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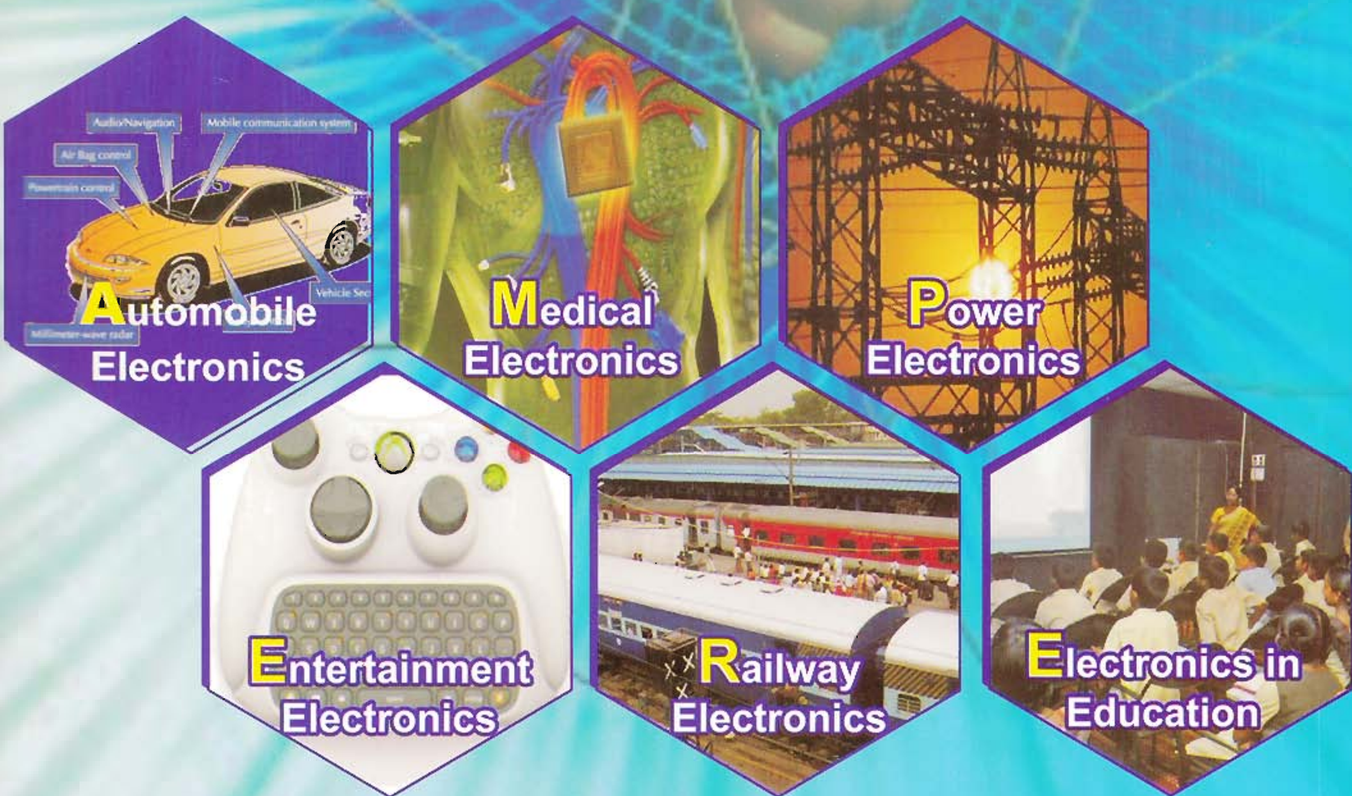


# Souvenir & Proceedings

# Universal Analog Hardware Test Bench

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*Abstract:*

***Teaching basic Analog and Digital Electronics at undergraduate level consists of theory classes with hands-on-training conducted in an electronics laboratory equipped with Oscilloscopes, Function Generators and Regulated Power Supplies. Students are taught the characteristics of basic components like diodes, BJTs, FETs, OPAMPs and Digital devices. We present a micro-controller based Automatic-Test-Equipment (ATE) combining the functions of standard laboratory equipment, providing a Low-Cost Teaching-Aid for Basic Electronics.***

***Key Words:*** ***Teaching Aid, Basic Electronics, Laboratory Equipment***

## I INTRODUCTION:

Carrying out practical laboratory experiments by students reinforces classroom teaching of theory in basic electronics. Typical experiments cover the characteristics of diodes, BJTs, FETs, OPAMPs and Digital devices and standard circuits based on these devices. Electronics Laboratories are equipped with Oscilloscopes, Function Generators, Regulated Power Supplies and other specialized equipment such as curve-tracers and precision power supplies. Alternatively, ATE systems which are used for experiments are based on PC based A/D and D/A add on cards and dedicated software tools. Both these approaches have a large cost element which restricts their availability and hence their usage is typically by students in small groups. By harnessing the power of ICT we present a simple low cost micro-controller based ATE system as an alternative to standard laboratory equipment.

