Have You Checked Your Pulse Lately? A look at the most recent advances in Pulse Power Supply Technology.

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This paper discusses recent advances in pulse power supply technology. Pulse-plating technology has been around for decades but it has become a mainstream plating method in just the last 5-10 years. The development of more complex parts, smaller geometries and new processes or applications have driven the end user to find more accurate, reliable and unique methods of increasing product quality and plant output. Nowhere is this more evident than in the semiconductor market where geometries have reached levels of less than 0.1 microns. Pulse plating produces results that DC plating cannot match. The latest advanced features are discussed in detail in this presentation.

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Pulse plating has been around for decades but it has really become a mainstream method of plating in just the last 5-10 years. The development of more complex parts, smaller geometries and new processes or applications have driven platers to find more accurate, reliable and unique methods of increasing product quality and plant output. Nowhere is this more evident than in the semiconductor market where plated geometries have reached levels of less than 0.1 microns. Pulse plating produces finished product results that traditional DC plating cannot match.

Pulse power supplies have matured well beyond the basic ON/OFF pulsing units that have been on the market for years. The latest advancements include such features as multiple channel and multiple cell configurations, extended operating ranges for increased power supply flexibility & accuracy, increased ampere time cycle control accuracy, pulses with fully controllable uni-polar or bi-polar bias levels, remote voltage sensing and control, arbitrary waveform generation, Ethernet communications and on-board web browser control programs, Windows-based process control software packages and automated calibration packages.

The key to making all these advancements possible is the microprocessor based control circuitry built into the power supply. Today's programmable pulse power supplies use on-board computers to process and manage large amounts of data. Managing this data is critical in order to tightly monitor and control the power supply's output to meet the operating parameters entered by the user. Simultaneously monitoring and controlling items such as requested output verses actual output, ampere time cycles and totalizers, real time cycles, pulse timing parameters, tolerance settings, recipe control settings, output regulation mode and error-logging provide major advantages to the end-user. Once all of the desired plating parameters have been entered, the power supply can autonomously complete the plating process.

Many of these programmable power supplies are controlled with a Windows-based control software that is available from your power supply vendor (Figure 1).

Figure 1: Plating Control Software

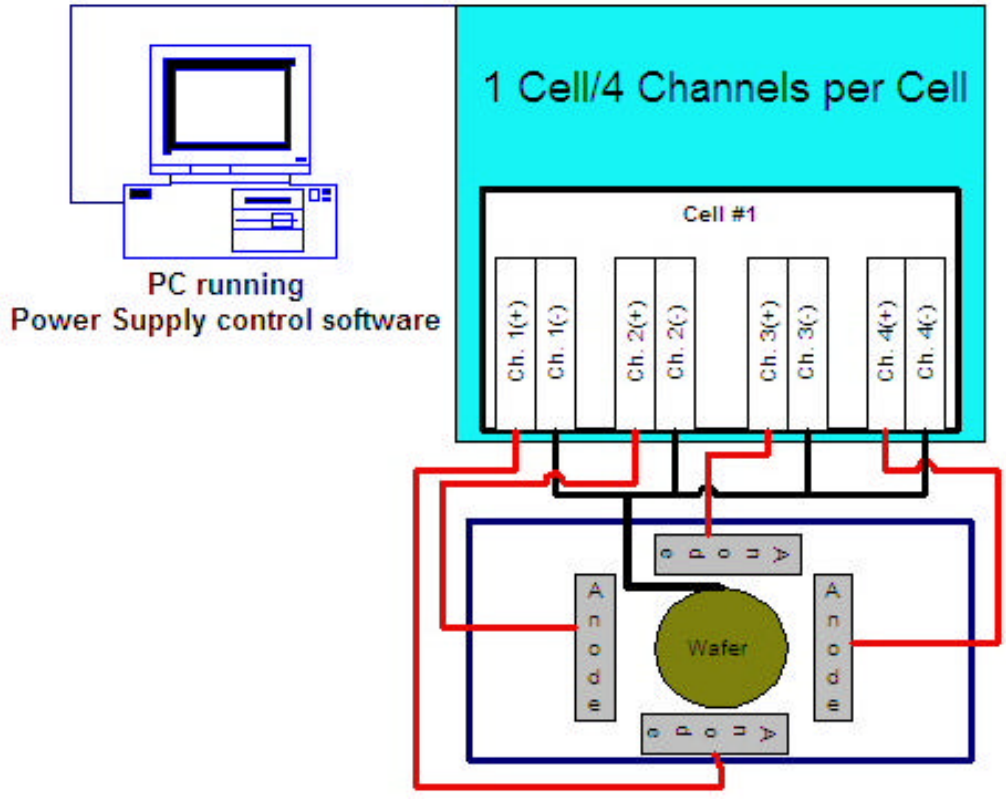
Some vendors are also are willing to provide you with the low level power supply code to allow you to write your own operator interface and/or incorporate the power supplies into a totally automated process control program.

