

A Universal Test Fixture Concept: The Standardized Breadboard

Gary Swager
Torrey Pines Research
Carlsbad, California, USA

Abstract

Product research and development requires a test fixture environment to support critical architecture studies, feasibility testing, data acquisition and process and materials experimentation. This presentation explores a new concept in test fixture development, the standardized breadboard, and the essential corresponding architectural considerations.

The standardized breadboard is a development platform with the mechanical, electrical and software infrastructure to support strategic experiments. Its very standardization requires a flexible infrastructure to make it a reusable test fixture. Supplementary specialized components, hardware and instruments expand the platform's usability and the scope of tests developers can perform.

This is accomplished by designing the breadboard so that components and hardware can be installed and removed to support the test being performed. By repopulating the breadboard with new hardware and loading the new software script required for the experiment, product development time is spent on developing products instead of test fixtures.

This reduction of time allocated to build new fixtures from "scratch" increases the time developers allocate to the strategic aspects of their program. Additionally, the breadboard's reusability would extend the life of test equipment, reducing costs. Most importantly, the familiarity gained by engineers, scientists and technicians in using a standardized breadboard would provide efficiencies in time and resources required to set-up, conduct, and conclude experiments.

Introduction

All product development passes through various phases. In most product development programs, a phase where the feasibility and risk assessment of new technology elements and novel architectures is required. This can be termed the feasibility phase.

As part of the feasibility phase, a normal course of action is to build fixtures to physically model technology elements and new machine architectures. These fixtures allow new thinking to be emulated, tested, and refined before substantial resources are employed to build a prototype incorporating this new thinking.

These fixtures are normally single purpose structures that are built to satisfy a particular product program, or for that matter, particular technology elements within a product program. Therefore, the architecture and usability of the fixture is constrained and makes it difficult to reuse. This leads to fixtures being abandoned after they have served their limited purpose and their relegation to a source of parts for the next fixture design cycle.

The Standardized Breadboard

The standardized breadboard concept is comprised of five parts: the mechanical structure, power distribution, control electronics, control software, and data acquisition software.

Mechanical Structure

The mechanical structure is comprised of a cart frame constructed from extruded aluminum rails with appropriate mechanical connectors, an optical tabletop, and the framework and bracketry for installing the components of the particular experiment onto the top of the breadboard.

The use of an extruded aluminum for the cart frame provides the builder some important advantages. The extruded aluminum pieces and the corresponding mechanical connectors form a very rigid structure. At the same time, flexibility in the cart design is obtained. In many cases extruded aluminum cart suppliers have CAD software that allows the builder to design a cart system with the features required by the builder. Some important features are cart size, the addition of casters for portability, and component mounting hardware such as rails and slides for rack mounting equipment.

The optical tabletop is a cost-effective way to provide a relatively flat surface that allows flexibility in the way that experiments can be mounted. Usually a honeycombed optical tabletop is used to reduce cost, increase flatness, and reduce weight of the overall breadboard. The tabletop is attached to the cart with vibration isolation hardware. Optical tabletops are available in a wide range of sizes so that it can be matched to the size of the cart and surface area requirement. The tabletop has threaded holes in a fixed grid over its entire surface. This facilitates a flexible-mounting scheme for the experiment components. Although most optical tabletops are constructed using stainless steel, it is important that the stainless steel be of a type that will allow the use of magnetically mounted clamps.

The framework and bracketry used to mount the components needed for an experiment are somewhat unique to the type and range of experiment to be conducted on the breadboard. For instance, if a rotating shaft is required, such as that used in a typical EP process experiment, a generalized framework can be constructed that has a precision shaft and a motor-drive system. This framework can be rigidly mounted to the tabletop using the grid of threaded holes. Between the threaded holes in the tabletop and the vertical frame, additional bracketry can be designed to mount the process components that are arrayed around the rotating shaft.

In another example, an inkjet oriented breadboard would require a generalized framework that would support mounting of multiple kinds of inkjet heads and precision movement of same, and precision perpendicular movement of media. Such a framework can support a range of experiments and the addition of other components such as imaging equipment.

Such framework and bracketry should be designed with a couple of things in mind. First, the components and bracketry should be logically arranged on plates so that they are easily mounted and dismounted from the tabletop surface for quickly switching experiments. Secondly, the builder should strive for a mechanically open structure so that there is room for observation, mechanical changes to experimental components, and integration of additional components.

Power Distribution

In designing the power distribution system, the primary power source must be determined, and the amount of power required by the breadboard must be analyzed (i.e., fuser experiments require more power than inkjet head testing). Only then can the components of the power distribution be picked. Where the power requirements are modest but the primary voltage is incompatible, a transformer can be used shift the voltage to a level that is compatible for most equipments and power supplies.

