

Supplementing EET Analog Labs with Switched Capacitance Integrated Circuits

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Abstract

Programmable Analog Integrated Circuits (IC) provides designers the capability to change analog circuits in the field. Although Programmable Switched Capacitance circuits are a technology that deserves study by itself, our main focus here is how such IC's can be used to supplement traditional EET Analog Labs.

Three major players in programmable switched capacitance are Cypress MicroSystems, Anadigm and Lattice Semiconductors. Cypress PSoC is a micro-controller connected to an array of digital and analog switched capacitance blocks. Anadigm produces a Field Programmable Analog Array (FPAA). Anadigm FPAA requires a micro-controller or FPGA to initialize and control the device via a SPI interface. Lattice Semiconductors is a competitor to Anadigm.

Circuits for all three development environments can be designed graphically before the lab to further save time. This paper will report on the utilization of three development environment to supplement the traditional analog labs. Actual circuits examples described were implemented in hardware for Cypress PSoC and Anadigm switched capacitance IC's. The paper will also provide a comparison table to discuss the features of the aforementioned development environments.

Introduction

Using programmable switched capacitance to enhance EET Analog Labs may bring to mind using CPLD/FPGA to enhance EET Digital Labs just a few years ago. The analogy between Digital and Analog Labs is not quite valid. In reality programmable switched capacitance is actually a hybrid digital/analog design technique [12]. As a rule of thumb the clock used to drive the programmable switched capacitance blocks must be about 10 times higher than the frequency of the analog signal to be processed [1][2][3].

There is also similarities that may be found between DSP's and programmable switched capacitance blocks. But once again the analogy between DSP's and programmable switched capacitance blocks is also limited.

Programmable switched capacitance blocks are a subject deserving study in its own right. Which begs the question of how programmable switched capacitance blocks can be used to enhance EET Analog labs.

Of course we perhaps should take a look at what material many EET Analog Labs currently cover. Traditional EET Analog Labs in a nutshell covers circuits where the following discrete components are used [4][5]: Resistors, Capacitors, Inductors, Diodes, Transistors BJT, FET, MOSFET, OP AMP and Linear Circuits. Typical circuits for EET labs are hard to pin down but often cover: Amplifiers, Filters, Modulation, Oscillator Principles, Rectification, A/D, and D/A.

A great advantage to having students work with discrete components gives the student a tactile learning experience. As we move further into this era of in house PCB software design and in house PCB fabrication capability breadboards and wire warping may well become obsolete [3].

Using programmable switched capacitance to enhance EET Analog Labs in the first phase simply adds switched capacitance experiments that can replace or supplement teaching the following topics[6][7][8]:

- Active Filters
- Amplifiers & Feedback
- Modulation
- A/D and D/A Converters

Configuration of Enhanced Analog Labs

The lab to setup for example filter and gain circuit is the same. There is rather simple signal generator to stimulate the circuit and an Oscilloscope used to ensure the output is as expected. The scope may also be used to confirm the input is as expected. Volt Ohm meters are available for use as well, to give students experience with meters. Figure 1 shows a block diagram of the lab setup.

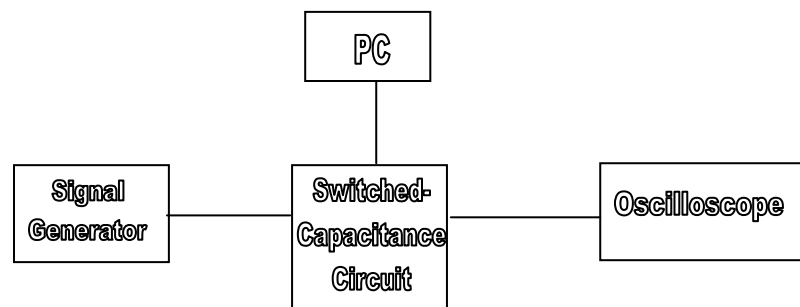


Figure 1. Block Diagram of Lab Setup

The analysis of the switched capacitance systems that follows is not about their usefulness as designer environments for which the systems were developed. The analysis of the three switched capacitance environments is from the standpoint of how each might be adapted to enhance the EET lab experience vs using more traditional discrete components.

