AUBE '01

12TH INTERNATIONAL CONFERENCE ON AUTOMATIC FIRE DETECTION

March 25 - 28, 2001
National Institute Of Standards and Technology
Gaithersburg, Maryland U.S.A.

PROCEEDINGS

Editors: Kellie Beall, William Grosshandler and Heinz Luck

NIST CENTENNIAL 1901-2001

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National Institute of Standards and Technology
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A modular data acquisition system for the measurement of fire characteristics

1. Introduction

This article describes the development of a computer-aided data acquisition system as a component of an installation in a fire detection laboratory. With this laboratory standardized test fires (EN54) are possible as well as fundamental experiments. Besides the required measuring techniques (measurement of smoke density according to the ionization current principle and the extinction principle, temperature and weight loss) the system offers the possibility of implementing new measuring instruments and sensors relatively simply due to its modular structure. Thus this system can accomodate new measuring instruments of interest in the future. The motivation for developing this new data acquisition system was to submit a proposal for a standardized data acquisition in other laboratories which can accomodate various existing and possible new standards. The goal was to launch a flexible hardware and a user friendly expandable software. Thus the source code of the program has to be understandable not only for experts such as e.g. C++ programs. On the other hand we wanted to replace the existing system with a much more comfortable system.

2. The fire lab

The existing fire lab consists of the main fire room with a base of 10.5 m * 9.0 m and two observation rooms, situated over the other. The ceiling in the main fire room is vertically adjustable (2.87 m ... 6.57 m). Therefore, the fire lab provides the opportunity to perform standardized test fires as well as basic experiments with different room heights and volumes. The technical equipment is placed in the upper observation room as well as on top of the adjustable ceiling. The top of the ceiling can be walked on if the ceiling is in the maintenance position. Non-inflammable plates (0.6 m * 0.6 m) on the underside of the ceiling can be removed. This enables easy equipment assembly.

Requirements for the data acquisition system to be developed:

1. Computer-based data acquisition system

   The data acquisition hardware should be placed on top of the vertically adjustable ceiling. That has the advantage that new devices can be installed easily and quickly. Further computing facilities should be placed in the observation room.

2. The existing devices should be connected directly and trouble-free. Figure 1 shows the structure of the data acquisition system to be realized.

