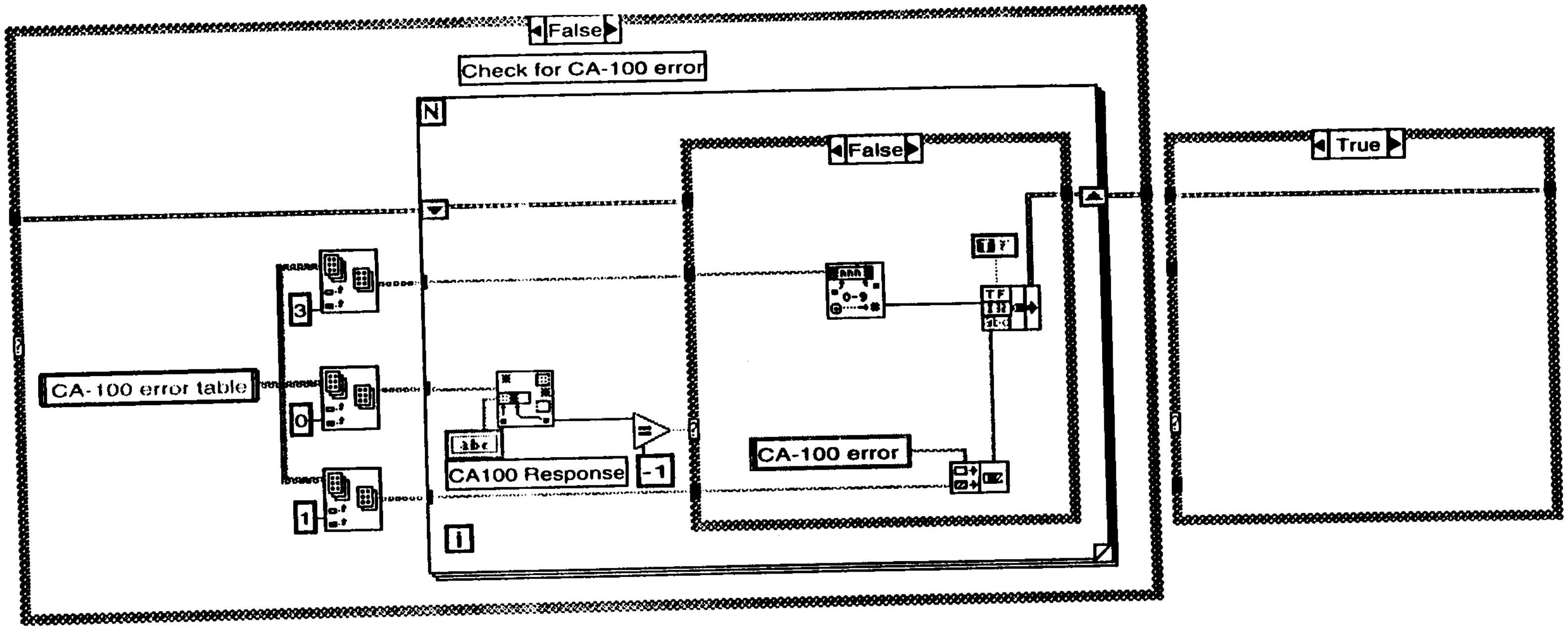

Figure 4.9 Continued

address after the latest GPIB operation and reports the GPIB error number (0-17). The Error handling VI takes the error number and populates the error out cluster accordingly. If this VI does not detect any GPIB error, it checks the CA-100 response and searches for all the possible errors that are listed in the *CA-100 error table* global variable. If it finds one of the CA-100 error codes in the response string, it will write the appropriate information in the error out cluster.

4.3.3 CA-100 error table

This global variable, as it is illustrated in Figure 4.10, contains a two-dimensional array called CA-100 error table. Error messages that may be output by the CA-100 in the remote control mode, along with corresponding explanations, comments, and their ATF error codes are listed in this table.

The next chapter discusses one of the television performance tests that uses the CA-100 driver.

Error message format	Explanations	Comments	ATF Error Code
P	Present measuring probe and measuring prob used for calibration to user-selected reference or for setting standard color are different.	Equal to liquid cristal error message E1.	6400
T	Ambiant temperature has changed since zero calibration was performed	Equal to liquid cristal error message E2	6401
F	Measured data is outside of measuring range.	Digital display is blinking.	6402
E3 :	Error in setting calibration values for user selected reference. RC disabled.		6403
E4 :	0% was set as analog display range		6404
E5 :	The command "E" was input before acceptable data was input for all four values (R, G, B, W) when inputting RGB emission characteristics		6405
E10 :	The input command is not acceptable. Rc disabled		6406
E11	A command string of more than 250 characters was input. RC disabled		6407
E12	Error in RS232 data communication. A command was input while CA-100 was unable to accept commands. RC disabled		6408
E13	The command "E" was input to input standard color (W) while "OVER" was displayed in the liquid crystal display. RC disabled.		6409
E20	Liquid Crystal display error message : NO SYNC SIGNAL		6410
E21	Liquid Crystal display error message : TOO BRIGHT		6411
P1 E22	Liquid Crystal display error message : OVER		6412
P1 E23	Liquid Crystal display error message : OFFSET ERROR PUSH 0-CAL KEY		6413
P1 E24	Measured value is over display range in TuvY dispaly mode.		6414
E25	Liquid Crystal display error message SET MAIN PROBE	Switch power off and then switch it on again.	6415
E26	Liquid Crystal display error message : PROBE ERROR	Switch power off and then switch it on again.	6416
E27	Liquid Crystal display error message : MEMORY CARD ERROR	Switch power off and then switch it on again.	6417
P1 E28	Liquid Crystal display error message : : DATA ERROR		6418
E29	Liquid Crystal display error message : : DARKEN PROBE		6419
E30	Liquid Crystal display error message : : DARKEN PROBE PUSH 0 CAL KEY		6420

Figure 4.10 CA-100 error table

CHAPTER 5

COLOR TEMPERATURE TEST

5.1 Introduction

Competitive analysis seeks to enhance design investment decisions by gauging the relative performance of competing television models. Sound decisions call for a statistically valid data base containing performance profiles taken across a large population of competing television models. The ATF system makes this possible by automating television tests using the LabVIEW programming language. The author has developed LabVIEW codes for 23 different television tests including several tests for direct-view TV, back-off tests, and tests for projection TV. Tests for direct-view TV examine the performance of the CRT picture. Back-off tests are done by screening and measuring signals at special points on the TV circuit board. Table 5.1 lists all the tests developed by the author.

This chapter provides an in-depth narrative of the Color Temperature Test for direct view TV as an example. The purpose of

Table 5.1 Some standard tests for television

Back-on tests	Back-off tests	Projection TV tests
Color Temperature	Black Level Stability	PTV Color Temperature
Color Correction	RGB Video Outputs	PTV Contrast Ratio
Color Killer	Tint Range	Screen Pitch
Contrast Ratio	Interlace Performance	Misconvergence
Closed Captioning	Automatic Color Range	PTV Brightness
VCR Playback	Raster Size Change	
CDI Performance	Video S/N Ratio	
PIP performance	Power Consumption	
Doming	High Anode Voltage	

the Color Temperature Test is to determine the x and y chromaticity co-ordinates, the color difference from blackbody locus, and the color temperature of the direct-View TV receiver at high and low light conditions. The measurement principle is described in section 4.1.

5.2 Color Temperature Test procedure

The system hardware configuration is given in Figure 5.1. A flat white field 10 IRE video signal pattern is routed to the channel 5 video modulator. The modulated signal is transmitted to the television under test (TUT) through one of the RF outlets. The RF level is set to 1 milivolt using the channel 5 attenuator. Then the IRE level is adjusted until the light output of the TUT is one foot Lambert. At this point, which is the low light condition, the x and y co-ordinates, duv, and T are measured. Then the IRE level is increased until the light output is 40 foot Lamberts (high light condition), and all the parameters are measured again. This test is done for each TV under test, and the results are saved in a spread sheet file. Table 5.2 lists all the steps of the Color Temperature Test for direct-view TV.