Anadigm Designer 2

The Anadigm Designer 2 provides a design tool to develop filters. The internal circuit for the IC is automatically generated by depressing the “Build Circuit” button on the filter design tool screen. An example of the filter design tool screen is given in figure 1.0. Some filters require more than one Anadigm IC to implement the circuit.

This feature may or may not be productive from the lab viewpoint in that it eliminates the student from having to design the circuit from scratch. A positive benefit is the capability to try a large number of filters in a lab circuit simple by downloading each one in turn to the actual lab circuit. This is especially useful when the filter is just one section of the lab circuit under consideration.

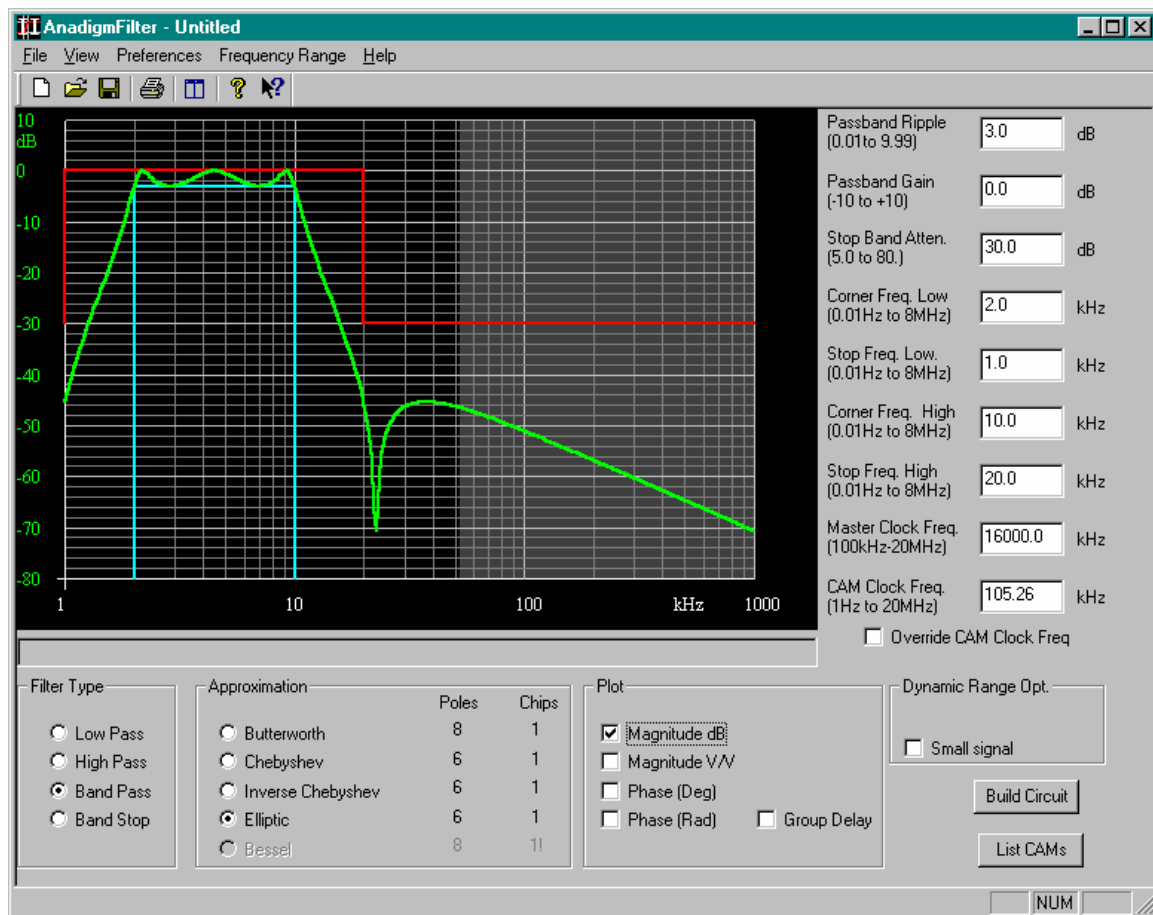


Figure 2.0 Filter Design Tool