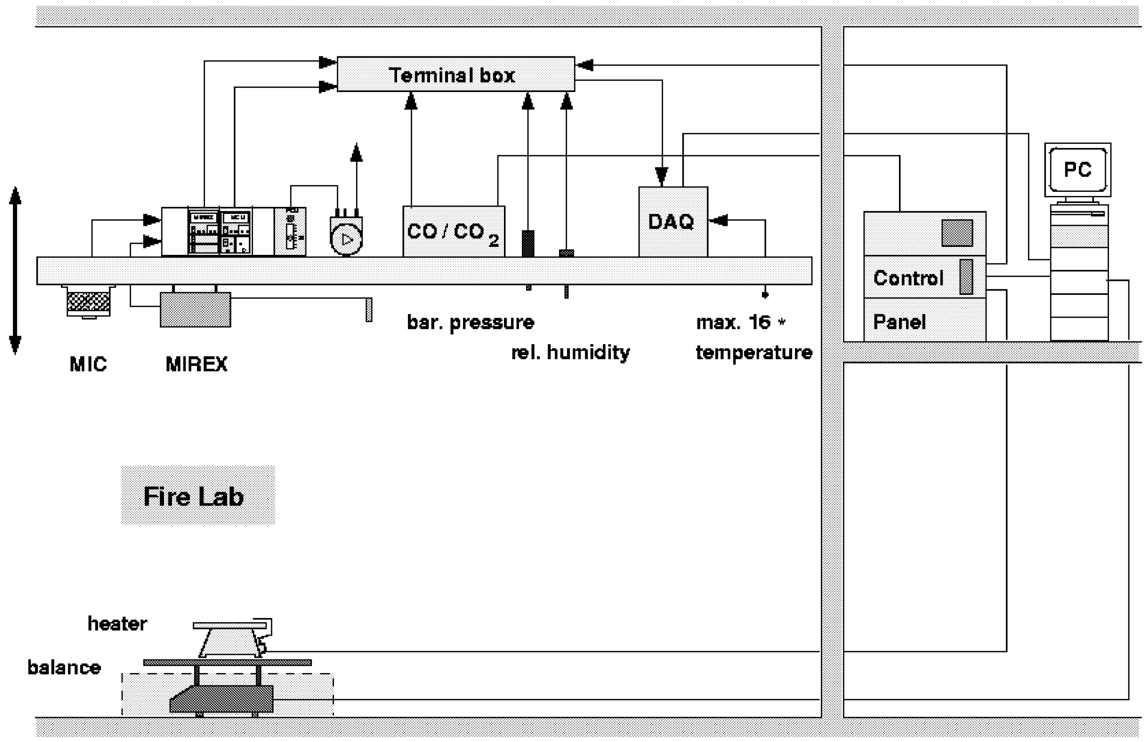


Figure 1: Structure of the data acquisition system to be realized

- Basic measuring equipment meeting the requirements of the European standard EN 54:

  Measuring ionization chamber (MIC), smoke density measuring instrument according to the extinction principle (MIREX), temperature sensor (Pt100), balance, controller for the heater and measurement of the heater temperature

- Further devices for basic experiments:

  The reduction of false alarms is only possible if (as much as possible) information about normal surrounding conditions of fire detectors is known (e.g. relative air humidity, barometric pressure, temperature distribution under the ceiling). The inclusion of gas detection within multi-sensor detectors requires a new reference measuring technique. Therefore measurement of the CO and CO_2-concentration is recommended. Appropriate measuring instruments are installed.

3. The hardware should be produced and tested by a well-known manufacturer. A trouble-free installation and a world-wide support had to be guaranteed.
4. The software to be developed should be written in a programming language which is adapted to the chosen hardware. The software should have the ability to monitor the measured data online.

3. Modular hardware design

The implemented system consists of the following components:

- Data Acquisition System (hardware and software)
- Computing Facilities
- Measuring Devices
- Control Panel

To develop a high quality data acquisition system for measurement and control it is important to understand the function of all components. In this field signal conditioning is especially important because existing sensors provide multiple electrical signals in various forms. The data acquisition system has to be adapted to measure all these different signals. The type and number of sensors (thermocouple, RTD, voltage or current output of a device) define the components of the system. Interesting is for example the number of channels (single-ended or differential), the resolution of the analog signals and the sample rate.

The chosen modular SCXI-system is produced by National Instruments Corporation. The data acquisition system consists of a module housing (SCXI-2000), a data acquisition card (SCXI-1200) with 24 additional digital inputs and outputs for the adaptive control of devices (e.g. controlling the air conditioning system) during a test fire, a 16-channel-multiplexer (SCXI-1122) for temperature sensors (Pt 100) with a terminal box and a 32-channel-multiplexer (SCXI-1100) for voltage channels with a 32-channel-terminal-box (BNC-2095) with BNC-connectors (for various measuring instruments). Figure 2 shows the structure.

