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Interview with Michael Freeman of Semitrex

A New Way to POWER the World

Revolutionary Power Technology from Semitrex

An Introduction to Feedback Loops «

Enabling the Maker Movement «

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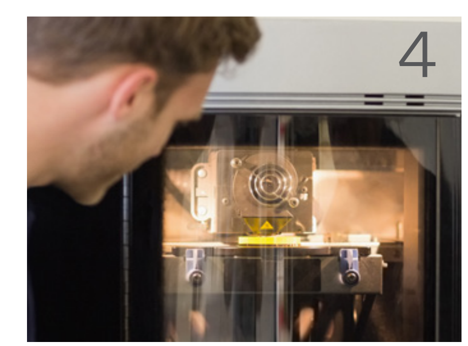
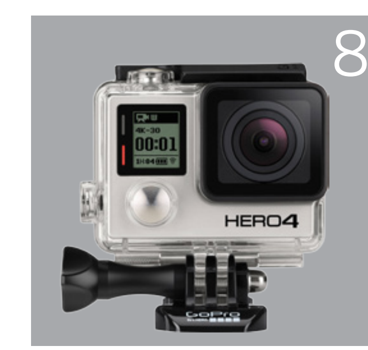
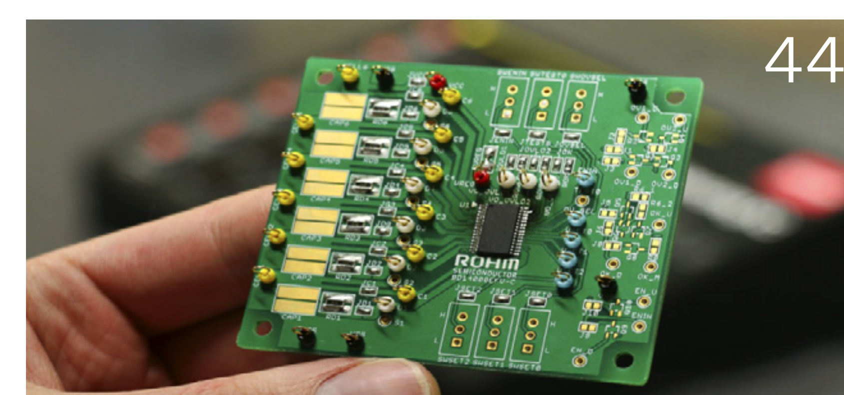






TapTapTech

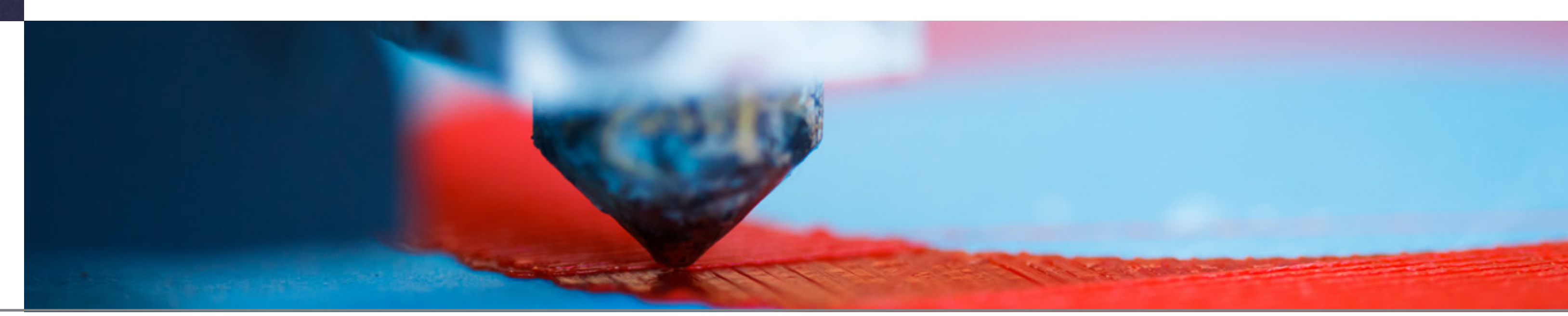
The Maker Movement

By Josh Bishop

Prototyping and even very small-level production runs are now possible in someone's bedroom, with the hope of them eventually growing into a thriving small business.

Today, we're going to discuss the Maker Movement, otherwise known as The Coolest Thing in Technology ever. Just like the garage computer explosion of the '70s through the '80s—which brought us such things as Apple, Pong, Bill Gates' hair, and the proliferation of personal computers—the Maker Movement is the new garage *hardware* explosion. While the Maker Movement is strongly associated with electronics, it really is more a matter of scale, particularly small scale. Making is about individual, "Do-It-Yourself-ers" being able to design and create with tools that were, as of a decade or two ago, only available to large, cash-rich corporations. CAD tools, CNC mills, 3D printers, low-quantity PCB manufacturing, open hardware such as Arduinos, and similar inexpensive development boards are all items that have made it easier and relatively cheap to make whatever we imagine.

For individuals, maker tools can change how someone views their home or their hobbies. If you want to make a little custom widget that holds your favorite Bluetooth speakers onto your bike frame, you can quickly design, print, or make it, and then use it almost immediately—and it will be perfect for your application. I believe, and fervently hope, that this will change our viewpoint as a society in terms of what is considered disposable. I have a slow cooker at home that works just fine, however, the handle to the lid is broken—a small plastic piece. When I contacted the manufacturer, they said they can only replace the lid, not just the handle, and it would cost nearly as much as if I were to buy the whole thing again new. As Making becomes more prevalent, I imagine a world where I can print a new piece for a couple of cents. I can then post the design online in some public repository for anyone else to use with a similar problem. Ideally, manufacturers



If you haven't tried making yet, go ahead and do it!

could even be more responsible and provide the designs for portions of their products that are prone to failure.

For the business minded, the Maker Movement signals that the barrier to entry for new products has been lowered. Prototyping and even very small-level production runs are now possible in someone's bedroom, with the hope of them eventually growing into a thriving small business. Maybe it's not for everyone, but I imagine there are many Makers out there who would love to be the next Lady Ada or even Nathan Seidle.

Upcoming Maker-inspired companies aren't just the fulfillment of personal dreams, they're making a serious impact on our economy. On Kickstarter alone, there has been over *1.3-billion* dollars pledged to successful projects and the money pouring in has been increasing wildly since 2009. *1.3-billion* dollars. That's a lot of jobs and a lot of innovation.

The Maker movement is getting bigger and it's everywhere from the White House to your basement. If you haven't tried making yet, go ahead and do it! You may be amazed at what you can do. EE

TechXposed

TEARDOWN SERIES

GoPro HERO4 Black

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Front View

Back View

The HERO4 is the latest offering in the increasingly popular GoPro mountable video camera product line. With up to 240 frames-per-second, the HERO4 is the first camera of its kind to capture 4K ultra-HD video. This enhanced video capability paired with built-in Wi-Fi and Bluetooth® requires processors twice as powerful as the previous version. This TechXposed Teardown will take a look inside at the brains behind the most advanced GoPro yet.

GoPro HERO4 Product Features

HD Video Recording
4K30 and 2.7K60 video with 1080p120 and 720p240 slow motion capability

Burst Photos
12MP Burst photos at 30 frames per second

SuperView™
Immersive, wide-angle view

Time Lapse
Intervals of 0.5, 1, 2, 5, 10, 30, and 60 seconds

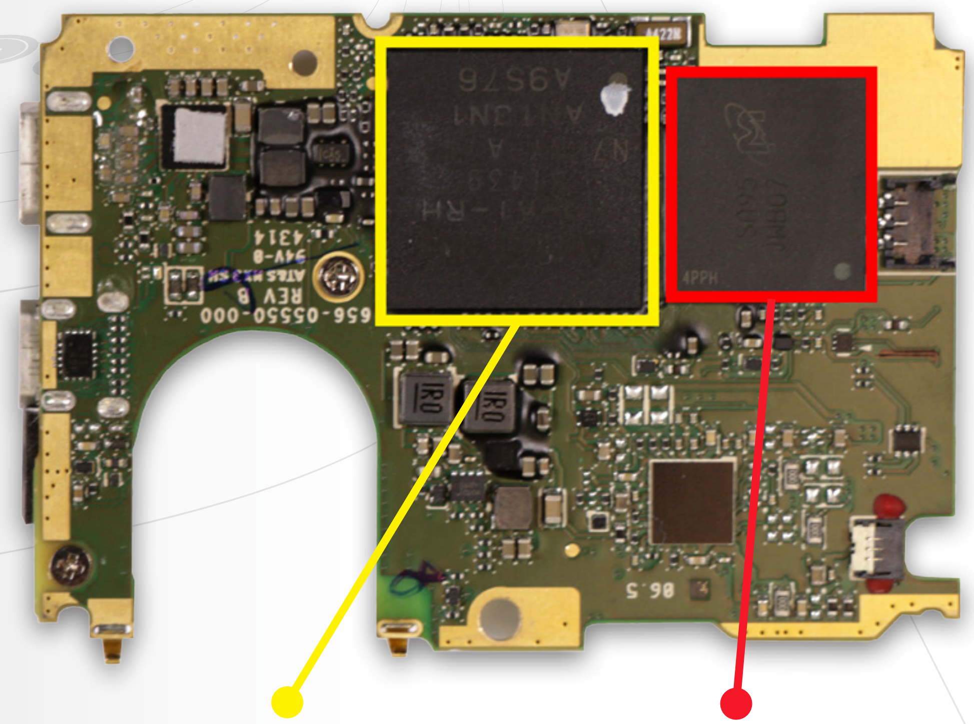
Protune™
Advanced image controls for color, ISO, limit, sharpness, and exposure