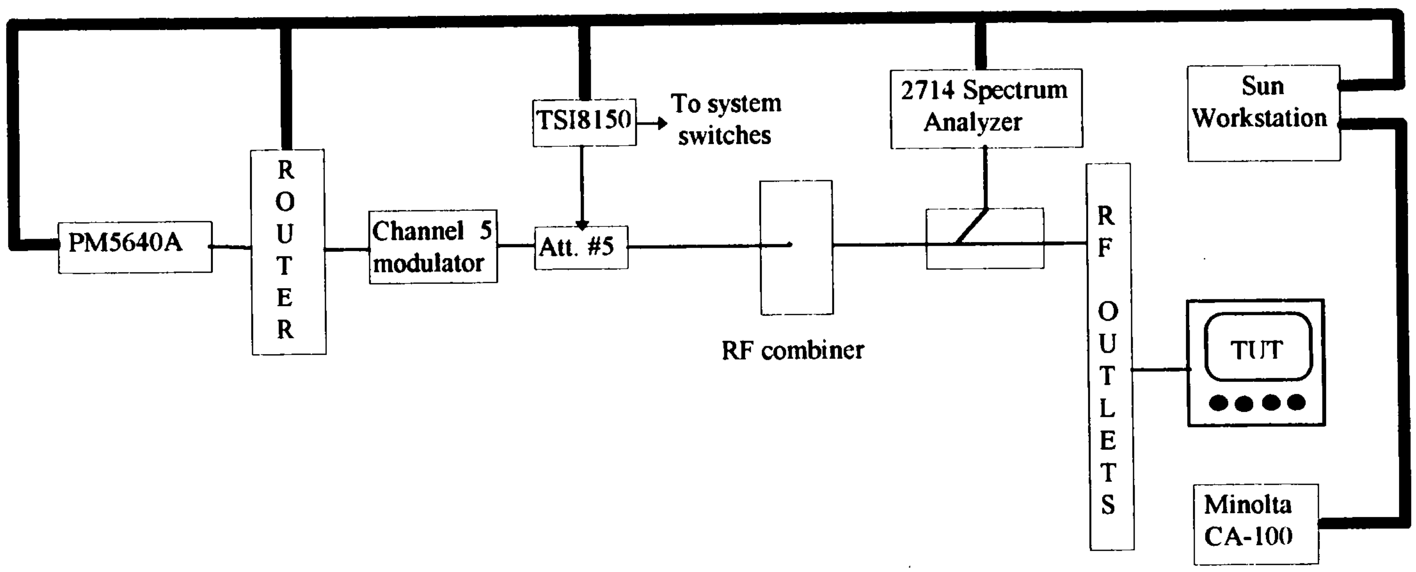

Figure 5.1 System hardware configuration for Color Temperature Test

Table 5.2 Color Temperature Test procedure

Step 1	Connect all TV antenna inputs to RF outlets.
Step 2	Turn on all televisions and tune them to channel 5.
Step 3	Route a flat white field 10 IRE pattern to the channel 5 video modulator.
Step 4	Set RF level to 1 millivolt.
Step 5	Darken the room.
Step 6	Position the CA-100 probe in the center of the screen of the TV under test.
Step 7	Measure the brightness in foot Lamberts. adjust the IRE level until the CA-100 reads 1.0+/-0.1 foot Lamberts.
Step 8	Measure and record x and y chromaticity co-ordinates, duv, and color temperature at low light condition.
Step 9	Adjust the IRE level until the CA-100 reads 40.0+/-0.1 foot Lamberts.
Step 10	Measure and record x and y chromaticity co-ordinates, duv, and color temperature at high light condition.
Step 11	Repeat steps 6 through 10 for each TV.
Step 12	File information in a file.

As was mentioned earlier, the entire ATF is set up in a menu driven hierarchy wherein the user starts from the Top Menu and works his/her way down through different paths. Figure 5.2 shows the path from the Top Menu to the Color Temperature Test. From the Top Menu, Competitive Analysis should be selected. Then, the user must log in at the Login Menu, after which the Category Menu opens. Here Raster Series should be selected. Finally, from the Raster Series Menu, the Color Temperature Test must be selected. Next, the list of televisions to be tested are entered in the TV Header. Then the test starts.

The remaining sections discuss the software that was written to implement this test.

5.3 Color Temperature Test software

There are many subroutines that are used in all the tests. Therefore, a test template has been designed as a skeleton for all tests. The Color Temperature Test, like all other tests, is the result of tailoring this test template. Figure 5.3 shows the front panel of the main VI for the Color Temperature Test. The large gray square on the left contains controls and indicators for measuring and recording