Although programmable pulse power supplies have been on the market for close to 15 years, only within the last 5 years or so has there been a push to provide more complex features and options with the Window-based process control platform. Some of the different features available for today's programmable pulse power supplies are outlined below.

Multiple Output Channels

A multiple channel power supply will have multiple channels of output running to each part in the plating tank (Figure 2). Each channel has independent output control and each channel will deliver current and voltage outputs up to the maximum output rating of the power supply. One totalizer will totalize all of the ampere time for all channels. All channels of output will have the same pulse timing parameters and will start and stop at the same time. In some multiple channel cases, individual channel control is requested. This gives the operator the ability to have ampere time control per channel and the ability to start and stop each channel independently. With individual channel control, the pulse timing parameters must still be the same for each channel.

Figure 2: Multiple Channels

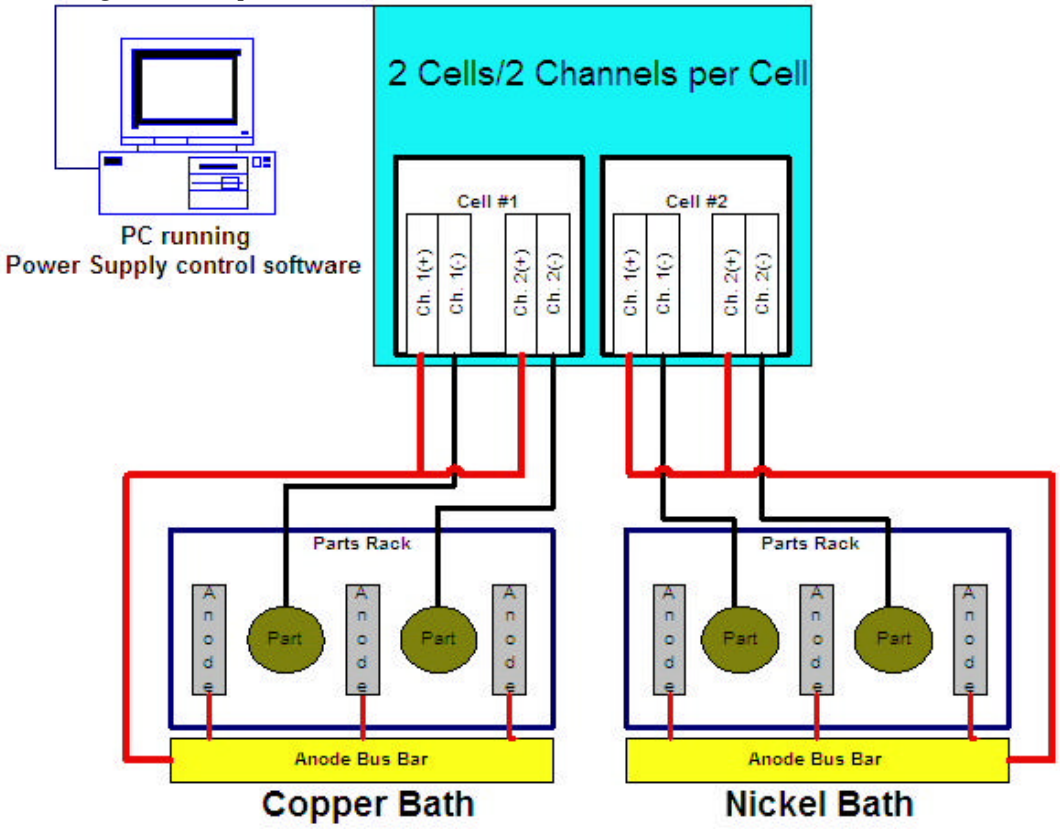


Multiple Output Cells

A multiple cell power supply is typically used in a situation when multiple plating tanks are being used, but the operator only wishes to purchase one power supply (Figure 3).

In a multiple cell application, each cell is essentially a stand-alone power supply. Each cell has independent output control, ampere time cycle control and pulse timing parameters. Each cell can also have multiple channels of output, which follow the guidelines outlined in the multiple channel section discussed above.