Figure 2.0 shows the generated circuit from the design screen shown in figure 1.0. The students can simulate any filter they design and see the results of a injected signal source by moving around a simulated scope probe .

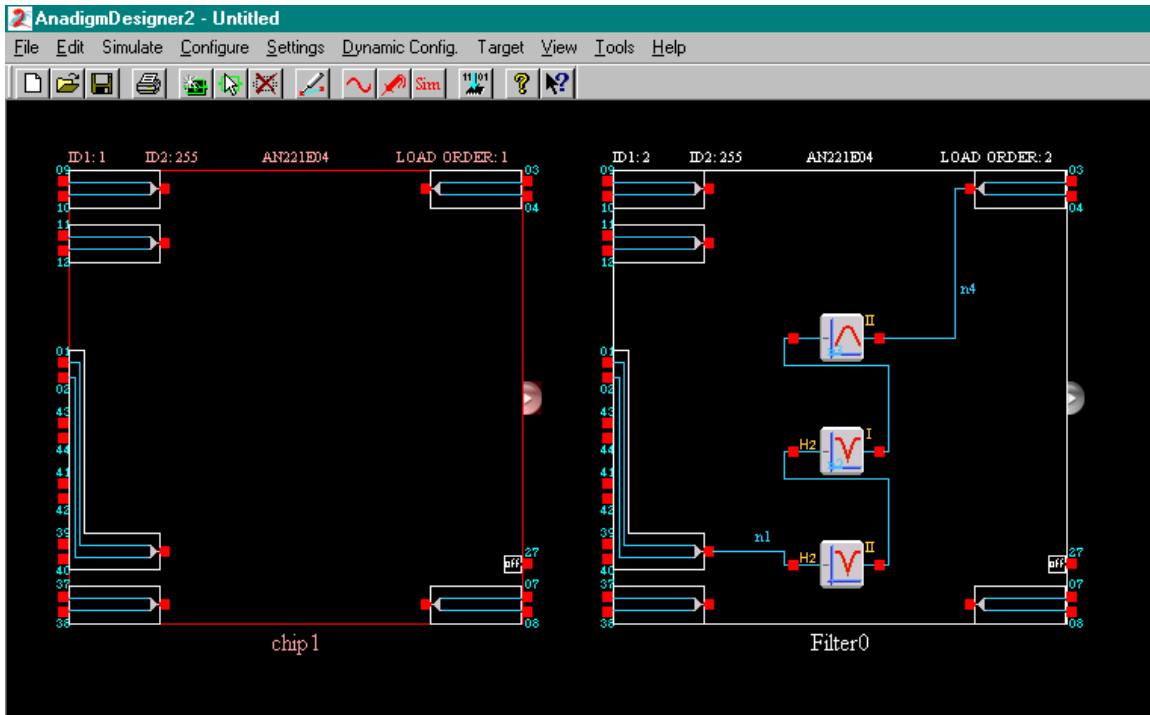


Figure 3.0 Filter Circuit Generated by Design Software

Circuits can be re-wired or configured by clicking and moving the various components or wires in figure 3.0. The students can also develop their own circuits using the circuit display screen in figure 3.0.

With the exception of filters and PID controllers all circuits are designed and built with screens similar to figure 3.0. Figure 5.0 shows an example of one of the PID controller design screens.

Once again a PID controller can be designed and built using a screen similar to figure 2.0, but the PID controller design tool allows quick design of the circuit.