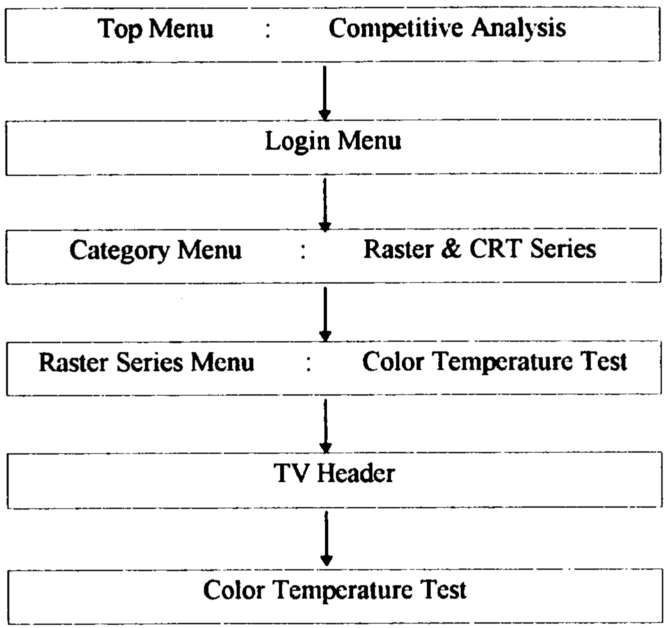

Figure 5.2 The path from the Top Menu to the Color Temperature Test

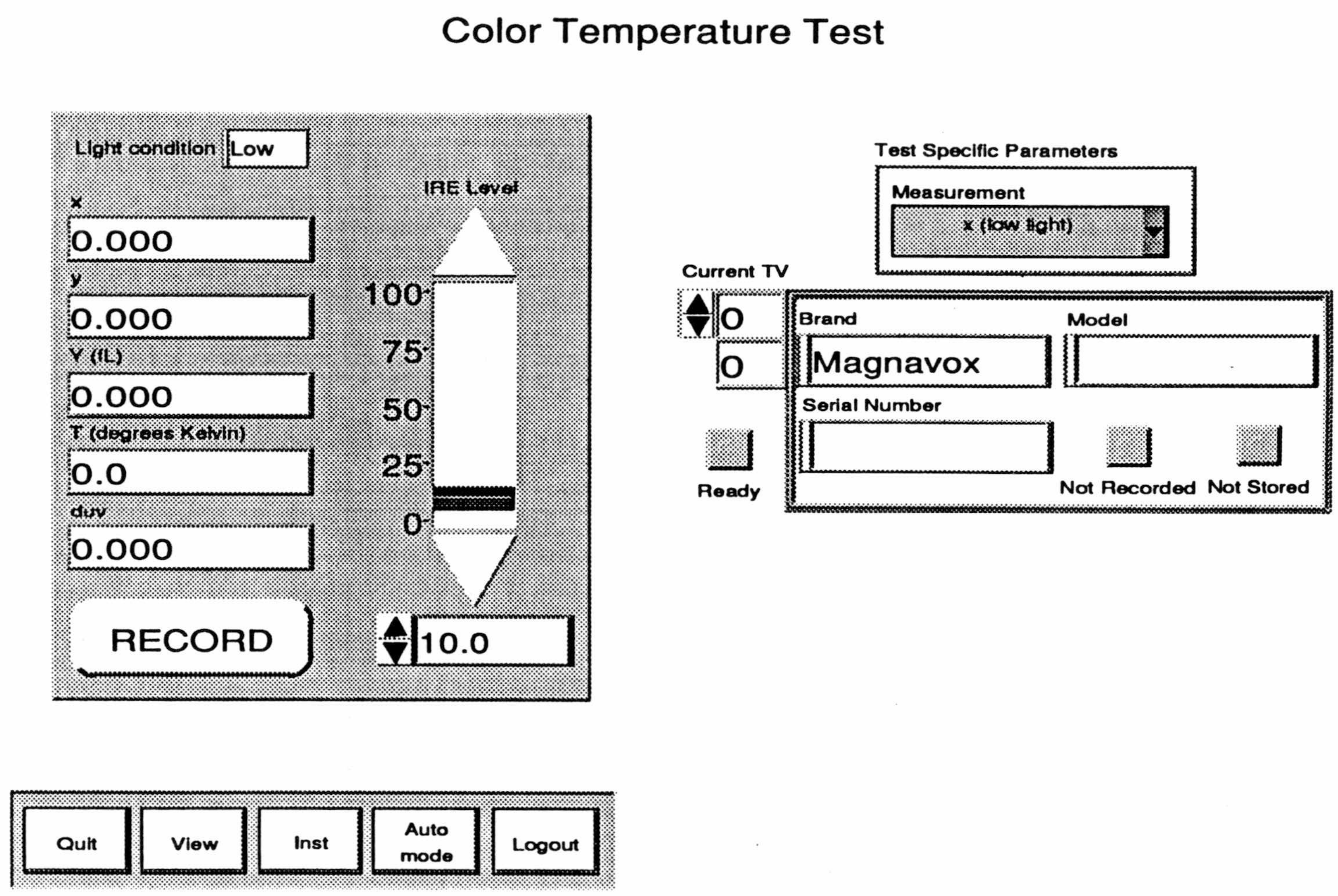

Figure 5.3 Front panel of Color Temperature Test

measurements. It contains a vertical slide control, *IRE level.* The control allows the selection of the video level of the test signal. The IRE level is also displayed in the numeric indicator under the slider. The *RECORD* button is a boolean control that allows a measurement its parameters, units, and other pertinent information regarding the television under test to be stored and viewed via a lower level panel. Five numeric indicators display their respective measured value for the current light condition which is displayed in a string indicator on top. The selection in the bottom left is home to various boolean test options that are available to the operator. All of the selections are shown in their default state. The *Quit* button ceases test execution and transfers execution to a higher level panel, the Raster Series Menu. The *View* button allows the user to see the measurements that have been recorded. These are shown in a lower level panel. There is also a set of instructions that explain the purpose and functionality of the test. The *Instruction* panel appears when the *Inst.* button is depressed. The Test Mode, Automatic or Manual, is determined by the *Auto Mode* button. *Auto Mode* allows the test to proceed in the default auto-sequencing mode. *Manual Mode* lets the user choose the order in which the television sets are tested or the order in which the test parameters are applied. The *Logout* option stops test execution and passes control to the Category Menu, a higher level menu. The right side of the panel is headed by the test specific parameter, the *Measurement* ring control. The control displays the current test parameter that is being measured. The *Current TV* cluster indicates the brand, serial number, and model of the current television under test. The information is passed from the higher level TV header where it is entered. The TV header is shown in Figure 5.4. There are two boolean indicators in the cluster. They show the *Recorded* and *Saved* status of each measurement respectively. The red color indicates that the measurement has not been recorded. If the measurement is recorded, the indicator becomes green. Similarly, the storage indictor is green for data that is stored and red otherwise. The test uses another indicator to show the status of the current television. If 15 minutes have elapsed since the television was turned on, the indicator changes its default red color to green.

The block diagram of this test is shown in Figure 5.5. It has four stages which are described in the following paragraphs. Each test has several global variables. Those used for Color Temperature Test are shown in Figure 5.6.