Ports
Mini USB, Micro HDMI, microSD

Storage
64GB

Wireless Capability
GoPro App enables playback on smartphone or tablet

LOGIC BOARD



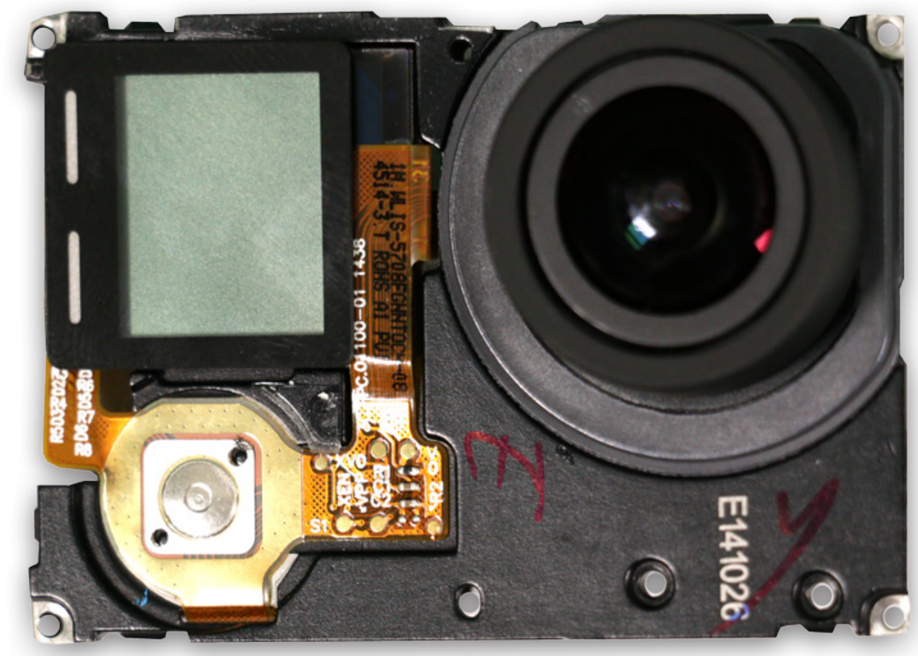
Ambarella A9

- Dual Core ARM® Cortex™-A9 @ 1GHz
- Ambarella Image and Video DSPs
- Integrated memory interfaces (NAND, DRAM, SDIO)

Micron MT29RZ4B-8DZZNHSK-18W.4T2

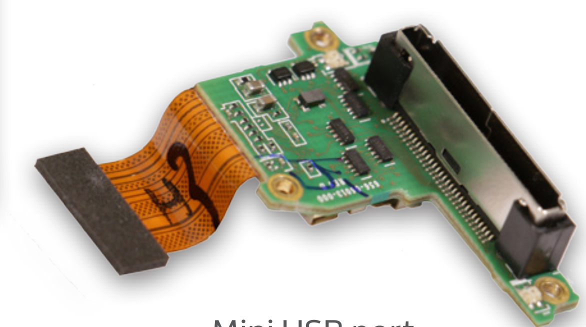
- 1 NAND, 2LPDDR2 MCP
- 4GB x8 NAND, 3.3V
- 8GB x32 LPDDR2, 1.2V, 533MHz

IMAGING SYSTEM

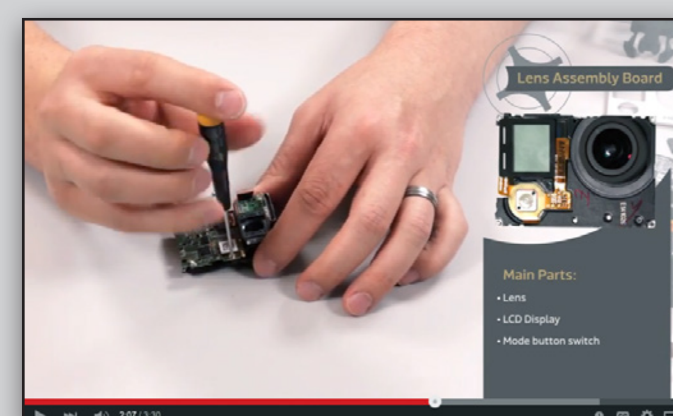


- 12MP stills, 30fps burst mode
- 4k30, 1080p120, 720p240 video Max aperture f/2.8

HERO PORT BOARD



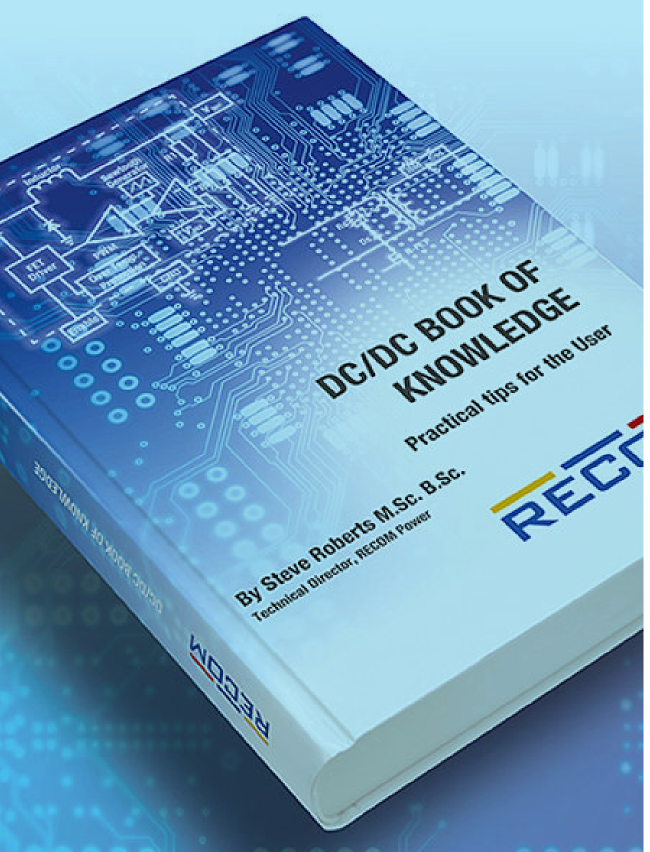
- Mini USB port
- Micro HDMI port



To watch a video of the HERO4 teardown, click the image at the left.

DC/DC Book of KNOWLEDGE

Chapter 2



RECOM

By Steve Roberts
Technical Director for RECOM

Feedback Loops

*RECOM´s **DC/DC Book of Knowledge** is a detailed introduction to the various DC/DC converter topologies, feedback loops (analogue and digital), test and measurement, protection, filtering, safety, reliability, constant current drivers and DC/DC applications. The level is necessarily technical, but readable for engineers, designers and students.*

Intro to Feedback Loops

Some of the most important design criteria in DC/DC power conversion design are the calculations and methodologies involved in the feedback loop compensation. If the feedback loop parameters are not properly calculated, the converter can exhibit instability or regulation failure.

The function of a feedback loop in a DC/DC converter is to maintain the output at a fixed value, which is dependent on a reference value only—i.e. it is independent of load, input voltage or environmental variations. This sounds simple and is relatively simple for static or slowly changing conditions, but to handle dynamic or step changes the feedback loop design becomes very complex. One of the most important compromises that has to be made is the balance between a smooth output during static operating conditions (low jitter, small deadband, and good accuracy) and the response to dynamic operating conditions (fast reaction time, quick settling time and low overshoot). In addition, the control loop must be stable under all operating conditions, including low load or even no load conditions. The feedback loop design is therefore one of the main factors defining the overall performance of the converter.

Open Loop Design

Not all DC/DC converters use feedback. The basic Royer relaxation oscillator used in the example shown in Figure 1.30 has no feedback network. The self-oscillating circuit runs at a frequency, which is determined by the physical characteristics of the transformer and the input voltage only, according to the following relationship:

$$V_{IN} = 4\,N_P\,B\,A_E\,f$$

Equation 2.1. Transformer Equation

Where N_P is the number of primary turns, B is the saturation flux, and A_E is the cross sectional area of the transformer. The formula can be rewritten to give the free-running frequency, f:

$$f = \frac{V_{IN}}{4\,N_P\,B\,A_E}$$

Equation 2.2. Rearranged Transformer Equation

The factor “4” differs from the standard transformer equation which uses “4.44” because the Royer oscillator generates a square wave and not a sinusoidal signal. The output voltage is dependent upon the turns ratio of the number of turns on the primary winding, N_P, to the number of turns on the secondary winding, N_S:

$$\frac{N_P}{N_S} = \frac{V_{IN}}{V_{OUT}}$$

Equation 2.3. Transformer Ratio

From these relationships, we can see that both the output voltage and operating frequency are not fixed and are dependent on the input voltage. Therefore unregulated DC/DC converters should ideally only be used with regulated input voltages.

In practice, there are “hidden” feedback mechanisms that improve the performance of Royer oscillators above what the theory predicts. The primary, secondary and feedback windings all exhibit an interaction with each other due to leakage inductances and coupling capacitances. The windings can be arranged on the core to increase or decrease these interactions or even to shield one winding from the influence of another. For example, unregulated converters can be made short-circuit proof by winding the secondary between the primary and feedback windings so that the short-circuited output turns form a shield which reduces the coupling from primary to secondary. The converter continues to oscillate when the output is shorted, but at a much reduced power that the switching components can tolerate. The unregulated converter will run hotter into a dead short, but it will survive. As soon as the short circuit is removed, the converter will revert to its normal operating mode with full power.

Closed Loops

The dependence of the output on the input voltage can be removed by using a feedback loop. Essentially, a feedback path is provided to an error amplifier, which compares the actual output with the desired output and corrects the output to bring it into line. As the correction is always in the opposite direction to the error (if the output is too high, reduce it, if the output is too low, increase it), the feedback is said to be “Negative.” If the feedback loop is “Positive” then any errors will be amplified and the output will either oscillate or rapidly go to the minimum or maximum level. Ensuring that positive feedback conditions do not arise under transient operating conditions is one of the most challenging aspects of the loop design.