Figure 3: Multiple Cells



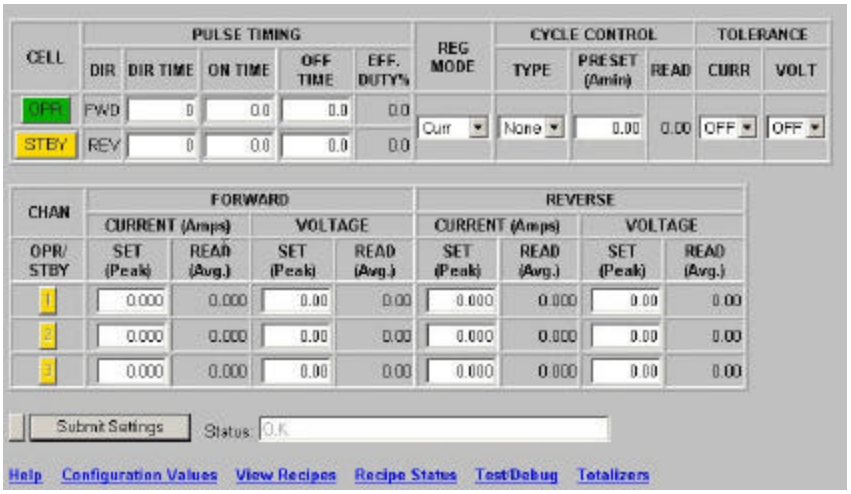
Ethernet Control

Many of the programmable supplies on the market today are using Ethernet-based control verses RS232 or RS485 control. Ethernet control gives you faster communication speeds as well as the ability to communicate to the power supply from a remote location via a local area network (LAN), wide area network (WAN) or even across the Internet.

Web-based Control

Having on-board computers allows the power supply designer to incorporate simple web-based HTML controls. Each power supply has a unique Internet Protocol (IP) address. Connecting to the power supply via an Ethernet cable, the end user can use a web browser program like Internet Explorer™, enter the power supply's IP address, and be connected to the on-board control program (Figure 4). Provided that you have the correct firewall settings, you could connect to the programmable pulse power supply via an Internet connection and control it from anywhere in the world.

Figure 4: Web Browser Control Software



Extended Range

For maximum accuracy and repeatability, the typical recommended operating range of a pulse power supply is from 10% - 100% of the peak current rating of the power supply. One manufacturer has recently patented a feature called Extended Range. The Extended Range feature has been developed to accommodate a wider range of accurate and repeatable outputs. An Extended Range power supply is able to maintain highly accurate pulsed outputs throughout a range of 0.1% to 100% of the peak output current rating (Table 1).

Table 1

Percent of Peak Output	
XR Range 1	0.1 – 1.0%
XR Range 2	1.0 – 10.0%
XR Range 3	10.0 – 100%

The power supply will automatically scale it's resolution to the appropriate range, based upon your peak output settings, and any range changes made during your process are completely transparent to the operator. This gives you the flexibility of processing a wider range of products with just one power supply.

For Example: A 30 amp peak pulse power supply will automatically operate in one of the following ranges, based upon your selected peak output settings (Table 2).

Table 2

Range	Resolution
XR Range 1	0.03 - 0.3 amps with 1 milliamp resolution
XR Range 2	0.3 - 3.0 amps with 1 milliamp resolution
XR Range 3	3.0 – 30.0 amps with 10 milliamp resolution

Increased Ampere Time Cycle Control Accuracy

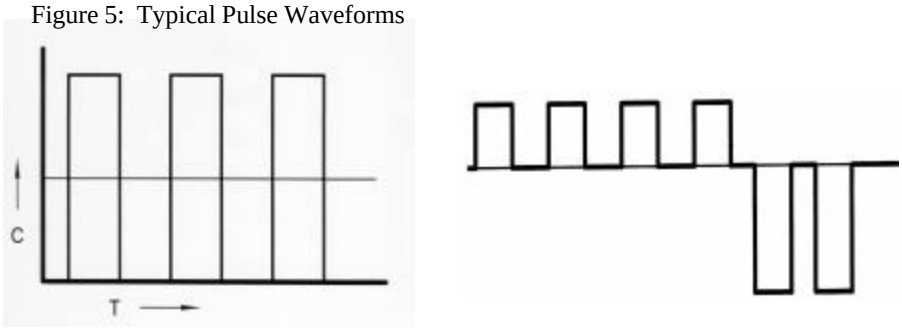
As plated geometries are getting smaller and smaller, the need to more accurately monitor the current or voltage flowing to the product has become one of the most critical parts of the whole plating process. Historically, output sampling (used to create output meter readings and for totalizer accumulation) only occurred 10-100 times per second during the on time of the pulse plating cycle. Today, these sampling rates have been increased to over 10,000 times per second. This increased sampling rate allows the power supply control circuitry to capture such things as overshoot, ripple or any other fluctuation and accurately report these back to the end user in the form of an averaged current reading.