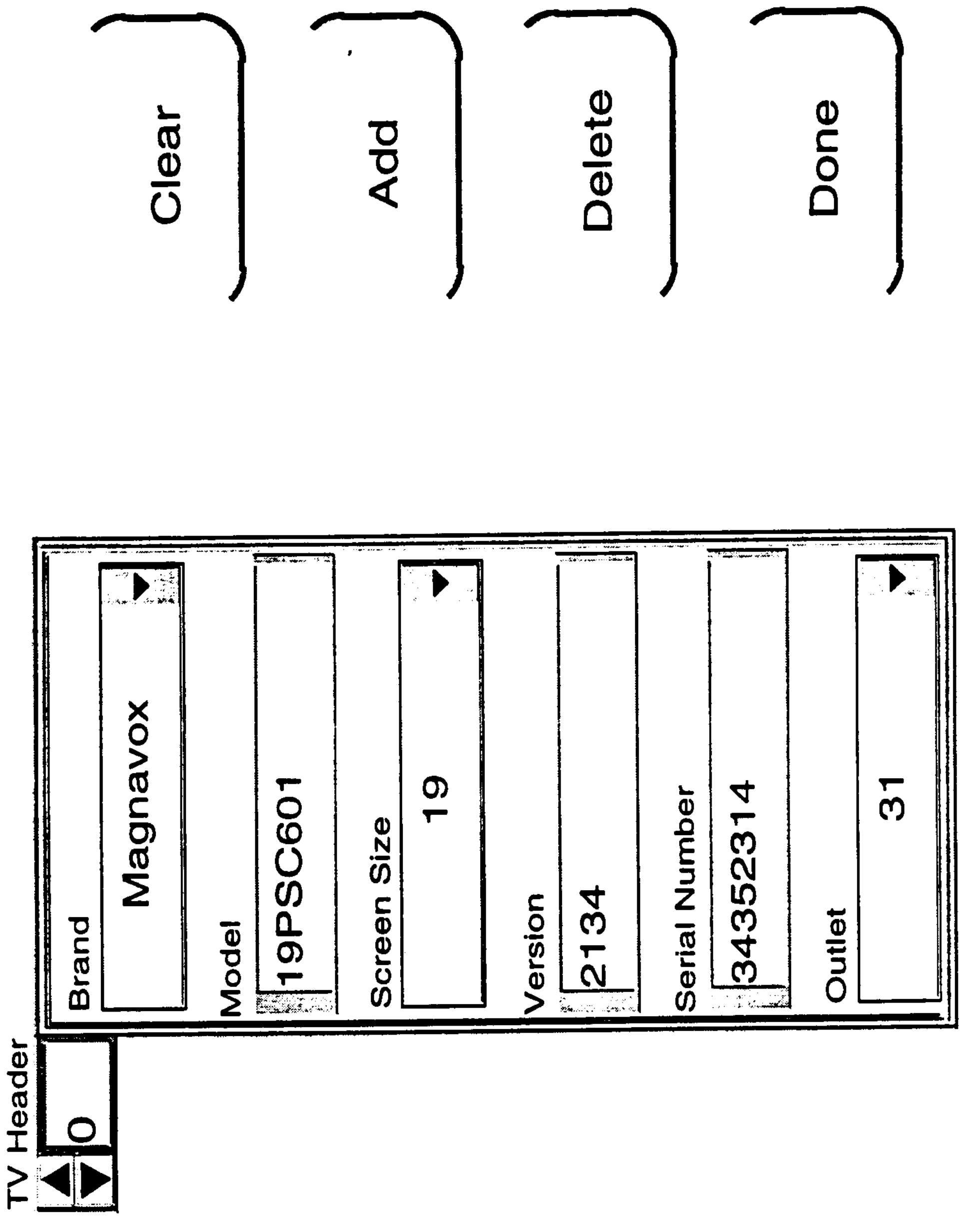

Figure 5.4 TV header

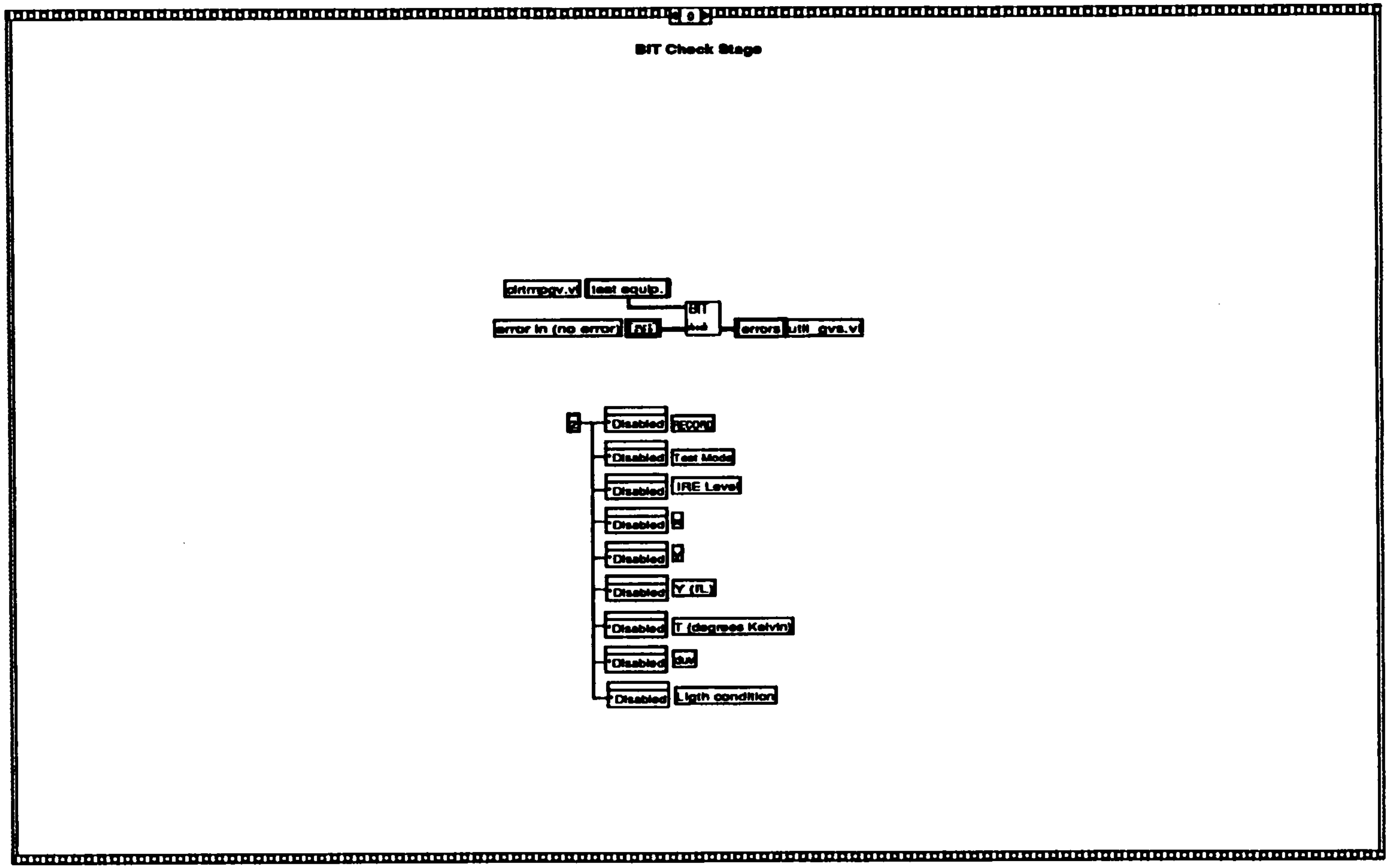

Figure 5.5 Block diagram of the Color Temperature Test VI

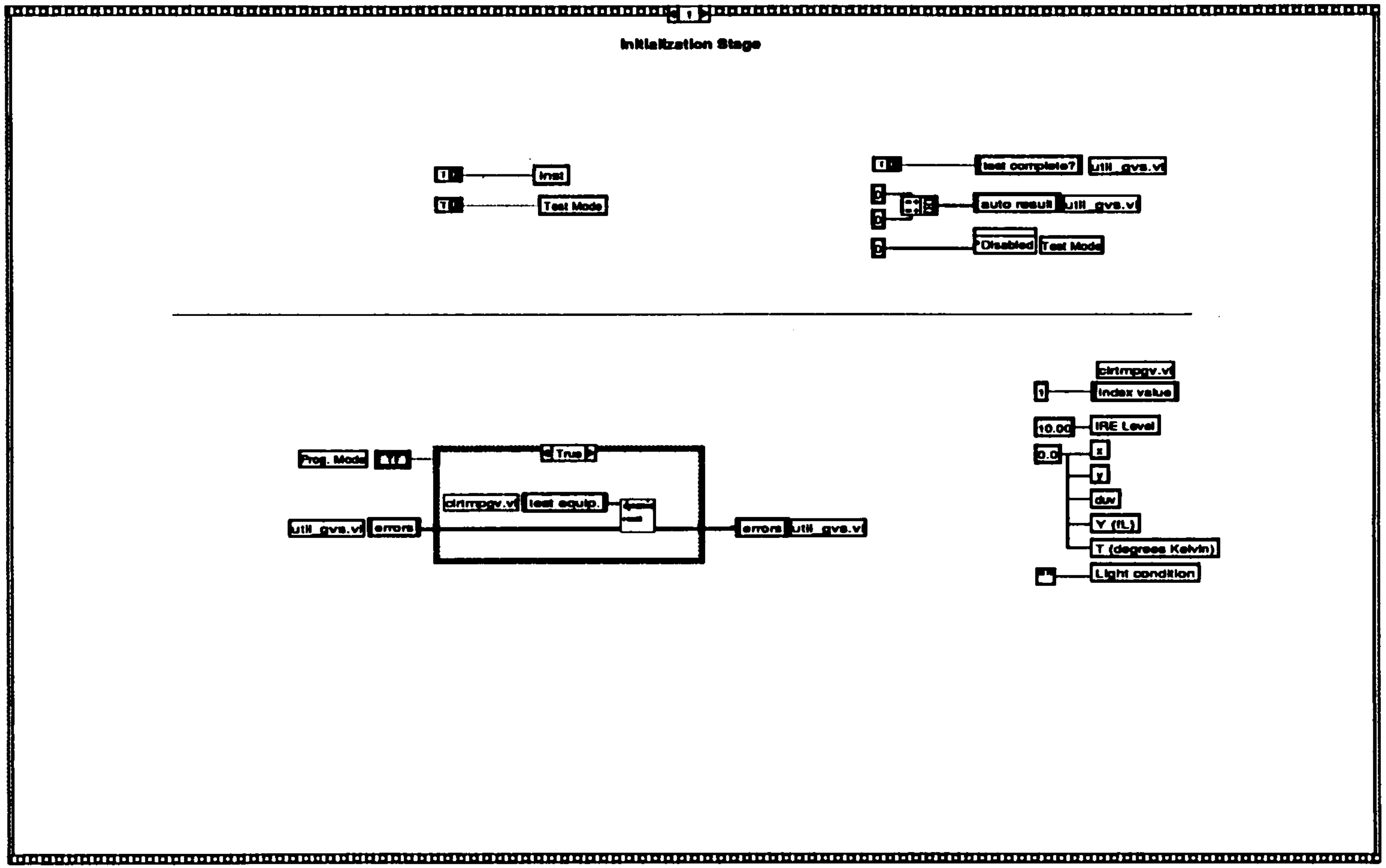

Figure 5.5 Continued

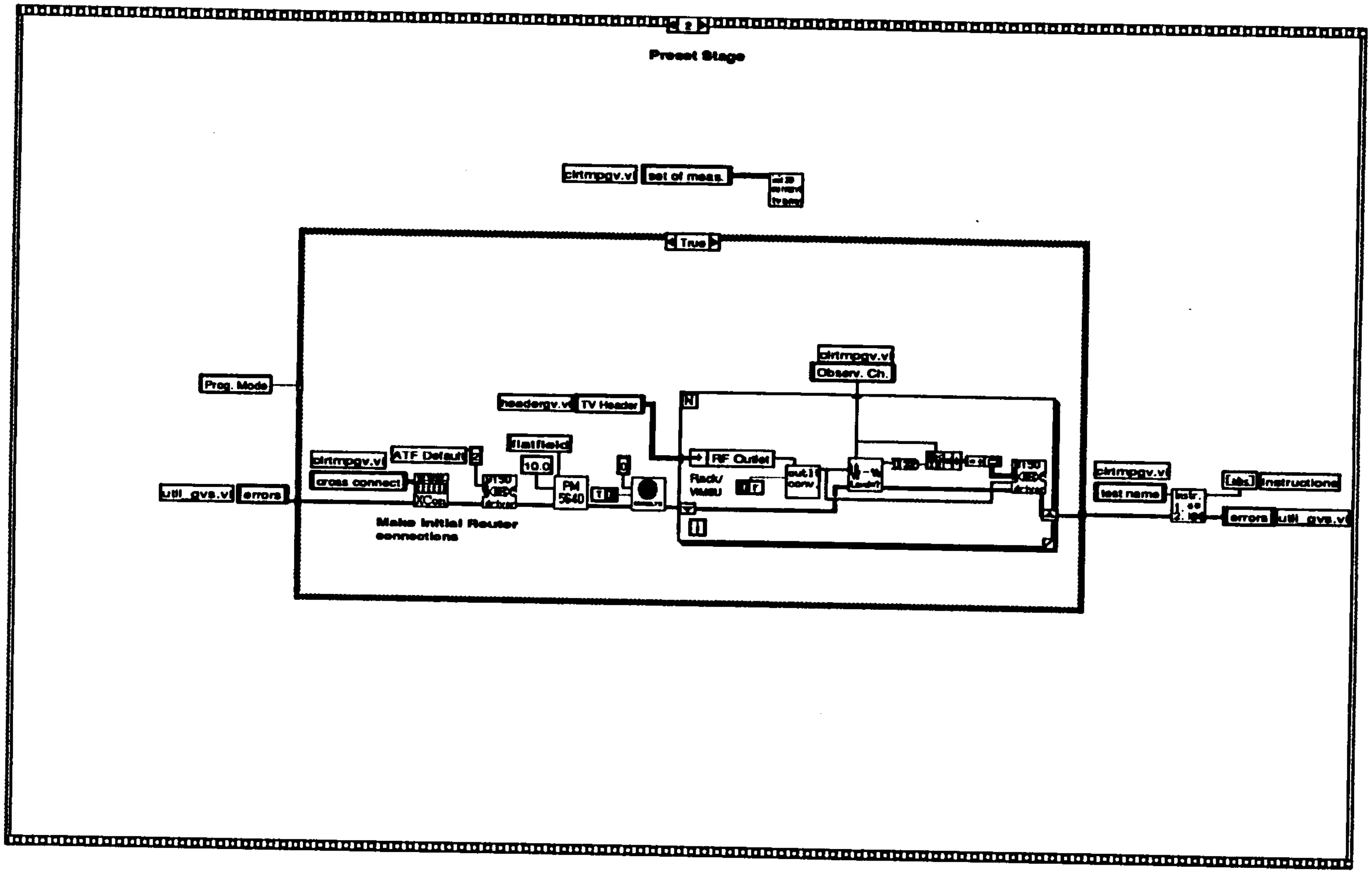

Figure 5.5 Continued

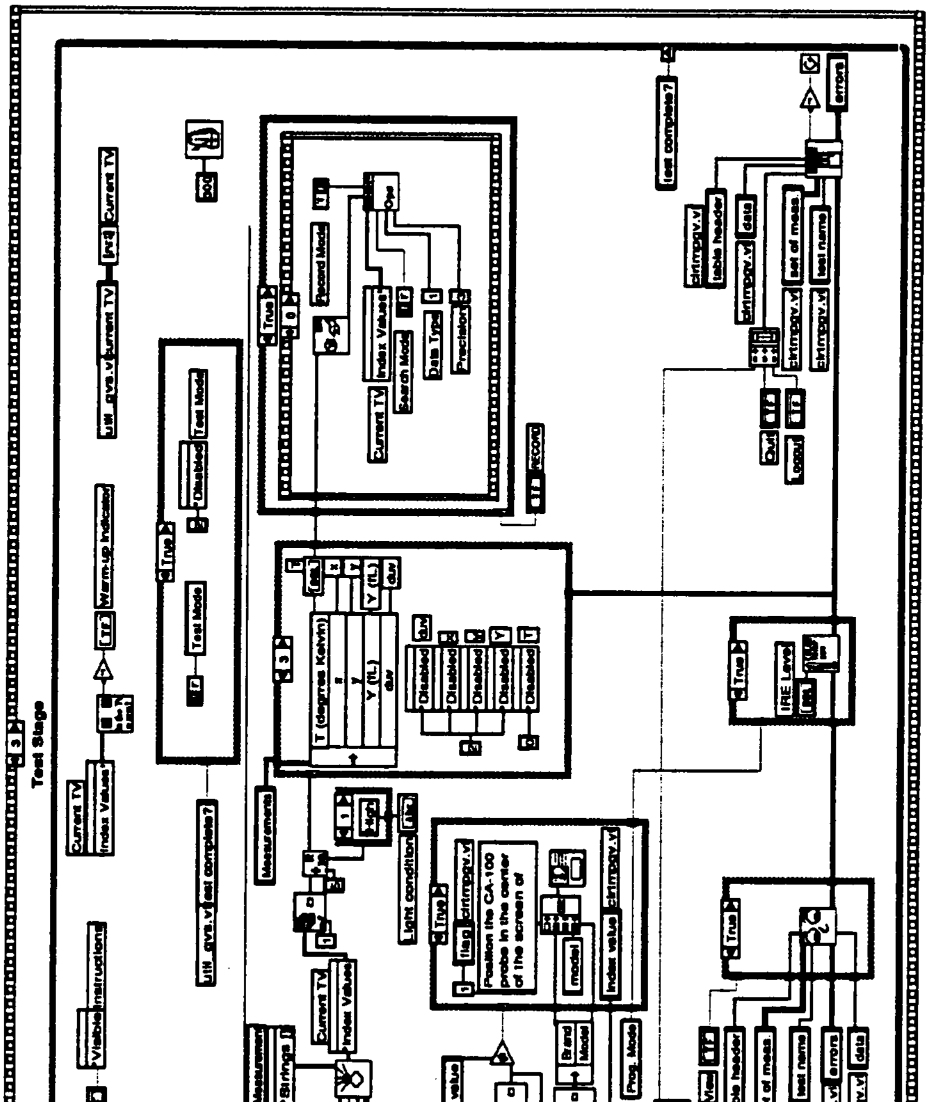

Figure 5.5 Continued

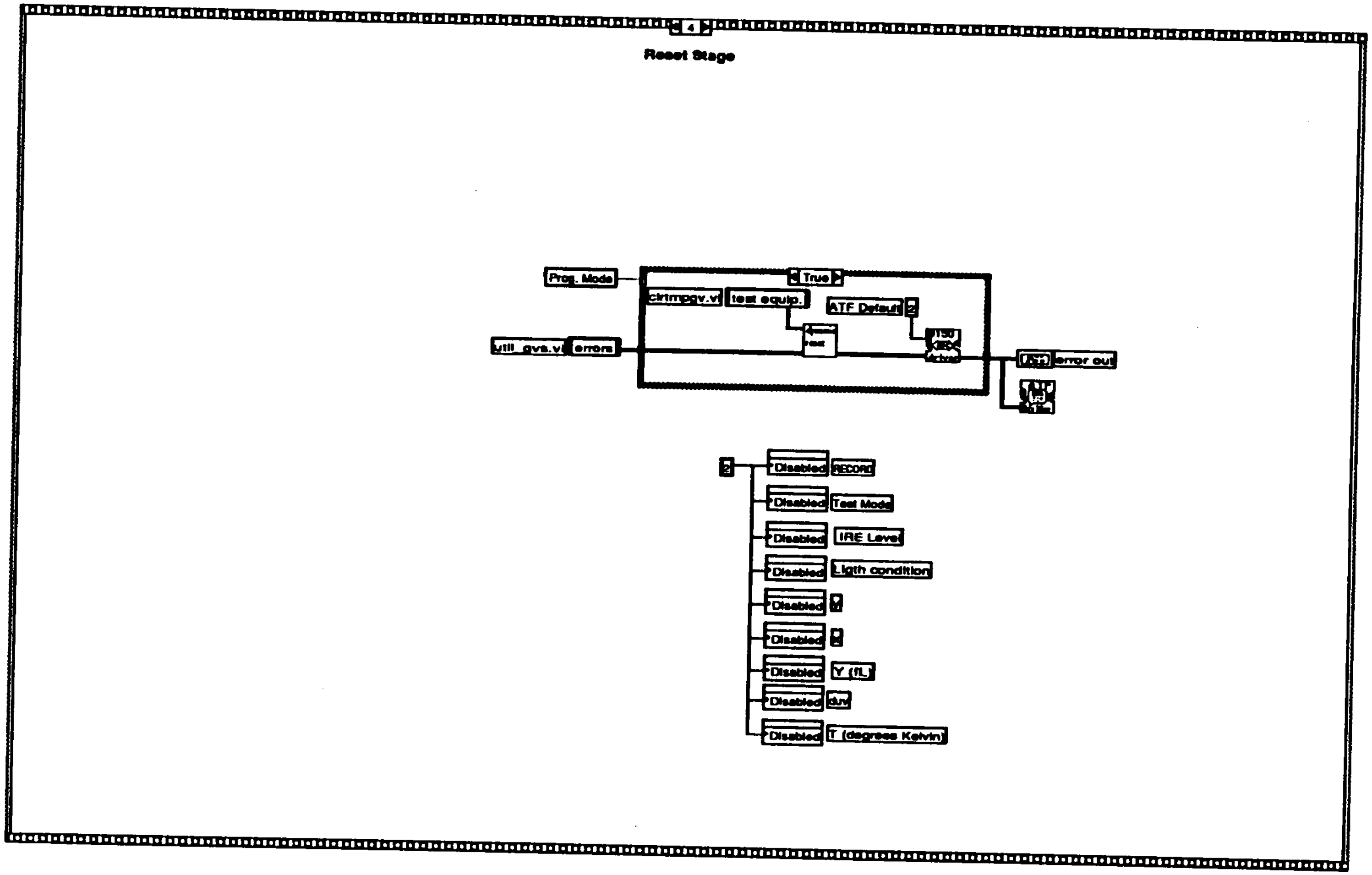

Figure 5.5 Continued