The beauty of feedback is that changes of input voltage will be compensated for as well as any changes in the output voltage due to changes in the load. The same feedback loop corrects for both situations. Another advantage of closed feedback loops is that the input and output do not have to have the same units. A feedback loop can be used to make a constant current output from a variable input voltage supply. The error amplifier simply adjusts the output according to a feedback signal based on the output current rather than on the output voltage (in effect, it becomes a transconductance amplifier instead of a voltage amplifier).

To analyze the feedback design, let us take a simple, non-isolated buck regulator. A typical circuit diagram could be:

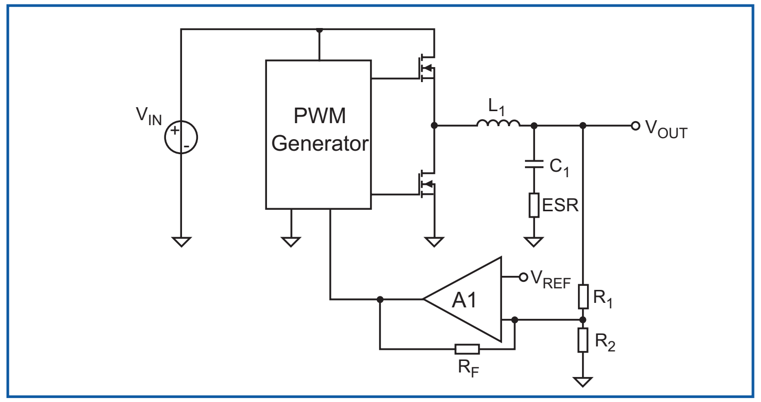


Fig. 2.1. Simplified Buck Converter Schematic

In terms of functional blocks, Figure 2.1 can be reduced to:

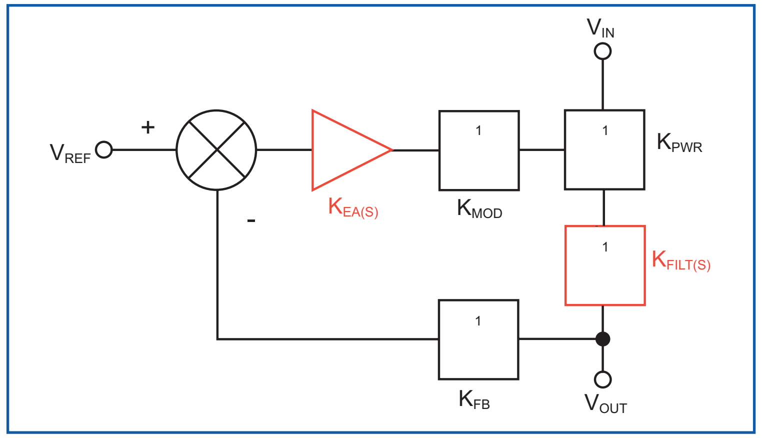


Fig. 2.2. Feedback Loop Block Diagram

Each functional block will have a gain, K. The power switching elements (FETs) will have gain of K_{PWR}, the output filter formed from L_1 and C_1 with $K_{FILT(S)}$, the feedback element (the resistor divider formed from R_1 and R_2) will have gain K_{FB}. The resulting feedback signal is compared with the reference voltage, V_{REF} at the summing point and the error amplified by the error amplifier A_1 with gain $K_{EA(S)}$ to control the PWM modulator which has a gain K_{MOD}. Some of these gain blocks will have a high amplification and some will attenuate the signal, but overall the open loop gain (the sum of all of the gains) will be positive and typically be around 1000.

Open Loop Gain, $G_{OL} =$

$$K_{PWR} + K_{FILT(S)} + K_{FB} + K_{EA(S)} + K_{MOD}$$

Equation 2.4. Open Loop Gain

The simple circuit shown in Fig 2.1 will have resonances (poles) caused by the LC output filter at the frequency:

$$f_{PO} = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

Equation 2.5. LC Filter Corner Frequency

And an additional resonance (zero) caused by the capacitor's ESR:

$$f_{ZO} = \frac{1}{2\pi\,(ESR)\,C_1}$$

Equation 2.6. Capacitor ESR Corner Frequency

At frequencies above f_{PO}, the gain decreases at a rate of -40dB/decade due to the second order LC characteristic of the output filter. The point at which it reaches unity (0dB gain) is the crossover frequency, f_C. At the frequency f_{ZO}, the effect of the first order RC filter due to the ESR of the filter capacitor changes the gain slope to -20dB/decade. A plot of the normalized gain against frequency shows that the slope and phase change with frequency:

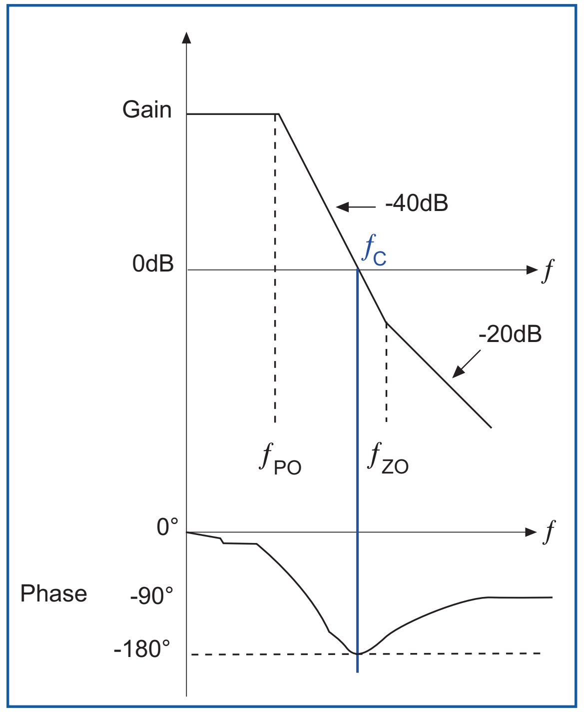


Fig. 2.3. Normalized gain and phase plot of Fig. 2.1

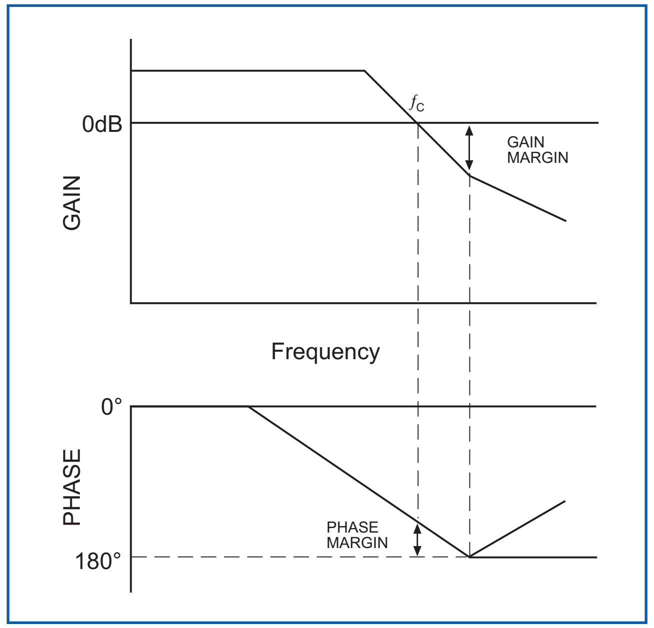


Fig. 2.4. Gain and Phase Margins

The phase plot is the phase change additional to the 180° caused by the inverting input f the error amplifier, A_1.

As we can see from the phase plot, the circuit is unstable at the crossover frequency as the phase change is -180° or -360° in total. This will cause the converter to veer into the positive feedback region and the output will start to ring or break into oscillation.

By increasing the gain in the error amplifier stage, the frequency where the overall gain equals unity can be moved to a safer region. The phase margin (the difference between the overall phase and -180° at the system f_C) and the gain margin (the system gain at -180° phase) define how stable the feedback loop is (Fig. 2.4).

Feedback Loop Compensation

The further away the chosen system crossover frequency from the power stage cross-over frequency is, the more stable the output (it has better gain and phase margins), but the slower the transient response. A phase margin of approximately 45° provides for good response with a little overshoot, but no ringing.

Besides simply increasing the error amplifier gain at all operating frequencies to move the system corner frequency into a safe area, the error amplifier phase shift can be made frequency dependent by adding compensation to the op-amp feedback:

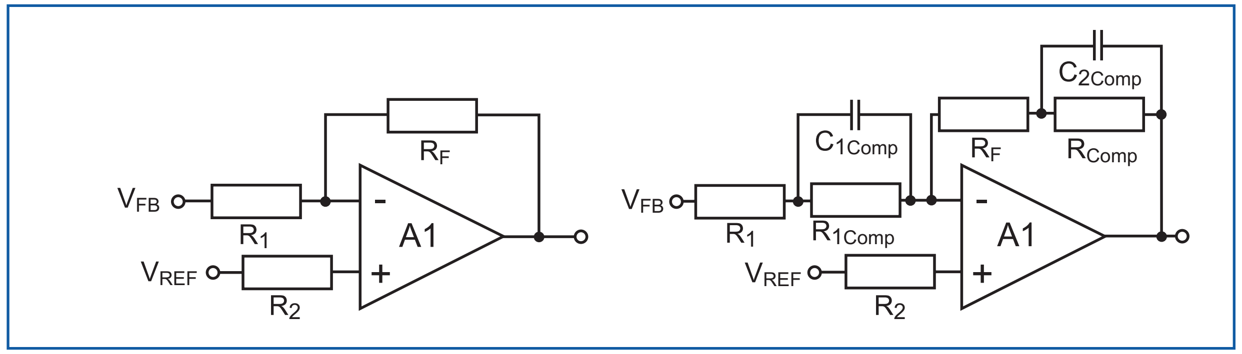


Fig. 2.5. Uncompensated (left) and compensated error amplifiers (right).