Configurations for accumulating ampere time have recently changed to allow more flexibility also. Platers can now accumulate forward output only; multiple forward output levels (used in an application where there are two forward pulses verses a forward and reverse pulse) and forward minus reverse output.

Arbitrary Waveform Generation

As semiconductor manufacturers continue to push chip technology to new heights, researchers have had to start thinking "outside the box" for chip development. Research is scheduled to begin soon within the semiconductor market on using pulse power supplies capable of Arbitrary Waveform Generation (AW) for chip manufacturing. Traditional square-wave pulse or pulse reverse waveforms (Figure 5) start in the forward (cathodic) direction and will have off times at zero output. These waveforms typically will also have some inherent dead time in the transition from forward to reverse (anodic) direction.

Figure 5: Typical Pulse Waveforms



Arbitrary Waveform Generation is a combination of software, firmware and hardware development that is being applied to an existing line of programmable pulse power supplies on the market today. The Arbitrary Waveform feature will allow the user to create a waveform that can consist of standard pulses, multi-level pulses, ramped output, uni-polar or bi-polar bias levels, saw-tooth pulses, sine wave pulses, pulses with zero dead time in the transition from forward to reverse, or any combination of these pulse waveforms. (Figures 6-8)

Figure 6 : Bi-level Saw-tooth Pulse

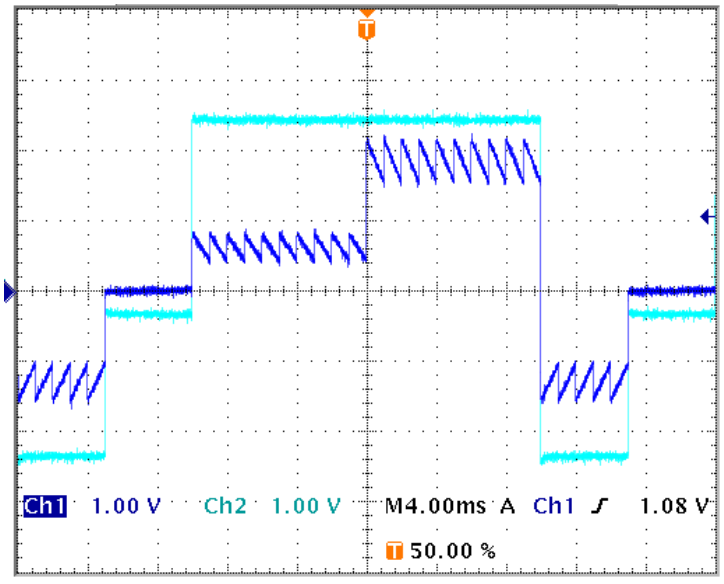


Figure 7 : Bi-level Ramped Pulse

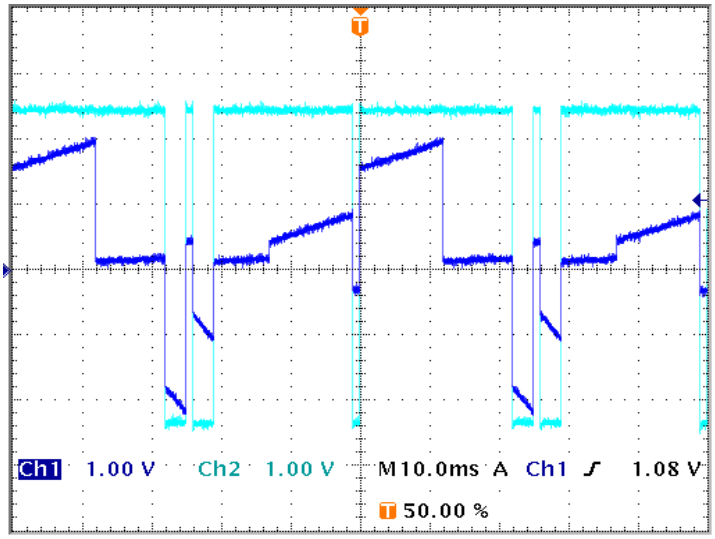
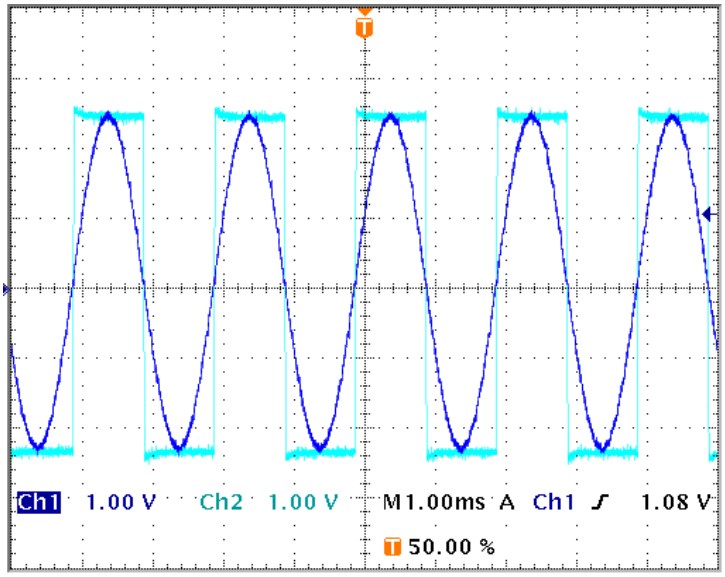