The ATE system is built around a dsPIC30F4011 [1] micro-controller with simple analog/digital I/O interfaces connected to a PC through a serial link. The micro-controller operations are commanded by the Host PC using a GUI developed in Visual Basic. For ease of availability and in order to provide power to the circuits under test, a standard PC SMPS is used as the power supply.

The simple hardware can be fabricated by the undergraduate students themselves. By providing technical data and executable software free for non-commercial use we wish to encourage the computer aided teaching of basic electronics.

## II ATE HARDWARE

Figure 1 shows the simplified block schematic of the ATE system. In order to provide power to the ATE-Unit and the circuits under test a standard PC SMPS is used as the power supply. Three fuses are added in series with the +5V, +12V and -12V lines from the SMPS to the ATE-Unit for safety, as the SMPS though short circuit protected, is rated for a much higher current capacity than required for testing of simple circuits.

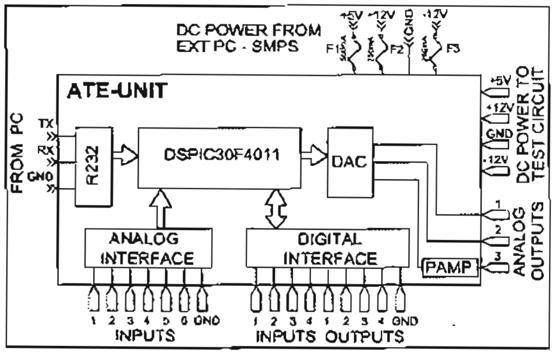


Figure 1 ATE-Unit Hardware Block Diagram

The ATE-Unit is connected to any available serial port on a PC with Windows XP operating system. It is also possible to connect the unit to the PC USB port using a USB-Serial port adapter. This serial port connection along with the "Universal Analog Hardware Test Bench" Ver1.0 software provides communication with the ATE-Unit.

The circuit under test can be rigged up on a standard breadboard and powered from the power sockets provided. Power to the ATE-Unit and to the circuit under test comes ON only when the power switch on the ATE-Unit is activated.

The ATE-Unit provides three ±10V, 10Bit, analog output channels Vout1, Vout2 and Vout3 to the circuit under test. While Vout1 and Vout2 are Op-Amp outputs with a drive capability of ±10mA, Vout3 is power amplified to provide a drive of ±200mA. The maximum throughput rate is 20 kHz.

Six ±10V, 10Bit analog input channels (Ain1- Ain6) with an input impedance of typically 1 MΩ are provided to read back analog data from the circuit under test. The maximum sampling rate is 2 mega-samples/sec.

Four buffered digital I/O channels (Dout1-Dout4 and Din1-Din4) are also provided for connection to the circuit under test.

## III ATE MICRO-CONTROLLER SOFTWARE

The dsPIC30F4011 is programmed to operate with a 6MHz crystal and an internal Phase-Locked-Loop multiplier of 16, effectively setting a clock frequency of 96 MHz. The A/D converters are set for 10 bit operation. The Pulse Width Modulated (PWM) outputs used for the DAC are set for 10 bit operation giving a throughput rate of 20 kHz. Serial communication is at 115 kbps. The micro-controller waits for a serial command and executes the following modes:

*1 ATE Test*

Once serial communication has been established and a Test message is received the system outputs an ATE Ready message.

*2 Read Analog Inputs*

On command the system carries out a 10Bit A/D conversion of individual channels, or all 6 channels and outputs the average of 10 samples.

*3 Read Digital Inputs*

Reads the 4 Digital channels and outputs the value as serial data.

*4 Write Analog Outputs*

On command the system sets the 10Bit PWM value of individual channels or all 3 channels, this outputs the Sample/Hold [2] value of a synchronized ±10V ramp voltage for the 3 analog outputs based on the PWM values.

*5 Write Digital Outputs*

Sets the 4 digital outputs to the value requested.

*6 Burst Mode*

Consists of three modules:

Load Burst Data: Reads up to 100 values of data to be output from Vout3. The number of values, delay between each output and number of cycles to be repeated are also read. The values are stored in internal memory.

Run Burst Mode: Sets the Vout3 voltages based on the values loaded and runs them for the required cycles in sequence with a programmed delay. The analog values of Ain1 and Ain2 are acquired after the delay setting after each analog out and stored in internal memory.