The compensation component values can be chosen so that the phase reverses and adds to the phase margin at the critical crossover frequency, thus increasing the stability. This allows the output filter to be less heavily damped, thus accelerating the DC/DC converter's reaction to transients without risking excessive overshoot or oscillation.

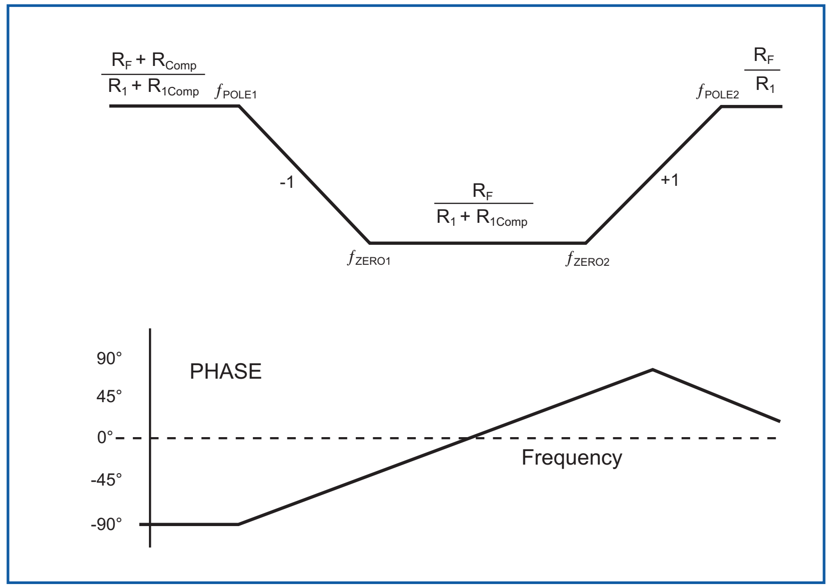


Fig. 2.6. Gain and phase relationships of the compensated error amplifier circuit shown in Fig. 2.5.

The dotted line shows the gain and phase against frequency for an error amplifier with additional gain, but without compensation. The solid line is the additional gain and phase shift due to the compensation components.

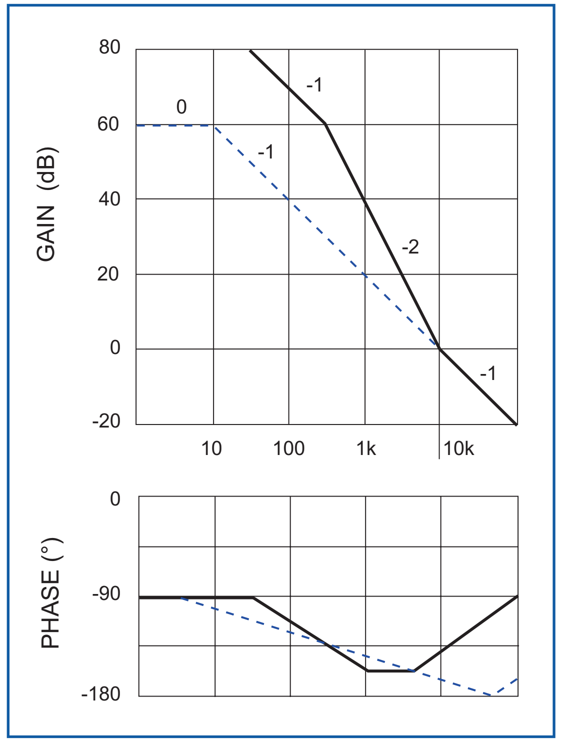


Fig. 2.7. Compensated (solid line) vs. single pole (dotted line) feedback loop characteristics for the circuit shown in Figure 2.5.

The maximum possible boost to the phase due to compensation is 180º (from -90º to +90º) and multiple poles and zeroes can be incorporated to compensate for the zeroes and poles of the output filter.

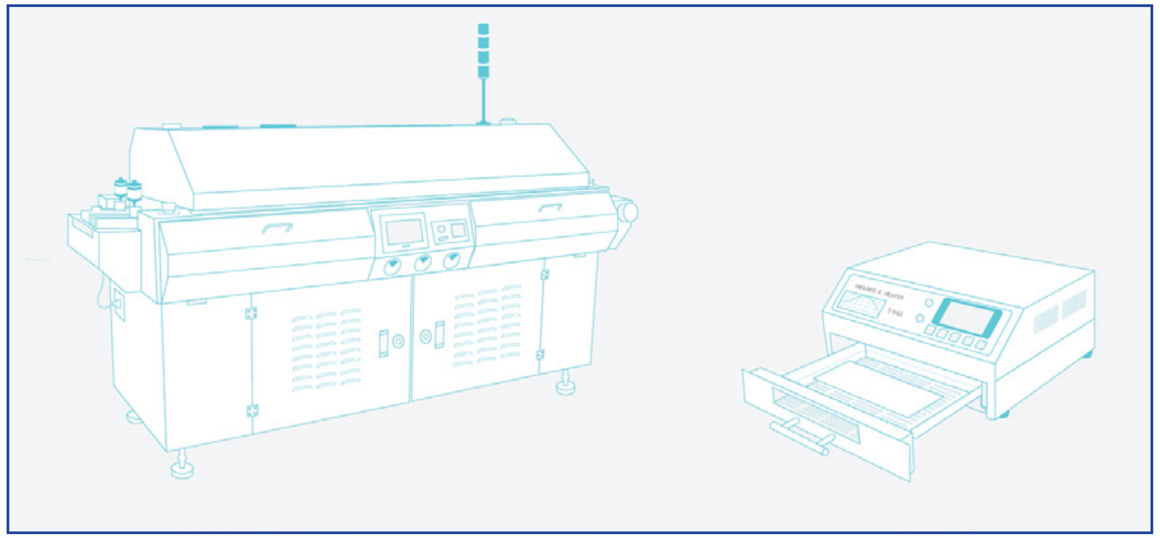
With the correct design, the response to step load or transient input voltage change can be sped up by a factor of 3 or 4 without compromising the steady state stability of the feedback loop.

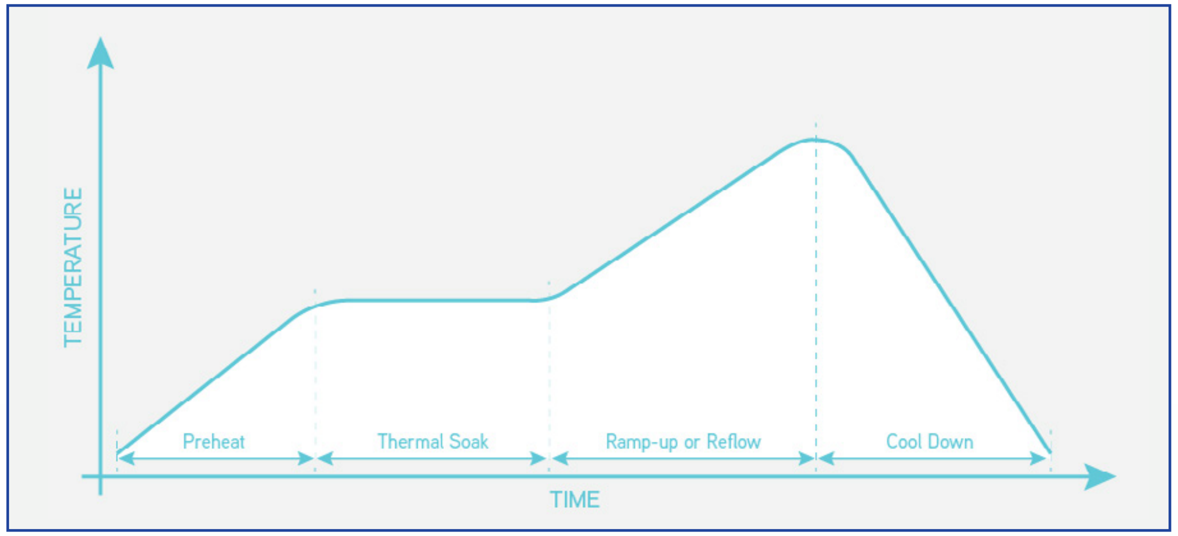
So far, Chapter 2 of the DC/DC Book of Knowledge has covered the various types of feedback loops as well as how to compensate them. The chapter goes on to cover potential feedback loop instabilities as well as digital feedback loop characteristics. To read the chapter in its entirety, visit: http://www.recom-power.com/downloads/book-of-knowledge.

REFLOW SOLDERING

Better than Easy-Bake

Desktop and homemade reflow ovens are becoming much more common in the tech world for both DIY-ers and small startups. The overall concept of reflow soldering is simple: put a pre-assembled board with some solder paste into an oven and bake it until the solder properly melts. As is true with many things in life, the actual application is a bit more complicated. When a board is reflowed, it typically is put through four different stages or zones of the reflow process. The difference between stages or zones is dependent on the reflow process. The smaller, do-it-yourself or prototyping-sized ovens do not move the boards, but rather change the internal temperature of the oven as needed. For larger, commercial-sized reflow ovens, the boards are moved through zones of different temperatures via a conveyor belt. These four different stages, and their settings, are crucial in achieving consistent results in the soldering process.





The first zone is the preheat, where the temperature is brought up slowly. This must be done slowly to allow all portions of the board to heat up at the same time and to minimize thermal shock. This is also the stage where the solvents within the solder paste start to evaporate. If the board is heated up too quickly, it can expand in certain parts and crack, the copper can separate from the laminate, and the internal portions of integrated circuits can even break. Slowing the heating process also lets the integrated circuits gently release any moisture in them, preventing "popcorning" when the IC literally pops as the minute amounts of water in the IC turn to steam. The average ramp-rate is three degrees Celsius per second, but can vary significantly. This portion of the profile is unaffected by the use of leaded or lead-free solder. However, the temperature-change rate can be modified to accommodate the different devices on a board, their sizes and heat masses.