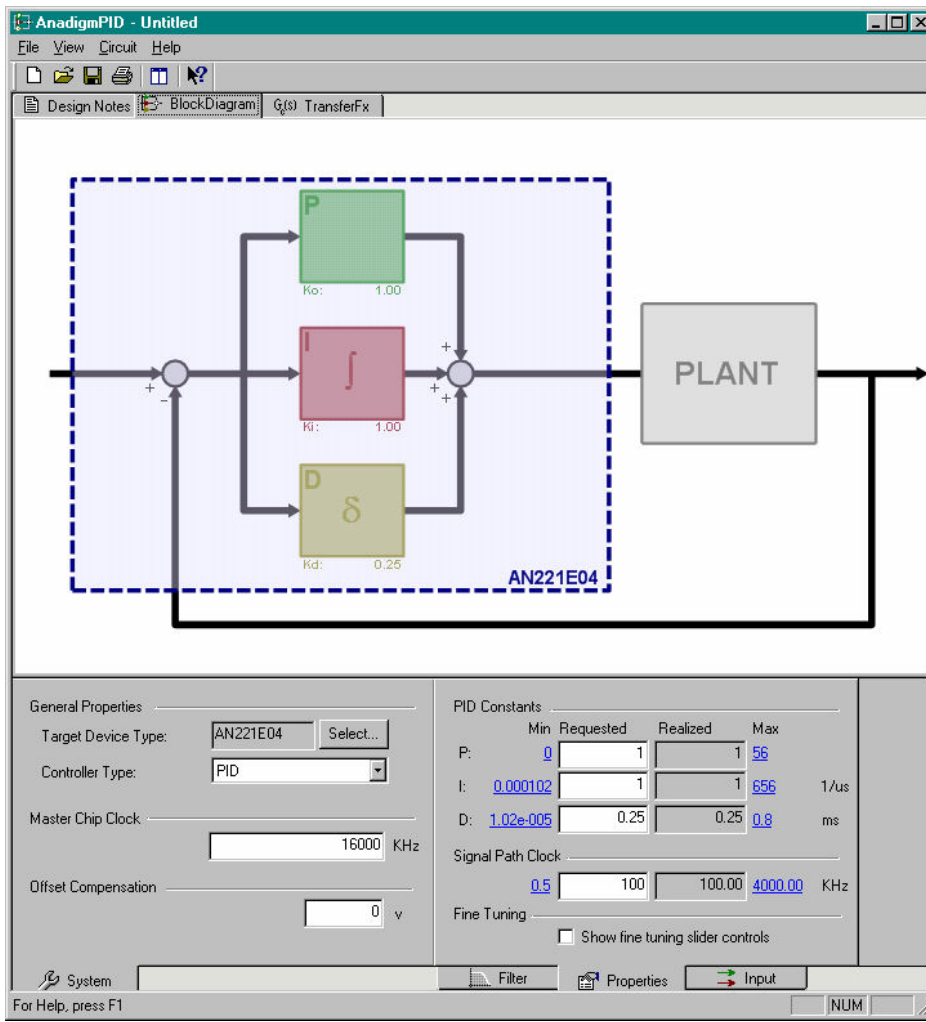


Figure 4.0 PID Controller Design Screen

Dynamic configuration updates of the Anadigm IC's in real time can create interesting audio applications, which is one area where the programmable IC has an advantage over more traditional analog circuitry.

The Anadigm IC requires an external processor to load the configuration. In an actual design the configuration could be loaded from a processor, PLC, or even memory IC. Anadigm sells an evaluation board that works in conjunction with Anadigm Designer 3.0 software.

Between the simulated scope, design utilities for active filters and PID controllers the students should be able to quickly design and test lab circuit components outside the lab saving valuable time and resources.

*Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition
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PAC-Designer 3.0

The first step in the PAC-Designer 3.0 environment developed by lattice is to select the type of circuit to download. Using the PAC Library Browser screen shown in Figure 5.0.