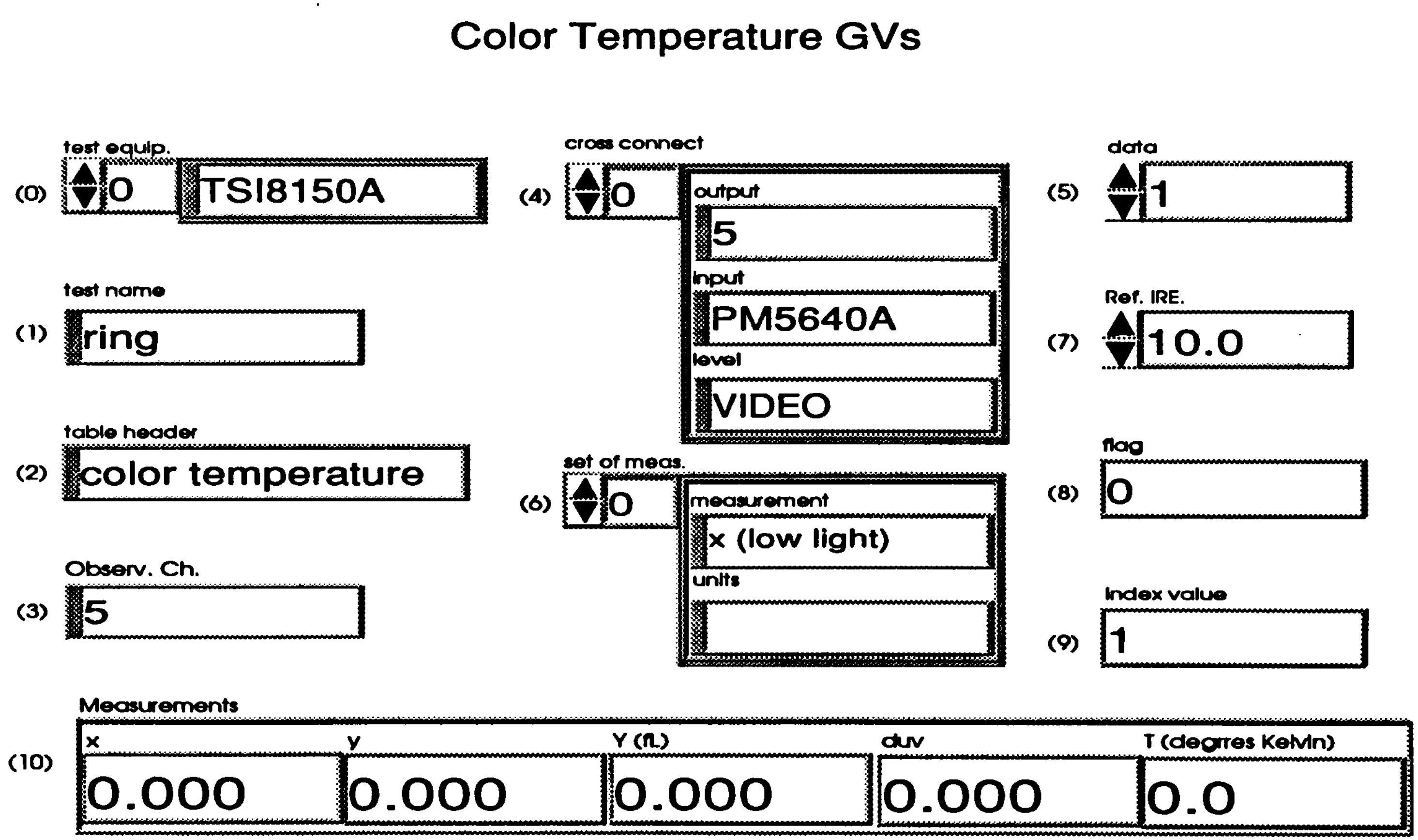

Figure 5.6 Color Temperature Test global variables

5.3.1 BIT check stage

At this stage all the indicators and controls on the front panel become disabled and grayed-out. This is done because the BIT check, initialization, and preset stages take several seconds to execute. Consequently, the user is locked out until the Test Stage is reached. The grayed-out controls signal the user that some activities are running in the background, so he/she cannot interact with the front panel yet. At this stage the **bit-ckeck.vi** also takes the list of equipment supplied in the test global variable and cross checks it against the result of the BIT. It analyzes its findings and updates the error cluster information accordingly. If **bit-check.vi** finds no error with hardware check, the test may continue. Otherwise, the test will be aborted.