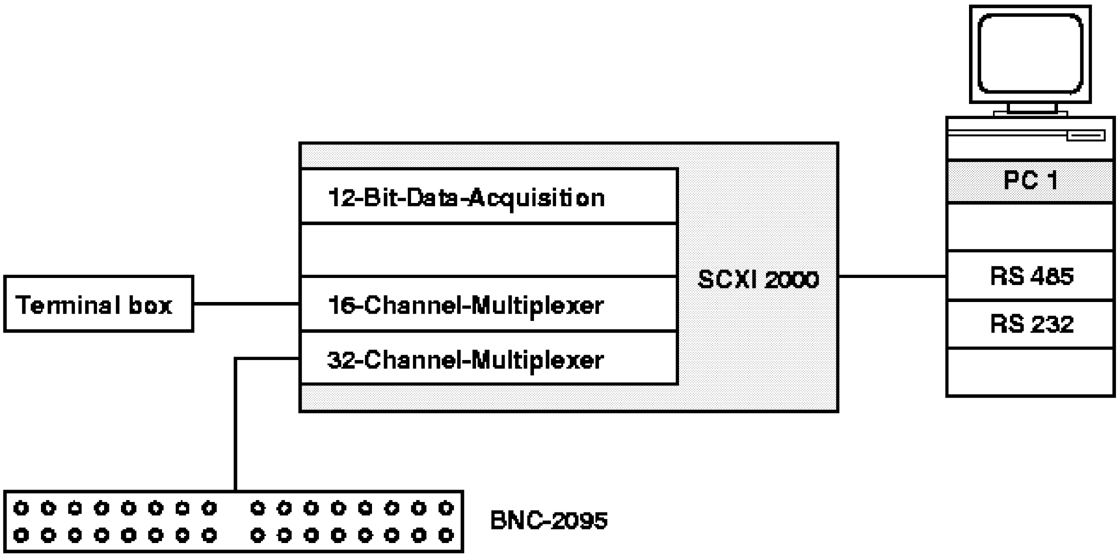


Figure 2: Structure of the chosen data acquisition system

The realized system concerns a modular structuredsystem which is expandable at any time and is connected to the central computer via RS-485 serial communication. The advantages of data transmission via RS-485 over the conventional RS-232 are:

- longer distance (max. 1200 m)
- faster data transmission (max. 1 Mbps), data throughput will usually be limited by serial communication rates
- lower error probability during data transmission (by symmetric signals)

The appointed computer is a standard-PC (Pentium 3 / 500 Mhz) with 256 MB RAM and an additional RS-485 serial interface, the operating system is Windows-NT. The presented flexible data acquisition system is an integral component of a computer network (see figure 3). The archived data can be accessed by all installed computers.
The control panel in the observation room contains the display unit for CO and CO_2, the components for controlling the heater, a module with the power switch, fuses and switches to drive the connected measuring instruments with the option to install further devices in the housing. It is connected to the central computer via a RS-232 serial communication.

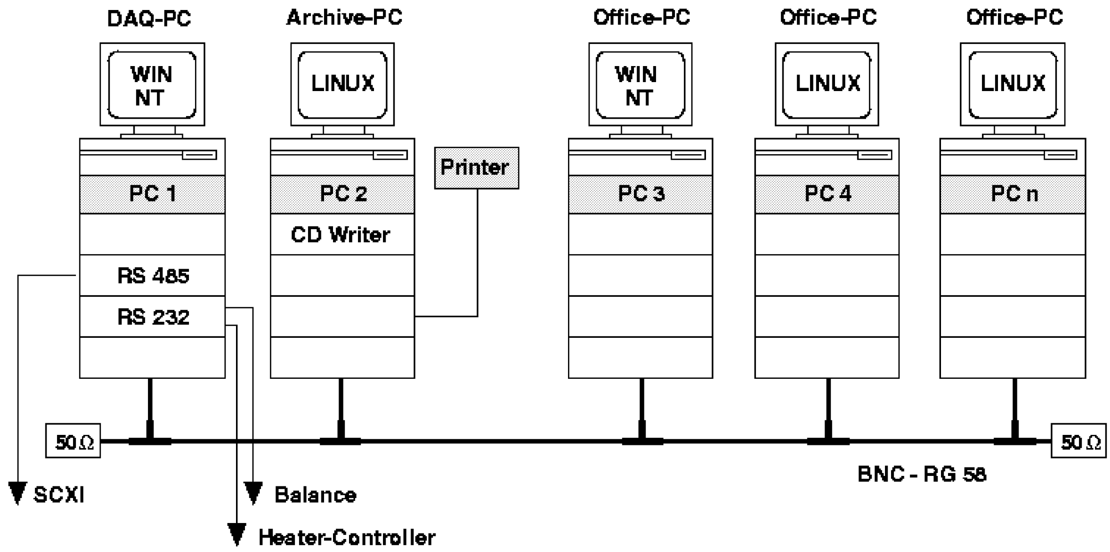


Figure 3: Structure of the computer network

4. Data acquisition software

The software integrates the sensors, signal conditioning, and data acquisition hardware into a complete and functional system. The developed software enables controlling of test fires with the ability to monitor measured data online. Filesaving and documentation are possible as well as the following representation and analysis of the measured values. The software is designed with the graphic programming language „LabView" and afterwards compiled into a not editable, only executable program by the „Application builder". This executable application runs at compiled execution speeds and does not require a separate run-time system. A non-changeable user frienly software is provided to the user, so that the source code is protected against undesignedly modifications. Modifications can be made only by an authorized person.