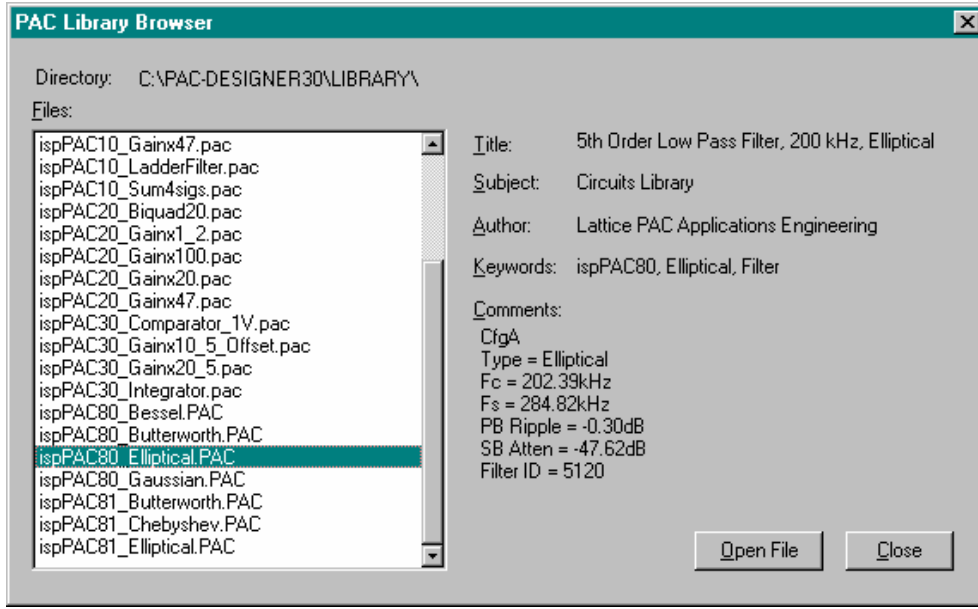


Figure 5.0 PAC Library Brower

Figure 6.0 shows the downloaded circuit or configuration for a Elliptical filter.