After the temperature has been brought up to a specific temperature, typically around 155 degrees Celsius, the board enters the second zone called the thermal soak zone. At this point, the temperature increase is either stopped completely or slowed down to 1 degree Celsius or less per second. This typically takes about 90 seconds. Whether it is a leaded or lead-free process will dictate the maximum temperature reached in this zone. Here, the board should equalize in temperature and the solvents in the solder paste finish evaporating while the flux activates.

Once the board temperature has equalized, it is then passed to the ramp-up or reflow zone. This zone requires a delicate balance, as this is where the solder is quickly brought to the eutectic point—the temperature where the solder melts. This temperature needs to be high enough and held long enough to provide the solder ample time to melt, joining the board and components. However, if the temperature is too hot or held too long it can cause damage to sensitive components or make the solder joints brittle. The melting point for lead-free solder is also significantly higher than lead solder, which makes the balance even more challenging. While there are different recommendations, the max temperature needs to be at least 5 to 10 degrees Celsius higher than the eutectic point and held anywhere from 10 seconds up to 60 seconds.

The final zone of the reflow process is the cooling zone, where the board is brought back down to room temperature. The temperature change is much quicker than the preheat and thermal-soak zones, taking around three minutes. It is recommended to keep the change less than ten degrees Celsius per second, with the average change being significantly less than that. This stage is important as this is when the solder cools, forming the mechanical structure of the solder. This part of the reflow process starts inside the oven but usually ends outside of the oven, as the boards will still be extremely hot when they are done and will still need time to cool down.

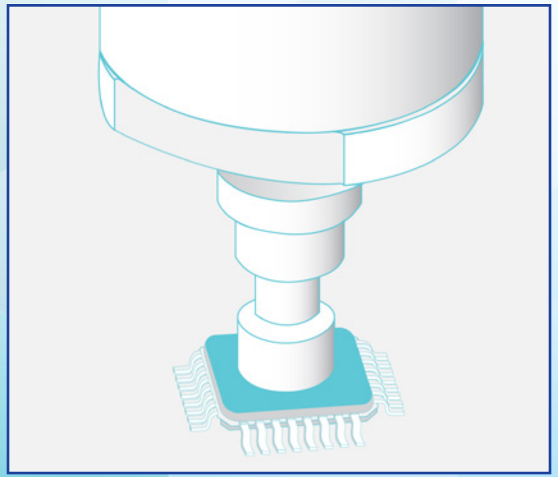
While not as simple as tossing boards into a convection oven and hoping for the best, reflow soldering is an achievable process that can yield consistent, high-quality results. Understanding the steps can help you if you need to reflow your own boards or discuss your custom needs when working with an assembly house. EE

The Pick and Place Unveiled

When the printed wiring or circuit board was first created in the 1940s, it was done so in part to reduce the increasing complexity of attempting to wire circuits manually. The PCB fulfilled its role perfectly and was an overwhelming success, since becoming a multi-billion-dollar industry. However, as PCBs became more prevalent and advanced, it also became difficult to quickly and accurately produce populated circuit boards in large quantities. This need to populate the tens to hundreds of thousands of circuit boards led to the advent of pick-and-place machines, an automated method of placing a large quantity of components on boards extremely quickly. While simple in concept, the pick and place is an amazingly complex and precise machine. The variety of situations in which the pick and place is used has created an interesting variety of styles for the pick and place machine, though all operate according to a set of basic principles are generally unchanging.

Once the nozzle has a firm hold of the component, it lifts it up and places it where it is needed, releasing the suction as soon as the part is in place.

Automated pick and place machines all function by picking up a component in one place and putting it in another. Instead of using fingers or tweezers like a human operator would use, the pick and place uses a small suction nozzle that presses against the component, using suction to hold onto it. Once the nozzle has a firm hold of the component, it lifts it up and places it where it is needed, releasing the suction as soon as the part is in place. While the original and final position of the component are programmed into the pick and place machine, or PnP, minor variations in location can occur. Then, these locations are confirmed with computer vision, verifying that the board is truly in the expected position. It also verifies that the component is actually picked up by the nozzle. Fiducials and tooling holes are mentioned frequently in discussion of automated machines, as both are used as references by the computer vision. Fiducials are created solely for this reason while tooling holes are created primarily to mechanically hold boards or panels in position though they can also be used as reference points.

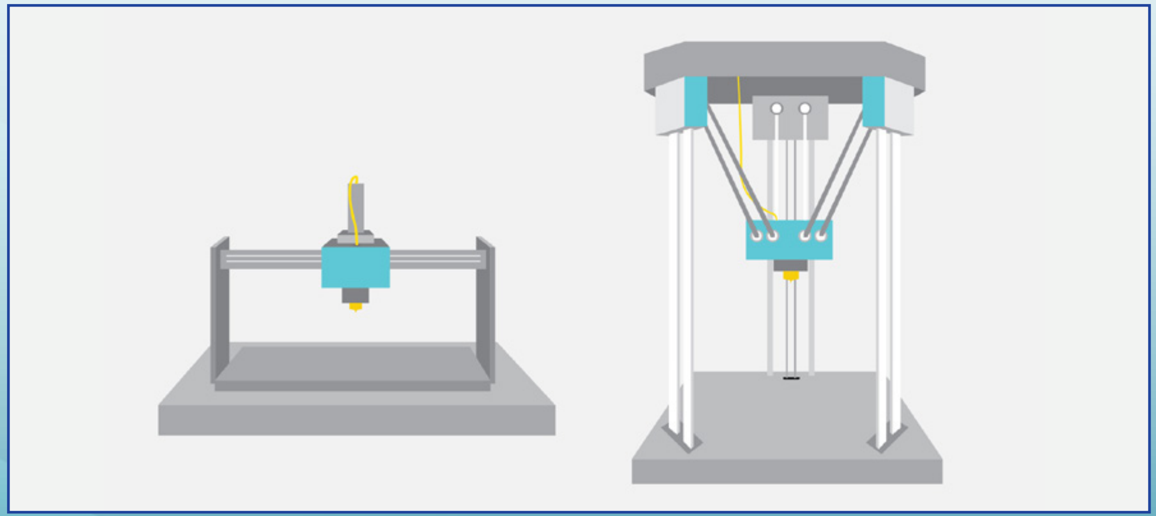


The vast majority of pick and place machines are based on a Cartesian coordinate system, with most motion available to the head moving in the X and Y directions. A limited range on the Z-axis allows for the nozzle to go up and down to select components, however, most movement is two-dimensional. Particularly in the low-cost, do-it-yourself community, there is currently experimentation on creating delta PnPs based off of similar designs for 3D printers. These are gaining popularity, as they are mechanically simple and low cost, though the mathematics behind the movement is marginally more difficult. They have certain limitations, such as limited range of motion. As the X and Y-axis requirements increase, the delta PnPs start to become significantly taller to accommodate the side-to-side motion, which makes the entire machine somewhat unwieldy and the arms become longer, heavier, and more prone to errors. Also, as the delta motion is a lower cost machine, it is less likely to have a rotational feature on the tip to align components as needed as well as other features. The Cartesian based systems are much easier to scale and the two dimensional nature also aids in quicker movement. Also, as it is the older, more established technology, it has had more time to be optimized for speed, accuracy, and cost.

Pick and places are not limited to a single nozzle. The lowest end pick and places will still likely offer different nozzles that can be attached to the head, though the swap will have to be done manually. However, for higher end machines, the pick and place can use multiple heads at a single time. This can be set up differently, such as by switching nozzles to handle a larger or smaller component, or grabbing more components of the same size at the same size by using different nozzles. There can be quite a bit of flexibility in the choices. With this flexibility also comes a certain degree of challenge in selecting and utilizing the nozzles correctly. Their size needs to be taken into account in the setup of the system, they must be small enough to attach to the smallest parts but large enough that they can hold the weight of the larger parts. They also must be well grounded to prevent small parts from becoming electrostatically connected to the nozzle instead of being left in their appropriate place on the board. Solder paste is helpful in these situations as it acts as a glue to hold the component in place.

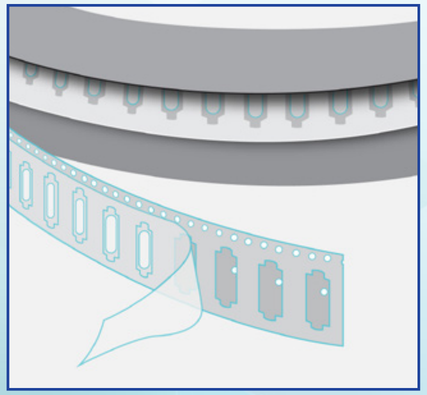
Solder paste can be placed on the board in one of a variety of ways. The most common for large production runs is the automated usage of stencils. Stencils are made by cutting holes into either a metal or plastic sheet in the places where solder is needed on the board. These are created with the information in the solder paste gerber file. Before entering the pick and place machine, this stencil is placed on top of the board or panel of boards and properly aligned so that the holes in the stencil match up with the pads of the board. A large dollop of solder paste is placed on the top of the stencil, which is then dragged across the stencil with a squeegee. The solder paste goes into the holes of the stencil, covering all of the pads. However, for very small prototyping runs when a stencil is not worth the time or money, some PnPs are equipped with solder paste depositing nozzles that will deposit individual dollops of solder paste on each pad. This is slower on a per unit scale but saves on cost and has a shorter waiting period for the arrival of the stencil after ordering.