The types of outputs desired from the power distribution system are multiple, computer-switched, primary power receptacles, un-switched receptacles, and DC power of various voltages for supplying discrete logic and sensors.

There are commercially available power distribution boxes available. The builder’s decision of make or buy comes down to the amount of flexibility required vs. cost and availability.

Another consideration is the mechanical configuration and how that integrates with the mechanical mounting and location of the devices and components to be powered. Harness routing for electrical noise, safety, and flexibility are important considerations in the power distribution design.

Control Electronics

Control electronics consists of a system controller, input and output lines, various device controllers, and the actual motors, actuators and sensors.

The system controller consists of a Pentium-class industrial computer with adequate system resources for the task. The system controller can run a real-time operating system such as VxWorks®. Installed in the backplane of the system controller are various I/O and timer boards. The software to manage time-driven events in the experiments uses these timer resources.

A separate chassis mounted in the cart would receive the I/O signals from the boards in the system controller. The purpose of the chassis is to provide flexibility to the builder in configuring a variety of I/O configurations. Through the use of patch boards, the builder can match the needs of a particular signal to the signal levels required by the I/O boards in the system controller. Such things as level shifting and optical isolation can be accomplished. Harnessing defined by the experimenter would be associated to I/O lines using screw terminals on the patch boards. In addition, the chassis mechanicals would allow for the mounting of solid state relays and a small number of servo motor drivers. I/O lines might be used to read the digital or analog state of a sensor, set the voltage output of a high voltage power supply, or drive a solenoid through a solid state relay.

Device controllers for both input and output devices, depending upon the size and number, can be housed in the I/O chassis, another chassis, or a component in the 19-inch rack. Whenever possible the breadboard designer should designate a family of devices that have common characteristics, such as having servo motor controllers that are of the same brand, with the same form factor, the same electrical configuration, and the same performance characteristics. By standardizing in this way, not only will the breadboard integration go smoother, but the user of the breadboard will have a more complete collective understanding, will be better at predicting the performance, and more productive in performing experiments.

Control Software

When considering the architecture of the control software several factors should be considered. Among the are:

- Who will be operating the software?
- Is real time operation required?
- What is the paradigm for programming the sequence of events that must occur?

Assuming the individual running the experiments is probably not a software programmer, an easy-to-use interface and an easy-to-understand, programming paradigm are required. As far as ease of use, the Microsoft® Windows® environment not only relatively standard and stable, but it is also ubiquitous in the technical community. Within this environment, an easy to use breadboard control application can be run.

The control program has three uses. First, it is the tool to define and name given I/O lines with names that match the electromechanical devices, or functions that are to be controlled. Second, the application must have a way to program the sequence of events (Scripting) that must take place to run the experiment. And third, if there is data acquisition equipment, the application must allow for the display and logging of the data to be acquired.

There are commercially available packages such as LabView™ that provide these capabilities. A common criticism is that these applications have a tendency to be difficult to use for complex experiments due to their general-purpose nature, and that it is difficult to make them perform in real time.

The latencies found in general purpose operating systems such as Microsoft Windows make it difficult to control experiments that require precise timing for sequence control or data acquisition. This can be overcome by either using special purpose hardware, to provide real time sequencing and data acquisition, or by using general purpose hardware such as an IBM PC compatible software running a real time operating system like VxWorks.

Data Acquisition Software

In some cases the user does not require the ability to print, display, and store the output(s) from data acquisition equipment. Therefore, to the extent that data acquisition software can be separated from the control application, it could save money and complication to do so.

An example of data acquisition is the reading of the voltage on a charged photoreceptor surface where the object of the experiment is to identify and isolate abnormally charged areas. In this case, it is important to tie the photoreceptor's angular position to time-stamp of when the abnormal reading occurred. Depending upon the precision required in identifying the location on the photoreceptor's surface, a data-acquisition program, operating in real time, might be required.

Conclusion

The standardized breadboard concept can reduce the normal allocation of time and resources to the inevitable process of creating test fixtures for technology and product development programs.

However, designing and building a standardized breadboard for maximum return on investment is not trivial. There are many factors to consider. Key factors include the long-term range of intended use, and designing the mechanical, electrical, and software architectures to provide the maximum flexibility over the range of intended use. It is also important to design it to maximize ease-of-use factors for the primary user.

Biography

Gary Swager has been involved in electronic printing since 1974. He was a Member of the Research Staff at the Xerox, Palo Alto Research Center (PARC) from 1974 to 1980. Gary worked in the Optical Sciences Lab where he participated in the integration of monochrome and color laser printing systems for office automation studies. He then worked at Versatec, a Xerox subsidiary, until 1990 as Director of Systems Development, responsible for host connectivity and raster image processing. Since 1990, Gary has been a Principal at Torrey Pines Research, managing a variety of projects for clients in all areas of electronic printing system technology and product development. Gary holds patents in the area of electrophotography.