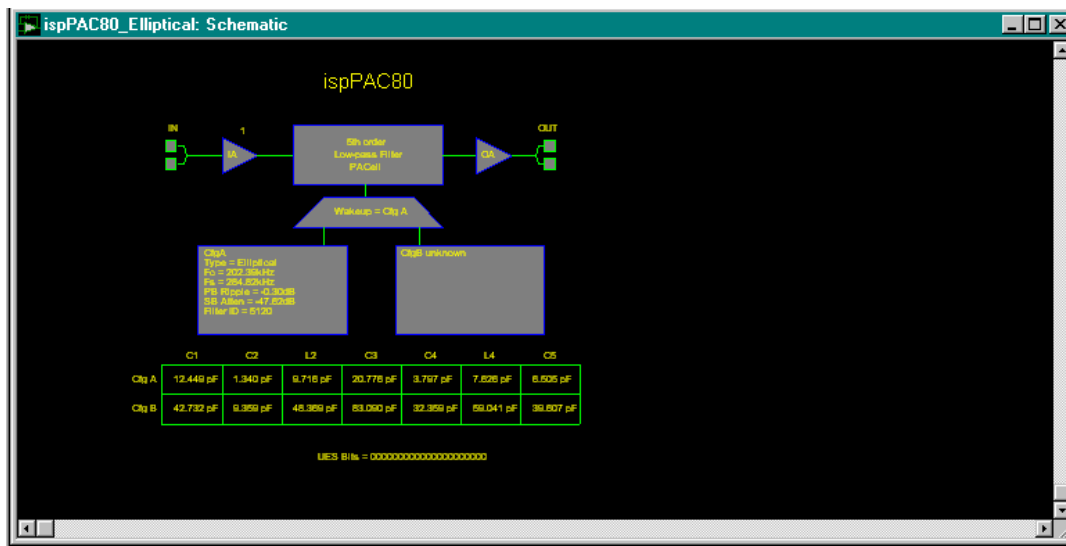


Figure 6.0 Downloaded Elliptical Filter Circuit

The Elliptical filter can be simulated and the results shown on graphs similar to figure 7.0. There are a variety of graphs that may be displayed showing simulated results. Out of the three environments this was the easiest to understand and utilize. The PAC environment seems to allow the least student manipulation of the circuits. The PAC Designer 3.0 environment would seem ideal for labs experiments where students changing filter types would add to the experience for understanding a larger system.

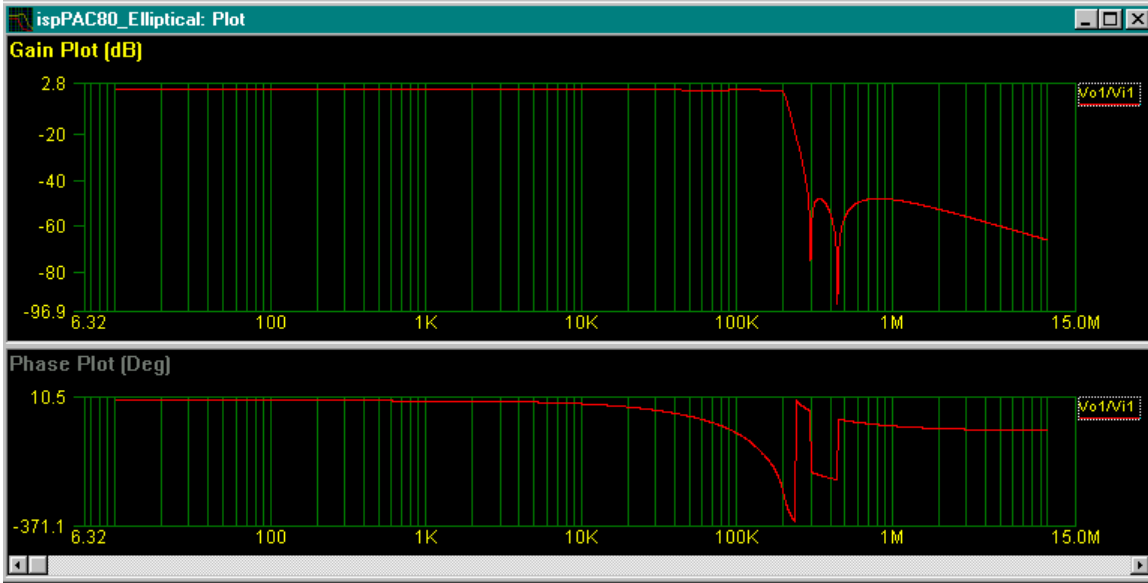


Figure 7.0 Results of Simulation of Elliptical Filters

PSoC Designer

Of the three environments the PSoC designed by Cypress was the most complex to learn but has many uses as far as the lab goes. Like the Anadigm and PAC environments there is a tool to configure different filter types. Figure 8.0 shows one of several screens used in the design of a filter.

2-Pole Band Pass Filter Design Procedure

Enter Data fields in yellow
 Optimize values for C2 and C3 in orange and C3 (auto-calculated) to:
 Verify calculated Q matches derived Q in blue within 10%
 Enter plot step Resolution in yellow.
 Select the "OK" button to apply changes to PSoC Designer.

Center Frequency (Hz)	1000.0	Enter Resolution: 5.000
Bandwidth (Hz)	100.0	
Gain (dB)	0.00	

Derived Filter Section Requirements:	
Q:	10
scaled f0:	1000
Gain (V/V):	1
User Module Design Parameters:	
C2:	10
CA:	32
CB:	32
C3:	10
c4:	3.135794994E
C4:	3
Calculated Q:	10.48625009
Required fs:	19709.682167
Divide by n (Calculated for 24 MHz clock):	304.4204564E
Adjusted Divided by n:	304
Sample Clock(Hz):	19736.84210E
c1:	0.9375
C1:	1
Gain (V/V):	1.066666666E
Over sample Ratio	19.73684210E

Plotting Reference Nominal

A disadvantage of the PSoC is the lack of a simulator that the other two switched capacitance environments have.