5.3.2 Initialization Stage

The purpose of this stage is to initialize the hardware necessary for this test. Thus the system is set to a known state. The code of interest is shown in Sequence 1 of the block diagram. There is a subVI called **dyn-rest.vi** which takes the list of the equipment from the test global variable and searches through a look-up-table to find the corresponding initialization VI to call. Then it executes all the initialization VIs needed for this test. If no error occuress at this stage, the test may proceed. Otherwise, an error message notifies the user that the test is being aborted because of some errors. Several local and global variables are also initialized at this stage.

5.3.3 Preset Stage

The hardware is preset at this stage. This is sequence number 2 in the block diagram of the Color Temperature Test. The purpose of this stage is to configure the hardware in the way prescribed for this test. For this test, the required router configuration is to have the white flat field pattern on channel 5. This is given in the cross-connect global variable shown in Figure 5.6. The TSI8150 driver is called to set up the system to the ATF default configuration. That means all attenuators are fully (127 dB) attenuated and all RF switches are open. The PM5640, NTSC test signal generator, output is set to a 10 IRE white flat field signal. The CA-100 color analyzer is preset and zero calibrated. Finally, the attenuation levels at the desired RF outlets are adjusted to have one milivolt output.

There are also two other VIs shown in the block diagram, one of which is **instpanl.vi**. The purpose of this VI is to read the instructions file for this test and output these instructions to a string indicator on the test panel which is turned on and off via the *Inst.* button. The other VI shown is **ini-2d.vi**, which initializes the two-dimensional data array for this test to keep track of the names and values of the measurements.

5.3.4 Test Stage

This stage (sequence 3 of the block diagram) is where the most test-specific code is required. The main test-specific VI is the driver controller where all of the calls to the necessary drivers are made. The driver controller VI for the Color Temperature Test is discussed later in this section. Before starting the test loop, those controls and attenuators that are commonly used in all the steps of the test are enabled.

The first subVI inside the test loop to be discussed is warmchek.vi. This VI was written by test template designers to determine whether or not the current television under test is sufficiently warm. This VI assumes that the tester had actually turned on the TUTs prior to logging in. If the difference between the current time and the log in time is greater than fifteen minutes, then the *warm-up* indicator is false.

The large case structure in the upper right is controlled by the *RECORD* button. If the button is not pressed, the false case is executed in which nothing happens. When the *RECORD* button is pressed, the true case calls in Sequence 0 **rec_opt.vi**, which is responsible for recording the measurement values and setting the Recorded and Test Complete flags. Furthermore, it computes the next step in the auto sequencing. The **flatten To String.vi** is used in order to make this operation generic to all tests. This VI accepts any data type as its input and converts it to a platform-specific string of flattened data.

The case structure in the bottom left is actuated by the *View* button. The false case is empty. The true case calls **vw_formt.vi**, which formats the measurement data in a table. This table can be reached by pressing the *View* button on the front panel. An example of this table for the Color Temperature Test is shown in Figure 5.7. After viewing the data the user has the option to save color temperature

ganji		Toshiba	Magnavox				
09/13/96 03:42:02 PM		ABCD	DCBA				
Test Description	Units	12345	54321				
x (low light)		0.253	0.273				
y (low light)		0.301	0.308				
Y (low light)	fL	3.540	15.500				
T (low light)	Degrees K	12800.000	9780.000				
duv (low light)		0.023	0.014				
x (high light)		0.280	0.281				
y (high light)		0.310	0.309				
Y (high light)	fL	38.700	39.800				
T (high light)	degrees K	9190.000	9010.000				
duv (high light)		0.011	0.011				

Figure 5.7 View panel for Color Temperature Measurements

them to the hard disk, print them, or just go back to the test panel by pressing the *Done* button.

The mode_ctl.vi in the top right controls the *Current TV* array and the *Measurement* menu ring on the front panel. If the test is in *Auto Mode*, then the menu and the *Current TV* array are controlled programmatically. The ring is used to display the current measurement, and the array is set to the current TV under test. In *Auto Mode* the user is not allowed to change either of them because the program has control of them. In *Manual Mode* the user forces the test to the next measurement or the next TV by changing them.

If the test mode is set for manual testing, then the ring displays all the possible measurements for the test, and the user is able to select the one he/she wants. Also, the user is able to select the TUT by using the up and down arrows on the upper index of *Current TV* array. The lower index cannot be changed. It is programmatically controlled based on the setting of the *Measurement* menu ring.

The edge_det.vi sends the test complete indicator to the exitchek.vi. It also keeps the *Test Complete* dialog box from continuously displaying.

The **exitchek.vi** checks the possible conditions under which the test could exit. These are:

1. Hardware error detected during the BIT Check Stage, Reset Stage, or Initialization Stage
2. Hardware error during testing
3. Pressing the *Quit* button
4. Pressing of the *Logout* button

If any of these conditions occur, **exitchek.vi** halts the test while-loop. Also, when the test is complete, this VI displays a dialog box listing the user's options.

There is a case structure in the middle left of the block diagram (Test Stage). Each time the while loop is executed, the current TV index value is compared to the previous one. If they are different, a dialog box informs the user to position the CA-100 probe in the center of the screen of the TV under Test. Then the new index value is written into the test global variable as a reference for the next iteration. Also, a flag in the test global variable is set to 1.

The case structure in the middle reads the measurement results from the test global variable, and depending on the measurement that should be recorded at each step, it enables the indicator for that measurement and grays-out the other indicators. Therefore, when the user presses the *RECORD* button, he/she knows which parameter is being recorded at the moment.

This test measures 10 parameters for each TV. But there are just 5 indicators on the front panel. Another indictor has been provided at the top of the front panel that shows the light condition at each step, which can be low or high.

Finally, the **clrtmpdrv.vi** is left to discuss. This VI controls the hardware needed for the Color Temperature Test, and It is shown in Figures 5.8 and 5.9. This VI compares the current value of the *IRE level* to the IRE value from the last iteration (stored in the test global variable). If they are different or the flag in the test global variable is set to 1, this VI calls the appropriate driver. Otherwise, nothing happens. In this way the driver controller VI calls a given driver only if its parameters are different from one execution to the next.

This VI, when necessary, calls the driver for the PM5640 video signal generator to change the IRE level of the flat field signal. It also measures the x and y chromaticity co-ordinates and luminance of the current TV under test by calling the CA-100 driver in the xyY mode. Then it calls the CA-100 driver in the TduvY mode to measure the color temperature and difference from the blackbody locus. It