4.1 Review of use of the graphic programming language „LabView“

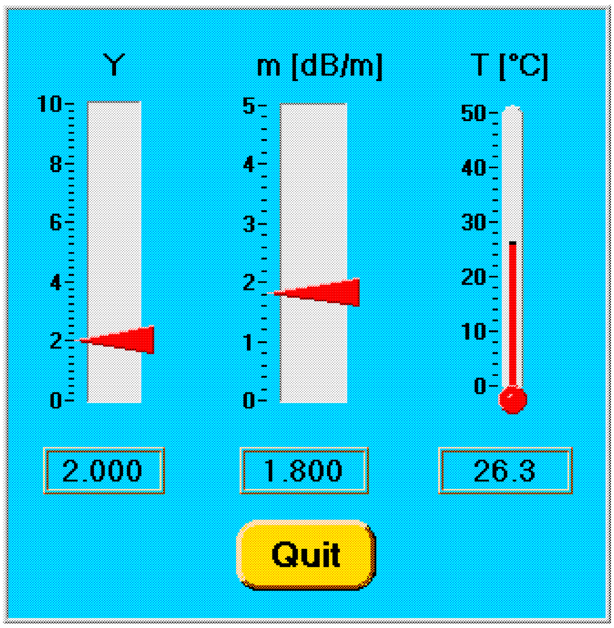
The graphic programming language „LabView" was developed by „National Instruments Corporation“ for controlling data acquisition hardware and has broad in the application field of automation and instrumentation. The use of „LabView" as programming language offers the advantage that a clear, easily understandable surface is provided, which can be served without detailed knowledge.

The programs are titled „Virtual Instruments (VI)“ and consist of two parts:

- the front panel user interface with indicators and operative functions for the interactive control of the software system
- the diagram with the wiring of the applied functions

Graphic programming with „LabView“ is accomplished in two steps: VIs are built instead of written programs:

- component placement (indicators and controls) in the front panel window: Objects are chosen from the „Controls palette“, e.g. numeric displays, meters, thermometers, charts, and graphs. Parallel to the component placement in the panel window corresponding symbols are generated in the diagram. When the VI is complete the front panel is used to control the system while the VI is running. Figure 4 and 5 show an example.
- component placement and wiring of the components in the diagram window: Component placement and wiring is similar to constructing a graphical block diagram. Objects are chosen from the „Functions palette“ e.g. arithmetic or logic functions and file I/O operations. These interconnections are used to transport data from one component to the next as well as controlling the program sequence at the same time. A component does not start processing until valid data are available at all inputs. This type of programming is called dataflow programming because the interfaces transmit data as well as controlling the program sequence.