Since there is a micro-controller that is on the digital bus there is no need for a external processor to load the circuit once the program is download to the IC. The Cypress IC does not require a external crystal to operate the micro-controller the IC can easily be bread boarded (through-hole versions of the IC are available).

There are a large number of digital and analog blocks to work with. Placement of blocks effects how the blocks can be wired or configured internally and externally. Students can design there own blocks since all block parameters are under user control. Different hardware block configurations can be selected under program control. If no programming is desired the students can graphically configure the entire IC and then have code which implements the configuration generated and compiled without the need to program the IC.

The PSoC could double or be used to supplement a course on micro-controllers. The frequency of the switched capacitance blocks is not as high as say Anadigm.

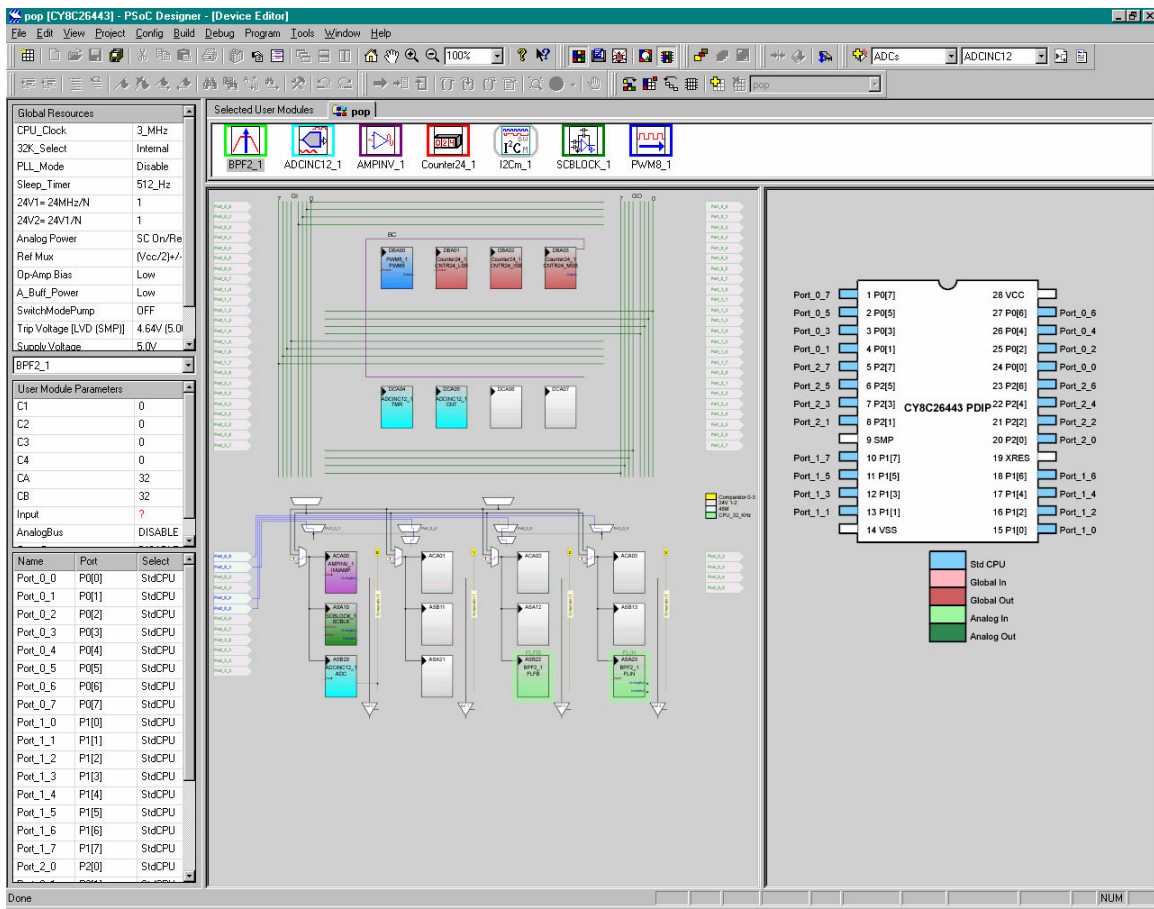


Figure 9.0 PSoC Configuration Screen

One large advantage is the PSoC support for A/D and D/A circuits. The D/A and A/D circuit blocks can be tied to filters, the input to the A/D is filtered or the output from the D/A is filtered. Examples of using the PSoC to modulate signals is given at the Cypress web site as are examples of amplifiers with feedback. Numerous other applications are available in the application notes. The students can also take advantage of distance learning audio/visual modules available free at the Cypress web site which should greatly enhance their ability to work through problems on their own.

Conclusion

All three web sites provide good support for their products and have a wealth of information that is useful. Cypress PSoC and Anadigm provide audio/video information to facilitate the learning curve in using the products.

All three environments may have some efficacy in supplementing existing Analog Laboratory assignments. The table that follows highlights some of the strengths and weaknesses of the three environments.:

Feature	Anadigm Designer 3.0	PAC-Designer 3.0	PSoC Designer V4.0
Simulator	Yes	Yes	No
Micro-Controller	No	No	Yes
Filter Design Tool	No	Selected by Block	Yes
PID Design Tool	Yes	No	No