Figure 8 Sine Wave Pulse



The goal of this project is to provide a turn-key system with a user-interface that will allow the user to draw a desired waveform on their computer and have the power supply re-create it. Although this may be strictly used as an R&D tool in the near future, the opportunities it brings to the table for new research ideas are endless.

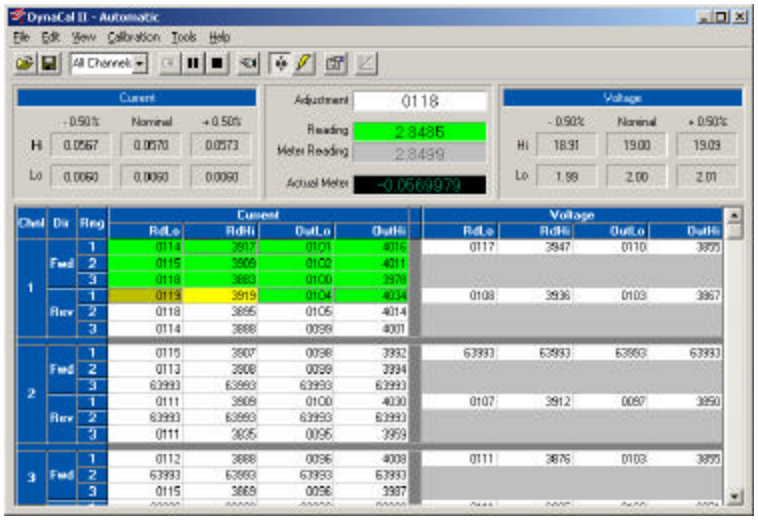
Remote Voltage Sense

Remote voltage sense takes the potentiostat out of the lab and puts it into production. The remote sense point can either be a connection point as close to the part as possible or a reference probe that is in the solution. This feature is used in an application where the voltage applied to the half-cell of an electrochemical reaction within a plating or electropolishing process is so critical that the voltage needs to be measured at the plating bath and this reading must be used as the feedback for controlling the output of the power supply. This does not seem like a new or innovative method of control, but based on the low voltage levels that are typically being monitored (0.01 volts or less), the power supply and remote sense need to be custom built around each individual application.

Automated Calibration Software

As programmable power supplies have moved into the world of multiple channels, multiple cells and extended operating ranges, one of the biggest issues has become the time it takes to properly calibrate these units. For example a power supply with 6 cells, 4 channels per cell would have 1,152 calibration points to be checked and re-checked. This large of a system could easily take a skilled technician one to two days to properly calibrate. With an automated calibration program (Figure 9), this system could be calibrated within a couple of hours.

Figure 9: Automated Control Software



One power supply vendor is currently offering a semi-automated, Windows-based calibration program. This program links your programmable power supply to a programmable reference digital multi-meter. Working in conjunction with each other, along with a set of calibrated output loads, the calibration software compares the readings from the multi-meter to the output settings and readings of the power supply and makes

adjustments to the output or read back signals if needed. Although the operator still has to move the calibrated loads and meter sense probes from channel to channel during the calibration process, this unique calibration package has reduced calibration times by 50% or more.

Conclusion

Microprocessors have taken pulse power supply technology from brute-force power supplies to highly regulated, extremely accurate and precise pieces of equipment that are now a critical component in the development and manufacturing of many of the things we take for granted today. The flexibility that this technology brings to the table allows the power supply manufacturers to completely customize each system to meet each individual end-user's application or process. Whether you need Extended Range for processing a wide range of parts, remote voltage sensing for an electropolishing or de-burring application or Arbitrary Waveform capabilities for R&D on your next research project, today's programmable pulse power supplies can be custom configured to meet all your needs and exceed all your expectations.