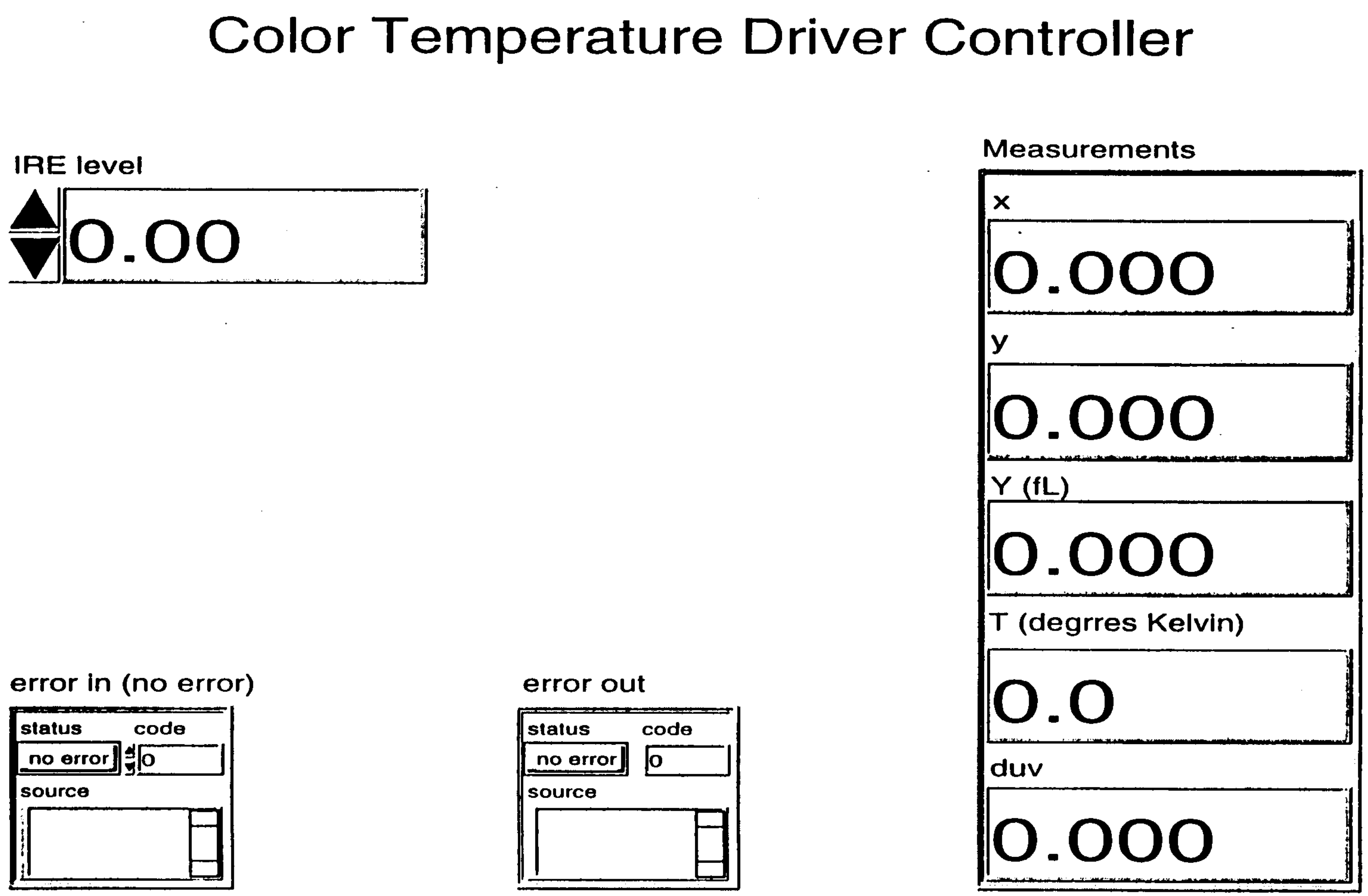

Figure 5.8 Front panel of Color Temperature Test driver controller VI

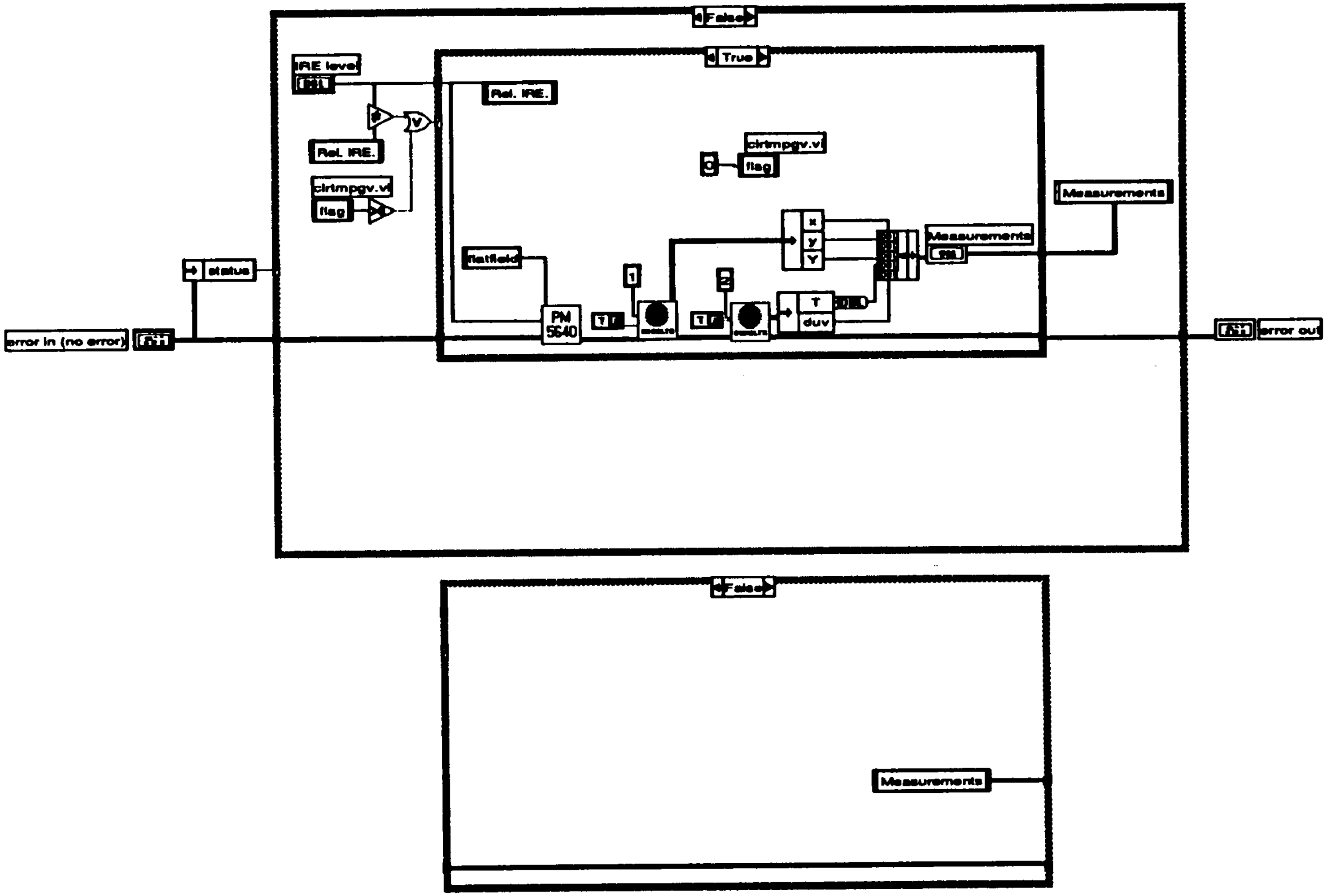

Figure 5.9 Block diagram of Color Temperate Test driver controller VI

writes the results of the measurements in a cluster in the test global variable.

5.3.5 Reset Stage

The Reset Stage is the last step of the sequence. The purpose of this stage is to restore the hardware to a known condition. This makes the ATF system more user friendly. Users do not have to spend time to understand the current system configuration and they can be sure that after each test everything is back to its normal configuration.

CHAPTER 6

CONCLUSIONS

The author joined the ATF team in the middle of the project. Therefore, she had a chance to take advantage of the other team members' valuable experience and work in order to make faster progress, gain much experience, and develop the LabVIEW code for a considerable number of tests. This experience proved that the ATF test system provides a greater resource of television performance information, better measurement accuracy, and higher labor productivity.

A few instruments involved in some of the tests are not computer controllable. Therefore, the software has to wait for the operator to do some adjustments or measurements manually. Even in this worst case the automated tests are much faster than their manual version. Automatic performance measurement improves productivity at least by mechanizing the initial setup for the test environment and by eliminating written records of the TV behavior. Automated tests are consistent, efficient, and reliable. The automatic testing system eases most of the test complexities and takes care of the various small problems. Therefore, the operator, confident about the setup, test, and recording accuracy can focus on the behavior of the television under test and examine it in more detail.

The design of the BIT software had a major impact on making all the tests faster and more productive. BIT provides a check of ATF system functionality as well as the up-to-date measurements of the output of the modulators. This makes the initial setup of the test environment much faster and saves a lot of time by performing its measurements during off times.

The LabVIEW programming language was found to be a wonderful environment for this project. Its graphical interface makes the software extremely user friendly. It is much easier to develop device drivers in LabVIEW than text-based programming languages.

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