Read Burst Data: Transfers as serial data the acquired values of Ain1 and Ain2 corresponding to the last cycle of analog data acquired.

*7 Capture Mode*

Consists of four modules:

Free Running Mode: This module A/D converts a fixed number of Ain1 and Ain2 samples in a continuous sequence based on a programmable delay setting. Capture starts from the moment of initiation.

Continuous Mode: This is similar to the Free Running Mode except that it now is based on an interrupt generated by a selected edge and level of Ain1.

Sliding Mode [3]: This mode carries out the A/D conversion of Ain1 and Ain2 based on interrupts similar to the Continuous Mode but based on a programmable incremental delay setting.

Read Capture Data: Transfers as serial data the acquired values of Ain1 and Ain2.

## IV HOST PC GUI-SOFTWARE

The Graphical User Interface (GUI) software for the host PC with a Windows XP operating system is developed in Visual Basic.NET 2.0. The ability to integrate an MS ACCESS database and the GNU library plotting extension [4] are utilized to generate programmable analog/digital output streams using the ATE-Unit. Test data from the ATE-Unit is acquired back into the database from where it can be saved, plotted or exported to MS EXCEL. The PC software executes the following modes:

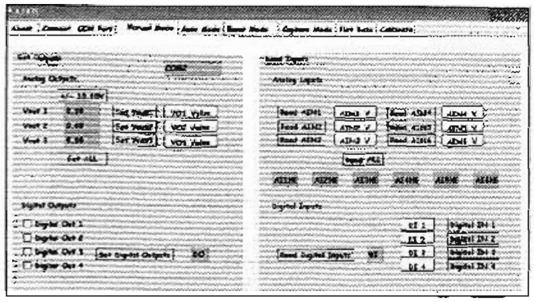

Figure 2 Manual Mode

*1 Connect to COM Port:*

This mode queries the PC on the available COM ports and permits the user to select the COM port to which the ATE-Unit is connected. Communication between the PC and ATE-Unit can be established and tested.

*2 Manual Mode:*

Figure 2 shows a screenshot of the Manual Mode. Analog/digital outputs can be set individually or as a group and analog/digital inputs acquired and displayed. While being the most basic mode of operation several experiments need fixed values for specific analog/digital outputs while others are being varied automatically.

*3 Auto Mode:*

The Auto Mode displayed in Figure 3 illustrates several of the ATE features. The values of Vout1-Dout are programmable with respect to the ID such that when they are output in a sequence with a programmable delay and number of repetitions, can create a user defined waveform or analog/digital output sequence. When applied to the circuit under test, the acquired values of Ain1-Din are written back to the database and can be saved or exported as an EXCEL file.

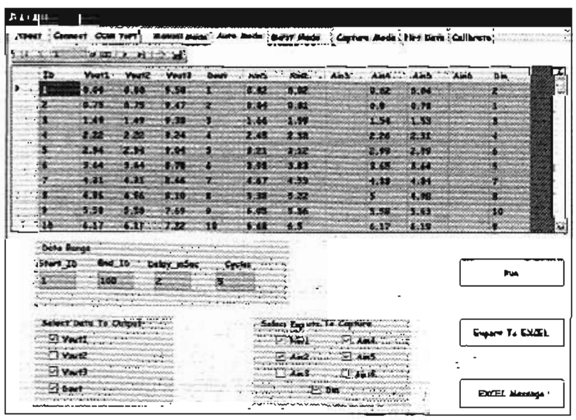

Figure 3 Auto Mode

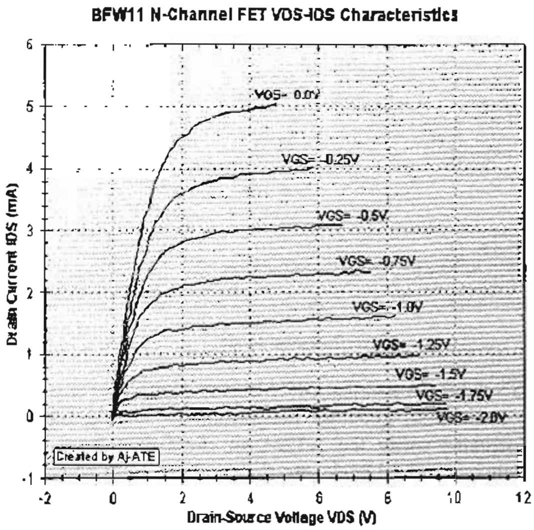


Figure 4 N-Channel FET Characteristics

*4 Plot Mode:*

Figure 4 shows a X-Y plot of the characteristics of an N-Channel FET. This plot is based on several traces each individually generated in Auto Mode for a sequence of voltages fed to Vout3 as VDS with fixed values set in Manual Mode to Vout2 as VGS. IDS values are measured across a load resistance.