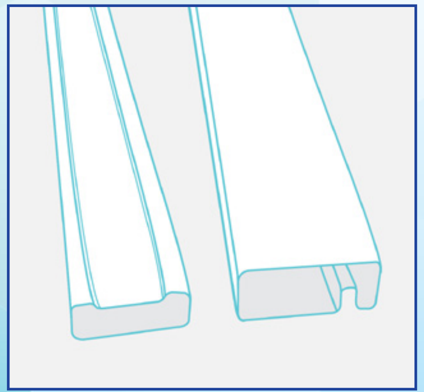
Pick and places are not limited to a single nozzle.



Another feature of pick-and-place machines is how flexible they are in their source of components to place.

In a full production line with the correct board design, bare boards can be placed in one machine and they will come out the end fully populated and soldered. They can be pasted, populated, and soldered without any human intervention. This movement through the machines and from one machine to the next is done with a rather straightforward conveyor system. The boards are moved into place, processed, and then moved automatically to the next step. Frequently, these same machines with the conveyors will not actually be connected so that while a human operator feeds boards into and out of each machine, they need to be manually moved from each stage in the process to the next. The smaller the system setup, the more likely that each machine, including the PnP, will be a batch process versus conveyor. In these cases, the boards are manually placed in the exact position where they are needed, they are then populated, and then the boards are removed to be replaced with the next board.





Another feature of pick-and-place machines is how flexible they are in their source of components to place. Anyone who has placed an order with any electronics distributor has noticed a myriad of different ways to receive their parts, predominantly Tape and Reel and Tube, though there are variations on these such as cut tape or custom reels. Tape, Reel, and Tube are all very popular with distributors because they are ideal for usage in PnPs. Reels of parts have small holes on one side of the tape, much like one would find with the paper used in very old printers. These holes are used by the PnP to move the tape forward as parts are pulled out and the tape needs to be advanced.

The clear plastic is also pulled off the tape to reveal the parts before they're picked up by the PnP. This plastic removal is done either by a motor with tension feedback or manually. A common trick when working with less expensive machines is to actually tie fishing weights to the plastic to use gravity to pull off the tape. Tubes are simpler in their usage but non-ideal for smaller components. Tubes are placed in the machine slanting downward toward the PnP to let gravity pull each component into place after the previous one is taken. So that the components don't get stuck to the tube, a small vibrating machine is used to encourage the parts to slide down. Most pick and places are capable of pulling parts from other sources, including trays or even custom plates. This is done instead of requiring more manual oversight of switching out the trays. For small runs, this is not as much of a concern.

Pick and places are impressive tools but they still have their limitations and drawbacks. As with any computer system that interfaces with physical reality, there are sometimes miscommunications. Occasionally, pick and places do not pick up their intended part, or lose it in transfer, or do not drop off the part at the intended location. There are many steps to reduce the likelihood of this happening, such as human supervision and computer vision. However, these precautions are meant to correct mistakes instead of prevent them.

Also, with many parts, in particular the small passives, once they are dropped, they are essentially gone. Their size and cost do not warrant a search and replacement and they are typically discarded. It is due to this that assembly houses request overages in parts that are provided. If the PnP is not fed all of the necessary information, it may also have the issues of hitting objects that protrude vertically from the board. This could cause serious damage and misalignment to the machine and, while not common, needs to be actively avoided.

Because of the large variety of options in pick and place machines, many designers and engineers are uncertain of what to do in their situations. The first question is whether or not to get a pick and place machine, to do the work by hand, or to get the boards assembled at a PCB assembly house. This is highly dependent on the time, budget, and experience constraints. For high school or college students on limited budgets, hand population and soldering may be the best option. The difficult decisions come where there's a bit more money and a little less time.

If equipment is priced reasonably, it is easy to think that it may be worth it to purchase and operate a PnP internally versus having the assembly work done by others. This is a valid option and in certain circumstances, may be entirely warranted. However, many small businesses fail to take the lifetime costs of owning a PnP place machine, which includes far more than the machine itself. The infrastructure that may be built to support it, the training required to adequately operate it, the maintenance and repair of the machines, certification and waste costs, and the personnel costs of operating it all come into account.

The benefit of owning a PnP machine in-house is increased flexibility, decreased time explaining a project to someone, and a potentially lower lifetime cost.

The benefit of owning a PnP machine in-house is increased flexibility, decreased time explaining a project to someone, and a potentially lower lifetime cost. If the PnP is merely for prototyping or <100 piece production runs, then a smaller, batch PnP with a single head will likely be sufficient to cover all your needs. More emphasis should be placed on the ease of changing out a design and flexibility on how to accept small quantities of parts. If this PnP is part of a new and large manufacturing process for large quantities of only a few types of products, then there will be more focus on outright speed optimization. In that case, it is recommended that you hire consultants to help with setup and in finding the right personnel to handle the manufacturing.

Pick and place machines have been an instrumental force in fueling the electronics revolution, enabling designers and manufacturers to be able to produce large quantities of electronics in very short amounts of time. Identifying their strengths and weaknesses, knowing what to use and when, and understanding the respective impact on all facets of design and logistics will allow for better usage of time and resources. Properly balancing the different parts of production and prototyping will decrease bottlenecking and make reaching deadlines a more achievable goal. EE

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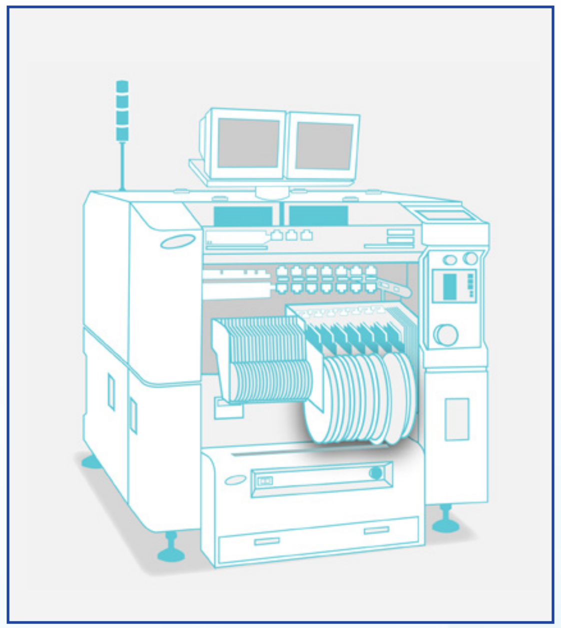

Advanced Assembly was founded to help engineers assemble their prototype and low-volume PCB orders. Based on years of experience within the printed circuit board industry, Advanced Assembly developed a proprietary system to deliver consistent, machine surface mount technology (SMT) assembly in 1-5 days. It's our only focus. We take the hassle out of PCB assembly and make it easy, so you can spend time on other aspects of your design.

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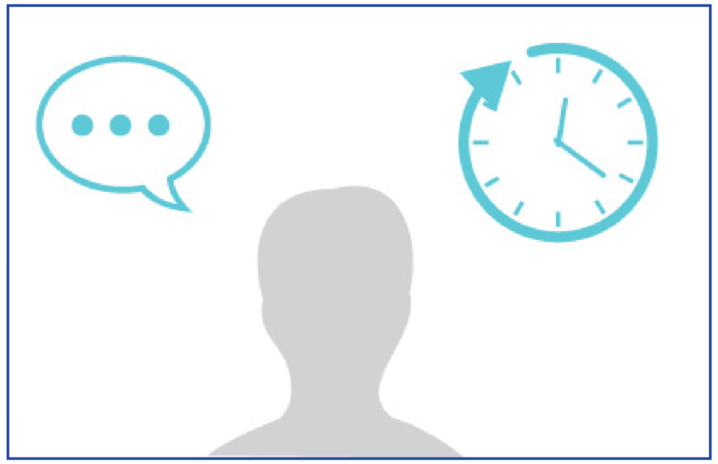
Why Assembly Jobs GO ON HOLD

There are a variety of reasons PCB manufacturers, assembly houses and engineering departments put jobs on hold. Once a job is started, the parts are kitted up, boards are procured and assembly time is scheduled. When this process comes to a grinding halt because something is wrong, it costs the manufacturer or assembler time, which is typically passed on to the customer in the form of additional charges. The time frame for the fix determines if the job stays on the floor for a short time or if all parts are recalled back to stock, rebadged, and the partially assembled boards go back in storage.



Ensuring that your job runs properly takes a bit of work, but having your assembled boards on time is worth the effort.

The number one cause of delay in assembly is a matter of communication timeliness. If a manufacturer promises a three day turn-time and they run into a problem, that promise is no longer valid because it may take two or three days to receive clarifying information necessary to resolve the issue. If time is critical, it is absolutely essential to keep communication open in order to overcome any problems in minutes versus days.

After a job has been placed on hold a number of times, the price may go up as the manufacturer attempts to recoup their losses. Because they cannot afford to shut the production lines down, even a short wait from a missing stencil or a Gerber router file may cause your job to be put on hold. The assembly company needs to change the stencil set up, fill the pick and place machines, assign the right people, do a test run, and finally process your job with intensive quality assurance and possible rework. For this reason, your job will be set aside at the station where the problem lies and cannot continue until the problem is sorted out. Ensuring that your job runs properly takes a bit of work, but having your assembled boards on time is worth the effort. The best advice is to communicate with the assembly house and make sure you have sent all the information and parts needed. Any special instructions need to be very clear and visible they can be captured in Engineering.