Time in the lab should be saved by students being able to design and configure filters, amplifiers, modulation circuits, D/A and A/D circuits with filtered inputs. The students can save additional time in the Anadigm and Lattice PAC environments simulating the circuits to ensure they are correct. Circuits or sections of circuits can be simply downloaded from the PC to the actual lab boards saving valuable lab time for building and debugging the circuits with discrete components.

In the case of filters all three environments support high level design tools, many filters may be tried out in a single lab since building the filters with discrete components is not a factor.

References

1. "Practical Electronics for Inventors" by Paul Scherz McGraw-Hill 2000
2. "Student Manual for the Art of Electronics" by Thomas C. Hayes and Paul Horowitz Harvard, Cambridge University Press 1989
3. "Pros and Cons of replacing discrete logic with programmable logic in introductory digital logic courses" by Kevin Nickels Trinity University ASEE Annual Conference Session 2532
4. "A Proven Different Approach to Teaching Linear Circuits" by Albert J. Rosa and Roland E. Thomas University of Denver/USAF Academy Proceedings of the 2004 American Society for Engineering Education Conference and Exposition.
5. "Know your Lab Styff: Laboratory Proficiency Exam for an Introductory Circuits Class" by Ian M. Nauhaus and Susan M. Lord University of San Diego Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition.
6. "Computer Aided Design of Internally Compensated CMOS Operational Amplifiers" b M.G. Guvench University of Southern Main, Gorham, ME 04038 Proceedings of the 2002 American Society for Engineering Education Annual Conference and Exposition.
7. "A Versatile Experiment in Electrical Engineering Technology", Ahmad M. Farhoud, Engineering Technology Department University of Toledo, Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition.
8. "Switching and Power Electronics An Innovative Approach", Klaus Wuersig, SUNY College of Technology at Alfred, Session 1547
9. Cypress Semiconductor web site cypressmicro.com
10. Andigm web site andigm.com
11. Lattice web site lattice.com
12. "Design for Reliability of Low-voltage, Switched-capacitor Circuits" by Andrew Masami Abo, A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in Engineering-Electrical Engineering and Computer Science in the Graduate Division of the University of California, Berkley Spring 1999.

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