*4 Burst Mode:*

The Burst Mode overcomes the relatively slow serial I/O process between the host PC and ATE-Unit which is used in the Manual and Auto Modes. In the Burst Mode, a sequence of values corresponding to Vout3 is first transferred to the micro-controller. A Run command outputs these values a much faster rate and acquires the corresponding values of Ain1 and Ain2 into memory. The acquired data is transferred back to the PC using the Read command.

Figure 5 shows the waveforms of a Monostable Multivibrator acquired in Burst Mode.

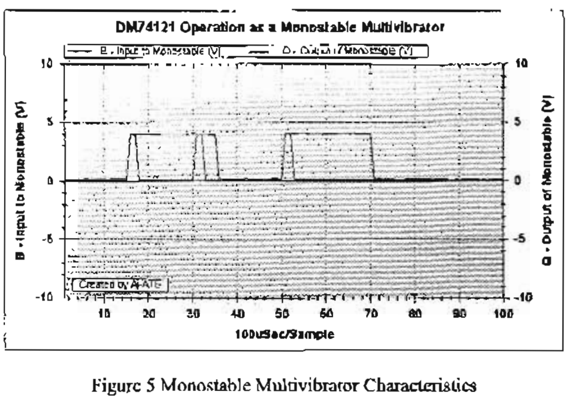


Figure 5 Monostable Multivibrator Characteristics

*5 Capture Mode:*

The 'Capture Mode' is a pure data-acquisition mode where no data is output from the ATE-Unit. When used in conjunction with the 'Plot Data' mode, the function is

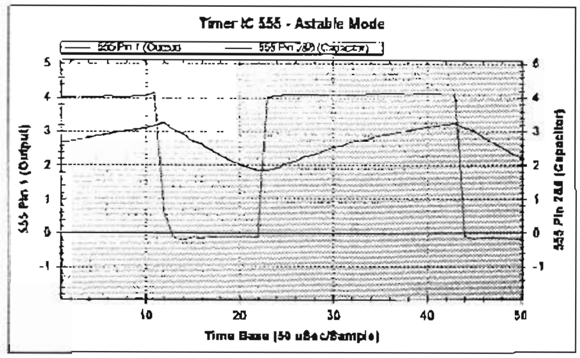


Figure 6 Capture Mode

equivalent to a 'Digital Storage Oscilloscope' with a maximum of 100 data samples.

For unknown signals, the 'Free Running Mode' is selected first as it is applicable for both repetitive and non-repetitive signals and does not need a trigger input. Once an unknown signal has been acquired using the 'Continuous Mode', the amplitude information is available and a trigger level can be set. This trigger level is applicable only to 'Ain1'.

The 'Continuous Mode' can be used for repetitive and non-repetitive signals where 'Ain1' is connected to the signal providing the trigger and 'Ain2' to any other point in the circuit to be monitored. The sampling rates are from 30μsec/sample to 50msec/sample. The maximum throughput rate is ~33 kilo-samples/sec.

In order to extend the bandwidth of the captured signals, the 'Sliding Mode' [3] utilizes the principle of sliding the sample point with respect to the trigger point by known intervals and reconstructing the input signal. This mode is applicable only to repetitive signals. The sampling rates achieved are from 0.5μsec/sample to 50μsec/sample with an effective maximum throughput rate of 2 mega-samples/sec. Input signals up to 50 kHz can be captured using this mode.

*6 Digital I/O mode:*

The four digital I/O channels can be used effectively in Auto Mode to study the characteristics of combinational and sequential devices such as NAND, NOR gates, flip-flops, counters and shift-registers. Figure 7 shows the results of an experiment on a 4-Bit binary counter.