Picture 4: Panel with three indicators, Checking start conditions

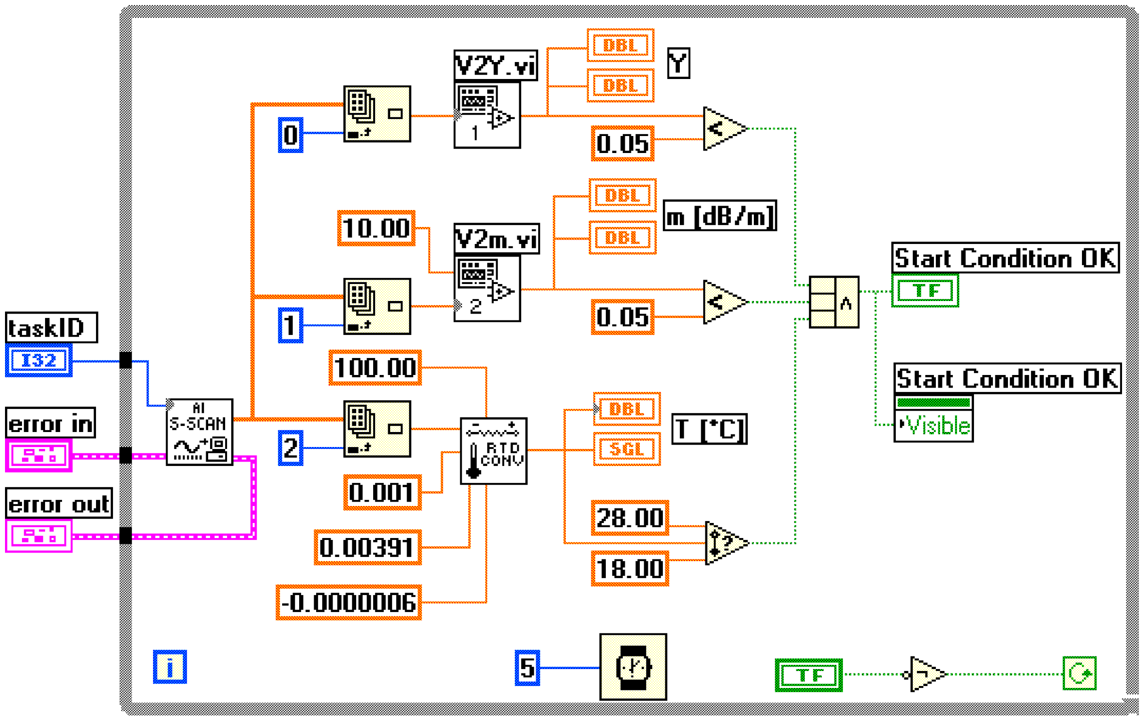


Figure 5: Diagram for the front panel shown in figure 4

A running VI is controlled by the flow of data between blocks, and not by the linear architecture of sequential lines of a text. Any VI can run independent or as part of another VI. It is possible to create diagrams that have simultaneous operations. „LabView“ has the ability to create VIs in a modular design. Created VIs can have their own icons, so that a hierarchy of VIs and SubVIs can be designed.

An example for a diagram with custom made SubVIs (with the icons „V2m.vi“ and „V2Y.vi“) and „LabView“-functions is shown in figures 5, 6 and 7. The diagram shown in figure 5 belongs to the front panel shown in figure 4.

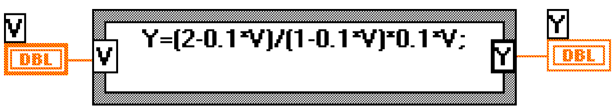


Figure 6: „SubVI“ converting MIC-voltage to „Y“

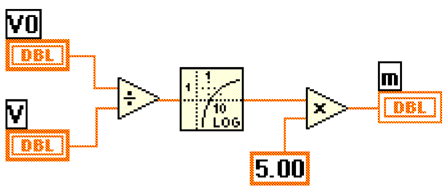


Figure 7: „SubVI“ converting MIREX-voltage to m [dB/m]

Smoke density measured with the „Measuring Ionization Chamber (MIC)“:

$$Y = \frac{(2-X)}{(1-X)} \cdot X \qquad [1]$$

$$X = \frac{U}{10V}$$

X: relative chamber current change

Y: smoke density

U: measured X-value

Smoke density measured with the „Extinction measuring equipment (MIREX)“:

$$m[dB/m] = (\frac{10}{d}) \cdot \log(\frac{1}{T}) \qquad [2]$$

$$T = \frac{U}{U_0}$$

m: extinction module

d: active light path in smoke

T: transmission

U: received light intensity with smoke

U_0: received light intensity with smoke

It is possible to modify, interchange, and combine created VIs with other VIs to meet application needs. Only the programmer can use these two levels. Operators may only use the front panels. Thus operators cannot modify programs.

4.2 Review of the developed data acquisition program

Beginning with the selection of the test fire to be recorded, the installation and selection of sensors, the representation of the measured values up to archiving and editing all functions are controlled by the system. The program is arranged in such a way that operating errors are largely excluded. Before a measurement can be started, the operator has to load a „profile“ (see figure 8) to provide the program with all necessary information:

- selection of the test fire to be recorded
- additional information:
    - operator, name of the project, additional remarks, etc.
    - sampling rate
    - data path
    - channel configuration:
        - status (inactive, to be measured, to be measured and displayed)
        - label (name of the sensor)
        - data range (minimum and maximum voltage level) of the sensor

After provide the program with these parameters it is possible to start the measurement. Measurement includes the following functions:

- checking start conditions according to EN 54 (see figure 4)
- offset adjustment of the input amplifiers
- data acquisition, scaling and online monitoring of selected measured signals (see figure 9)
- controlled fixing of the „end of test“ condition t_e and check of the reproduction requirements according to EN 54 part 9 as well as EN 54 part 7
- hand controlled setting of the „end of test“ t_e is possible
- filesaving

Following the measurement and filesaving it is possible to load and print prepared data (see figure 10) . Recorded data consist of two parts:

- the header with detailed information of the measurement
- measured values as a table

Its advantage is the representation of the measured values with a „LabView“ program as well as with a conventional spread sheet program (e.g. EXCEL).

5. Conclusion

The application of the chosen hardware, the programming language „LabView“ and the developed data acquisition software offers a high-performance data acquisition system, which is readily expandable. A further advantage of „LabView" as programming language is the compatibility with the installed hardware which bith come from the same supplier. „LabView“ was designed by „National Instruments Corporation“ to control data acquisition hardware. It is applied in various industry branches very successfully. World-wide support is guaranteed.