While communication is typically the largest and most frequent delay, there are many other delays that occur in the manufacturing and assembly process including:

MAIN ASSEMBLY HOLDS

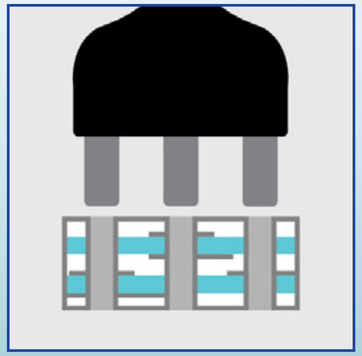
- Missing stencil paste files requiring the job to wait while a stencil is made
- Missing XYRS files preventing the pick and place machines from knowing where to place the parts
- Missing polarity markers for diodes, rectifiers and capacitors causing confusion
- Incomplete BOM information—missing part numbers, descriptions, and reference designations
- Manufacturer part number supplied does not match description
- Customers supplying the BOM with their own internal part numbers only
- Poor quality PCB with defects that make a PCB reorder required
- Multiple versions sent of same file causes confusion as to which file should be used

MAIN PARTS PROCUREMENT HOLDS

- Specifying a component that is Design does not pass a design rule check
- Choosing parts with long lead times, necessitating a buyer searching around for quicker replacements
- The client choosing obscure vendors for parts

MAIN PCB FABRICATION HOLDS

- Missing Gerber board outline
- Missing drill file
- Missing or incorrect fabrication specification info
- Missing layer sequences for multi-layer boards
- Impedance specification, which cannot be achieved
- Incorrect drilled hole size causing the component to not fit
- Extended lead time on PCB material—customer ordering boards without checking stock for less common materials such as thin copper foil, flex materials, or Kevlar
- Design does not pass a design rule check



MAIN CONSIGNMENT HOLDS

- Supplying panelized boards without panelized stencil requiring new paste stencil
- Missing parts from the kit up
- Wrong part kitted
- Insufficient quantity, including insufficient overages
- Missing information in the fabrication file

FORMAT REQUIREMENTS ON SMALL PARTS

- Lack of proper documentation with kit (packing slip with job number, purchase order number, company name, etc.)
- Not putting a full kit together then drop shipping miscellaneous parts (split shipments with no documentation)
- Failure to including specific fabrication notes with package
- Sending alternate parts without annotating the changes in the BOM

These items can be used as a rough checklist to make certain that everything is properly organized and your design is ready to be assembled. Even with advanced preparation and forethought, there are still occasionally issues and holds. If time is of the essence, being open to quick communication is the key to meeting deadlines and keeping projects moving forward. EE

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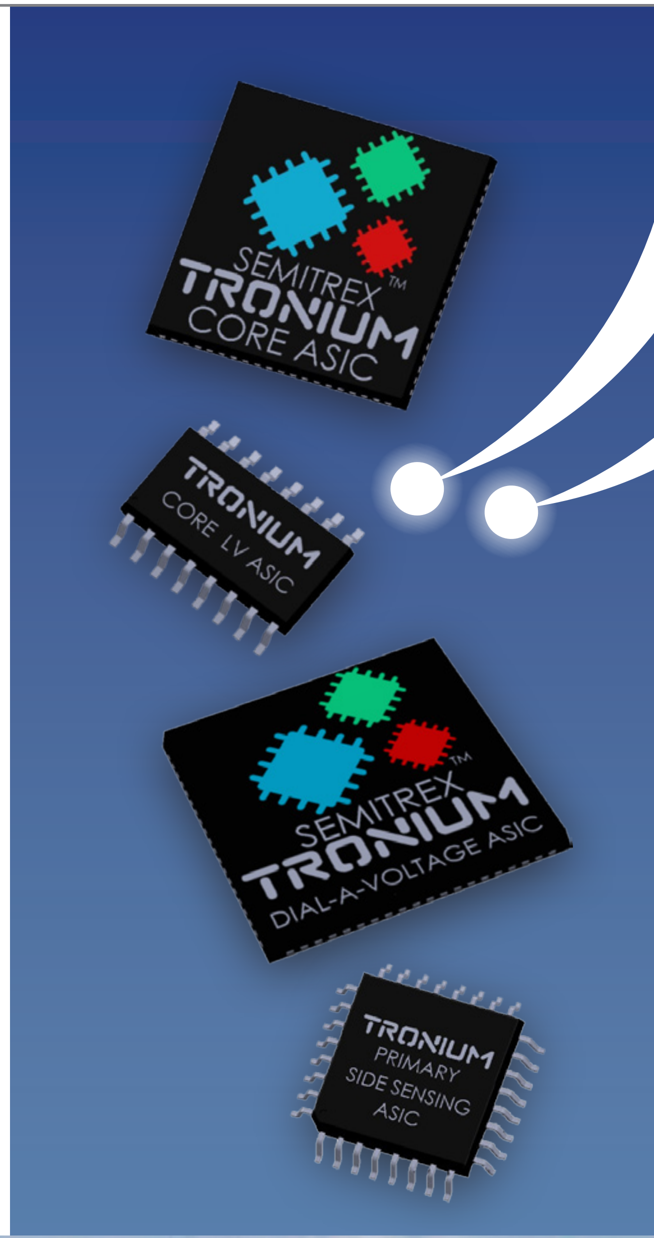
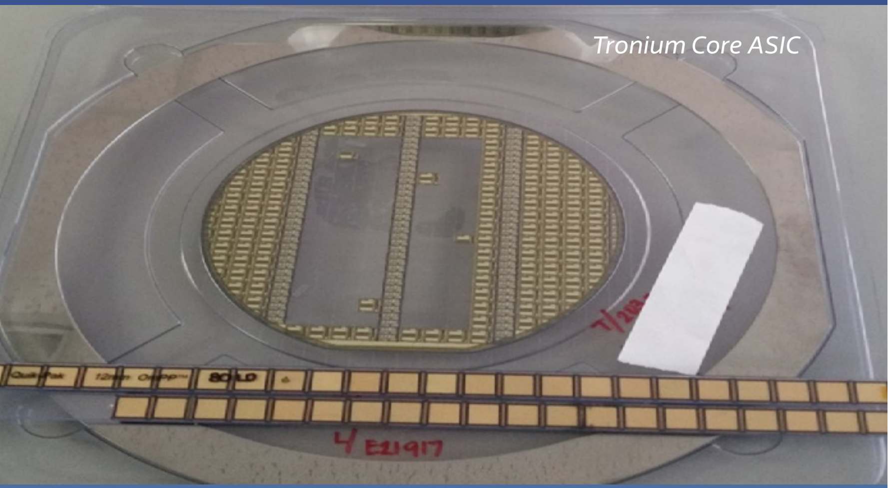
A New Way to POWER the World

Innovative Power Technology from Semitrex

Interview with Michael Freeman of Semitrex

Energy awareness is at an all-time high. As the demand for energy increases, the supply seems to be dwindling, causing restrictions at the government level to be enacted. The Department of Energy has issued a new LEVEL VI energy efficiency requirement in effect in 2016, stating that a minimum of 70 percent efficiency must be achieved. While this has some power supply companies scrambling to increase efficiency levels, Semitrex, a fabless power semiconductor company, has nothing to fear. Their revolutionary new Tronium power ICs achieve higher than 90 percent efficiency, while virtually eliminating the vampire loads that are collectively responsible for $80 billion a year in energy waste. But the innovation does not stop there. EEWeb spoke with Michael Freeman of Semitrex about the company's mission in reducing energy waste, and how their power ICs will signal a quantum shift in the power management industry.





Tronium Core ASIC

> Our goal is to reduce energy waste, circuitry cost, part count, and increase the ease of deployment of efficient power supplies globally.

Give us a little bit of background about yourself.

I'm actually a lawyer by trade but was exposed to engineering at an early age when my father bought a computer company, PC Designs. One of my proudest accomplishments is the invention of the first mobile video technology that became the foundation for IEEE 802.11(n) "MIMO" standards. These patents were licensed to virtually all cellular companies and were ultimately purchased by Samsung. In fact, in 2014 I testified in the *Apple vs. Samsung II* landmark case about the concept and invention of mobile video and video streaming technologies.

Could you tell us about Semitrex and its mission?

Semitrex is committed to reducing energy consumption through the development of radical new energy efficient power semiconductor solutions. Semitrex innovations are a quantum shift in the power management industry—and our goal is to reduce energy waste, circuitry cost, part count, and increase the ease of deployment of efficient power supplies globally.

Semitrex is an engineer-owned company. Therefore, all of our 30+ engineers around the globe have a high interest in the company's success. We have been around since 2012, and as founder, I was involved in the initial investigation for the algorithms and the capacitive breakdown ideas that led to the company's formation.

What industry trends or problems is Semitrex trying to solve with its offerings?

Global electrical grids are burdened to the brink. A recent Forbes article spoke about how "vampire loads" have reached over 400 terawatt hours-per-year in waste, which equals over $80 billion lost annually worldwide. Thus, better energy efficiency is one of the most important challenges of our time.

The Department of Energy will enact its LEVEL VI Efficiency Requirements in 2016, which will require 86 percent overall efficiencies at Active Loads and less than 100 milliwatts at No Loads. Our solution exceeds this standard with over 90 percent efficiency across all load ranges, at Active Loads, and beats the standard with less than one half milliwatt of power expended at No Loads for the U.S. and only one milliwatt of standby power needed for Europe and Asia.

What is unique about Semitrex's technology?

Semitrex uses a unique "pre-regulation" voltage conversion technology called Muxcapacitor™, which is based on capacitive voltage reductions, rather than inductive reductions. Muxcapacitor permits very high voltage conversion efficiencies of over 90 percent across all load variables, even down to 50 milliamps of current draw. We are the first to do this.

In fact, recently our core circuit was approved by the U.S. Patent and Trademark Office (USPTO), which said that our technology capacitor circuity was patentable all over the world. USPTO determined that our Muxcapacitor circuitry and gate technologies are patentable in 148 countries, due to the fact that they are "new and unique over all other prior art."

Additionally, our Dial-A-Voltage™ feature permits the chips to be programmed for the voltage output desired, so that a single chipset can be set to cover voltage output ranges from 1.8 to 48 volts. And we have our own version of Primary Side Regulation™ technology.