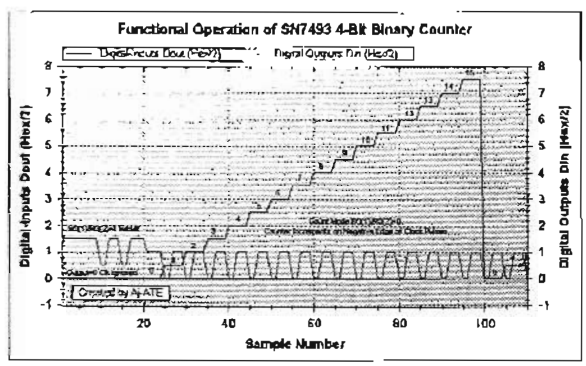


Figure 7 Digital I/O Mode

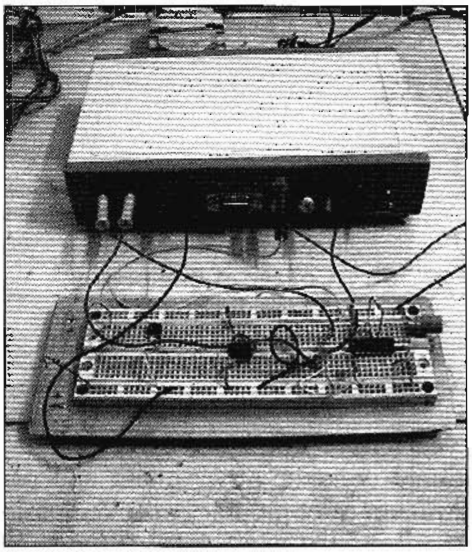

Figure 8 Experimental Setup

## V EXPERIMENTAL SETUP & RESULTS

Figure 8 shows the packaged ATE-Unit and a breadboard on which the circuit under test is wired. Power to the circuit under test is provided from the power sockets, and the input output cables are connected as desired.

To show the versatility of the 'Universal Analog Hardware Test Bench' 32 typical experiments carried out using this ATE system are listed in Table 1 below:

| | |
|---|---|
| 1 | Diode - Characteristics |
| 2 | Zener Diode - Characteristics |
| 3 | Diode - As a Rectifier |
| 4 | Transistor V- I Characteristics |
| 5 | Field Effect Transistor (FET) Characteristics -1 (VDS vs. IDS at different VGS) |
| 6 | Field Effect Transistor (FET) Characteristics - 2 (IDS vs. VGS at a fixed VDS) |
| 7 | Silicon Controlled Rectifier (SCR) Characteristics |
| 8 | Triode for Alternating Current (TRIAC) Characteristics |
| 9 | Op-Amp 1 - Inverting-Summer |
| 10 | Op-Amp 2 - Non-Inverting-Buffer |
| 11 | Op-Amp 3 - Non-Inverting-Amplifier |
| 12 | Op-Amp 4 - Difference-Amplifier |
| 13 | Op-Amp 5 - Comparator With Hysteresis |
| 14 | Op-Amp 6 - Relaxation Oscillator |
| 15 | Op-Amp 7 - Triangle-Square Oscillator |
| 16 | Op-Amp 8 - Wien-Bridge Oscillator |
| 17 | Op-Amp 9 - Quadrature Oscillator |
| 18 | Op-Amp 10 - Window Comparator |
| 19 | Op-Amp 11 - Precision Rectifier |
| 20 | Op-Amp 12 - Voltage Limiter |
| 21 | Digital 1 - NAND Gate |
| 22 | Digital 2 - NOR Gate |
| 23 | Digital 3 - S-R Flip Flop |
| 24 | Digital 4 - J-K Flip Flop |
| 25 | Digital 5 - 4-Bit Binary Counter |
| 26 | Digital 6 - Monostable Multivibrator |
| 27 | Digital 7 - Re-Trigerrable Monostable Multivibrator |
| 28 | Digital 8 - 2-Line to 1- Line Converter / Multiplexer |
| 29 | Miscellaneous 1 - EIA-232 Driver / Receiver |
| 30 | Miscellaneous 2 - LM555 Timer |
| 31 | Miscellaneous 3 - CMOS Schmitt gate |
| 32 | Miscellaneous 4 - B-H Curve |

Table 1 List of Experiments

## CONCLUSION

As an alternative to using expensive laboratory equipment, this paper presents a very Low-Cost micro-controller based ATE system for carrying out experiments in Basic Electronics at Undergraduate level.

The simple hardware can be fabricated by the undergraduate students themselves. By providing technical data and executable software free for non-commercial use we wish to encourage the computer aided teaching of basic electronics.

## REFERENCES


[1] Microchip Technology Inc. *DS70135G, dsPIC30F4011/4012 High-Performance, 16-Bit Digital Signal Controllers* Data Sheet

[2] Analog Devices, *Data Converter Architectures*, Section 3-1, pp. 167

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[4] http://www.resolverhacks.net,: *Charting with ZedGraph Basic Introduction*


### BIO DATA OF AUTHOR


**Ajoy Raman**, Fellow, IETE, retired as an Outstanding Scientist with 37 years of R&D experience in UAV electronic systems from ADE, DRDO Bangalore. Holding a BTech and MTech EE degree from IIT Madras he is a recipient of the Siemens Prize (IIT Madras), Scientist of the Year (DRDO) and Dr VM Ghatage (AESI) Awards.