In „LabView“ the interaction between a user and the application proceeds in panels. The topics of these panels are specified by the respective application. Panels can generate other, overlapping panels. But only one panel is active at a time. The source code of a

„LabView“-program is not a linear program in a top-down design. Thus it is not sequentially readable as with other text-based program codes (e.g. C++). The program consists of numerous partly serial sequences, loops or other child panels (SubVIs). „LabView“ is a multitasking system. Thus it is possible to create diagrams that have simultaneous operations with the result that large and complex programs require a high degree of discipline from the developer during programming.

Even though the designed data acquisition program is very large, it is possible to expand or modify the program to adapt it to different standards which create additional requirements. The source code of the introduced software is understandable. Created VIs can be combined with other VIs to meet new application needs.

The modular structure of the introduced hardware and the developed software offer the possibility of also adapting this system for use in other laboratories as well as for special requests.

[1] Delta Electronics : Instruction Manual for Smoke Measuring Equipment, MIC Type EC-912

[2] Delta Electronics : Instruction Manual for Smoke Measuring Equipment, MIREX Type EC-910

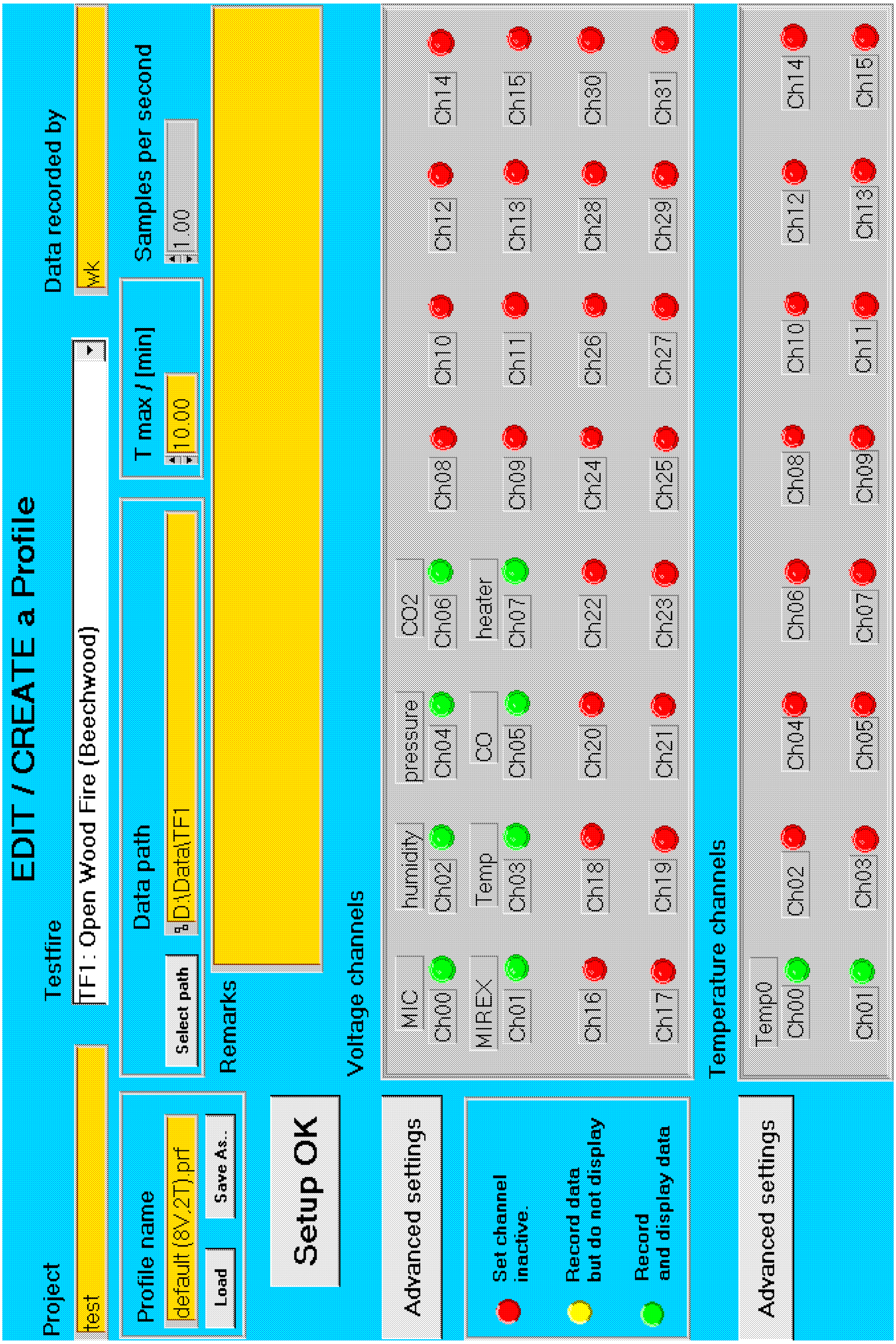


Figure 8: Load a „profile" to feed the program with all necessary information

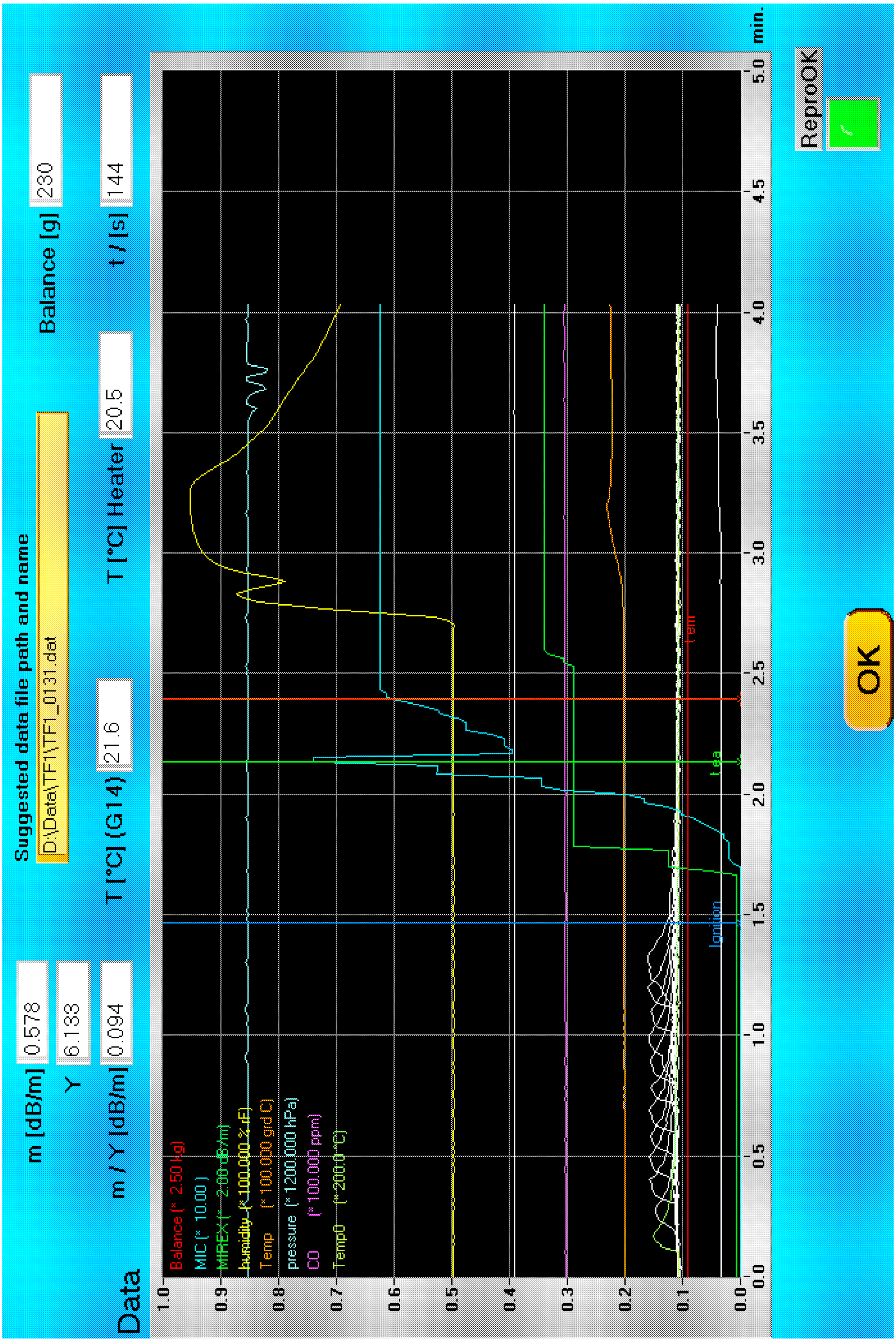


Figure 9: Representation of measured values during a fire test

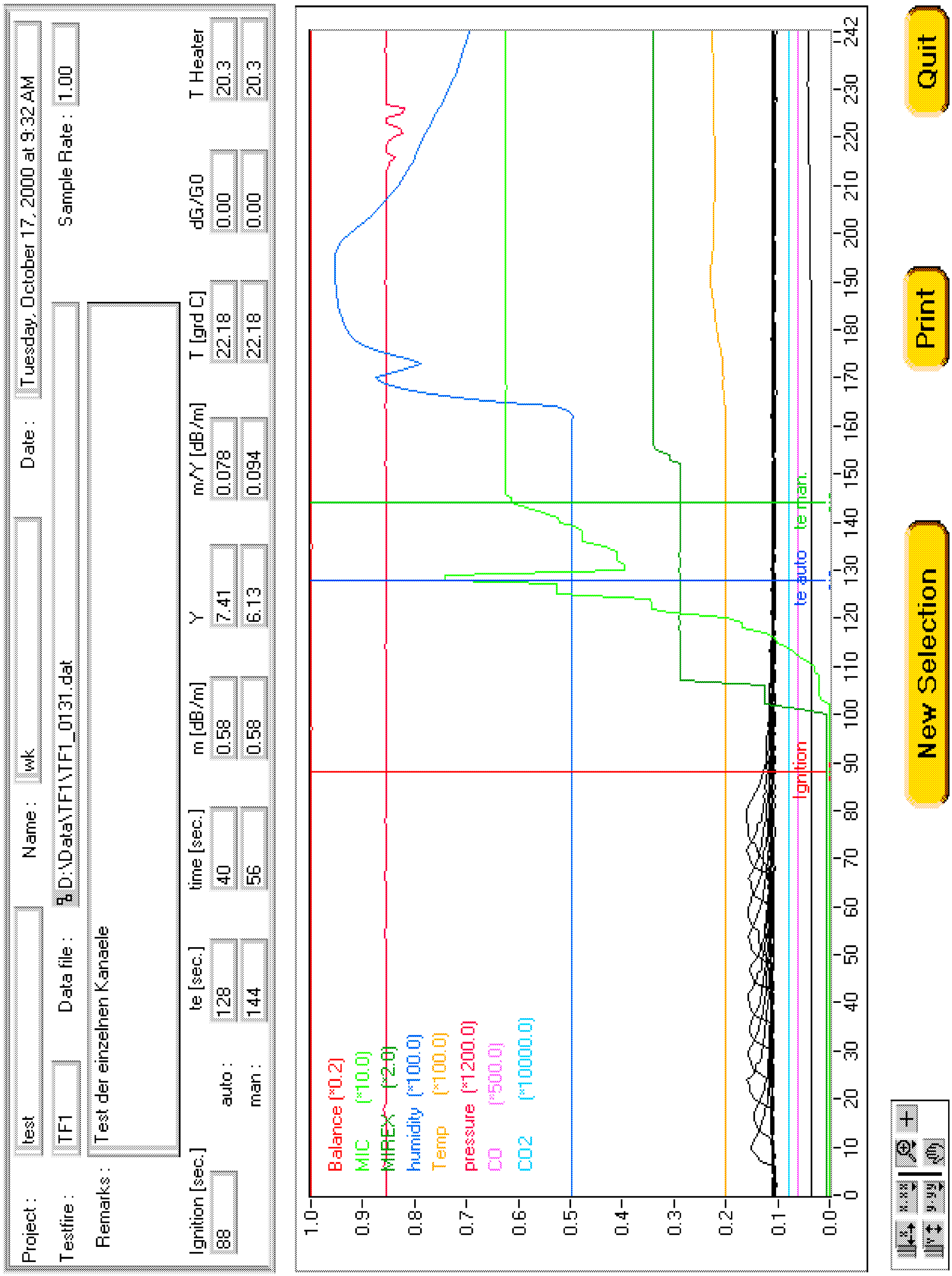


Figure 10: Representation of filesaved and prepared data