How do you achieve high efficiency across a wide load range?

With our Muxcapacitor technology, we still use a transformer, but our capacitive technology is a "pre-regulation" technology which permits us to do small-ratio conversions. With a transformer, it takes 110 volts and knocks it down to five volts. We take hundreds of mini capacitors which are opening their gates to let in little trickles of voltage that we then break down. We reduce the breakdown ratio incrementally to achieve higher efficiencies.

In regards to your switch capacitor technology, what levels of power can it scale up to?

One of our research and development teams is working with the foundry on silicon carbide to work this into the kilowatt range. Right now, it is stackable. Each chip has a wattage range of up to 100-watts, and we stack another chip

> Better energy efficiency is one of the most important challenges of our time.

Our Primary Side Sensing Regulation technology helps reduce the part count from 48 to 50 in a typical flyback configuration to less than 25.

on top of that to get 200-watts, and another on top of that to be in the 300-watt range. We put the chips in parallel for added current, and they can also be put in series if the outputs are isolated. Our technology allows you to turn the chips a quarter or half turn, then connect them either in series or in parallel.

You mentioned that Semitrex does use a transformer—is that where your primary-side regulation technology comes in?

Yes it does. We also have our own version of primary-side regulation that, unlike everyone else's, does not require the third winding to sense. We sense directly off the primary side of the inductor off the transformer, so that regulation is in two versions: a five-percent deviation regulation as well as a one-percent deviation regulation, for both the voltage and the current. Some other companies have primary-side regulation devices that do well on the voltage side, but they don't do very well on the current side.

How does removing the opto-isolator save power?

Existing power supply reference designs require up to nine required opto-isolation parts, which consume power and generate waste. Our Primary Side Sensing Regulation technology helps reduce the part count from 48 to 50 in a typical flyback configuration to less than 25.

Our technology aims to do three things: run at over 90-percent efficiency at very low-load currents, provide almost zero load at a half a milliwatt of standby power, and consolidate a fragmented industry. It typically takes 14 or more vendors to provide all of the parts to a power supply. By cutting the number of parts in half, we can reduce the size of the footprint and simplify the inventory and design side of the process.

What are some of the target markets and applications that will benefit from Semitrex?

Our Dial-A-Voltage feature permits the same die to be programmed for multiple voltage outputs. Because one chip can power so many things, Semitrex technology can be used in a vastly wide array of products.

With that said, our first target market is the 1.5 billion units-per-year charger market. Since our efficiencies do not change in scale, the efficiency of a 10-watt charger remains when you go up to a 90-watt power supply for a laptop. We are still at 92 percent at the low end and 97 percent at the high end of the current.

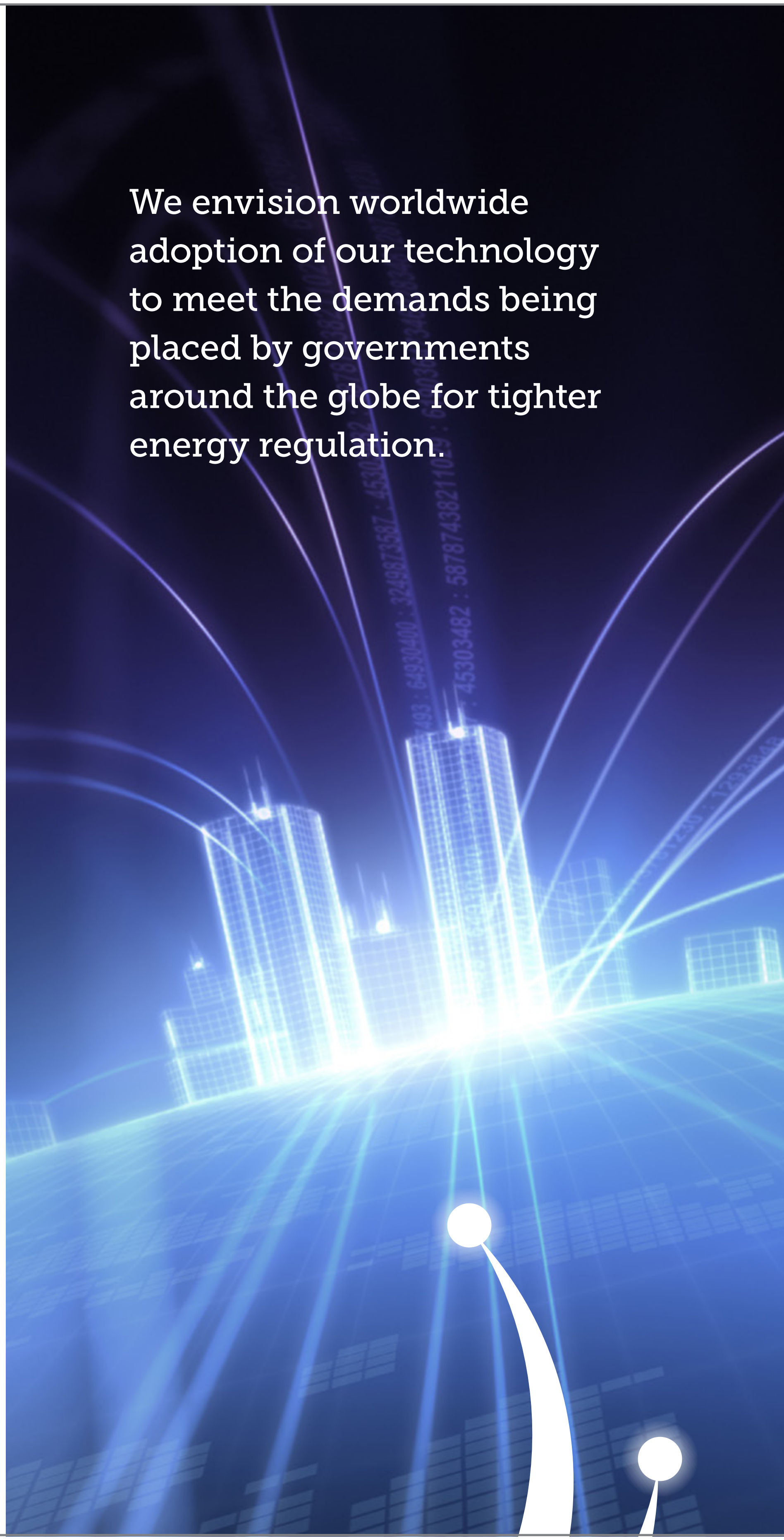
Another area of focus for us is the 100 million units-per-year TV/monitor market. Right now, a 60-inch television has up to 500 parts in it—300 electronic parts and 200 mechanical parts. Semitrex could reduce this number by up to 90 percent. With the high energy efficiencies at the low current flows and standby power, our technology runs a lot cooler than most typical power supplies, particularly for a multi-voltage power supply like a television.

Our technology can also benefit the following industries: medical, data centers, telecom, gaming consoles, white goods, and more. In all, we have estimated that there are 1.5 billion items sold per year from these market segments that could use one or more of our chips.

What is the next step for Semitrex?

In the near term, we will have samples of our new product. There is our all-in-one chip, which has 64 pins, and our two separate chips that will have everything on a 180 process and the high-voltage on a one-micron process. We also have a 20-500 milliamps pwIoT, which does not have a transformer and uses capacitive isolation. The pwIoT takes AC line voltage and drops it down to whatever voltage the sensor needs. We think it will be very popular for sensors and small devices that will be hooked up to the Internet of Things, especially since all Tronium PSSoCs can be connected, monitored or controlled wired or wirelessly.

Further down the road, we envision worldwide adoption of our technology to meet the demands being placed by governments around the globe for tighter energy regulation. By reducing the part count, and combining the circuitry of a power supply circuit on an analog power system die, which has embedded digital "intelligence," our technology will usher in a new era of power conversions. EE



We envision worldwide adoption of our technology to meet the demands being placed by governments around the globe for tighter energy regulation.

Supercap (EDLC) Cell Balancer IC
(BD14000EFV-C)

EDLC Style Supercaps

ROHM SEMICONDUCTOR

Even before the basis of electricity was fully understood, storage devices were fashioned to store charge for use at a later point. While the first electrochemical battery was developed at the turn of the 19th century, the first recognized capacitor was invented over fifty years earlier in 1745. The Leyden jar operated on the exact same principles as modern capacitors, with two electrodes physically separated by a dielectric. With time, capacitors became even smaller and increased in capacity as materials were refined and methodologies were improved upon. Capacitors filled a different niche in the realm of electrical storage devices due to the pros and cons as compared to the more common electrochemical storage. Their ability to charge and discharge hundreds of times faster than batteries makes them ideal for helping with situations that require quick power. However, despite the incredible improvements in the capacitors, they have always lagged significantly behind batteries in their energy density. While capacitors can charge and discharge quickly, their low energy density has limited them to supporting roles with other energy sources.

In the last several decades, many different organizations have been trying to go beyond an incremental increase in capacitance to overcome the limited energy density. Many different approaches were taken, including physically combining capacitors with electrochemical cells to take advantage of the benefits of both technologies. All of the approaches that were successful at pushing capacitance from the millifarad range up to one to thousands of farads are called supercaps or sometimes ultracaps. These capacitors are categorized for their phenomenal increase in capacitance versus the more traditional electrolytic capacitor technologies. The predominant type of supercap in use is the electric double-layer capacitor, frequently shortened to EDLC. The EDLC follows the same principles of a capacitor but uses unique materials and construction. Looking at the equation for capacitance, it is easy to see what can affect the capacitance. To increase capacitance, at least one of the following conditions must be met—the permittivity constant of the dielectric needs to increase, the surface area of the electrodes or plates needs to increase, or the distance between the two plates needs to decrease.

$$C = \frac{\varepsilon A}{d}$$

EDLCs accomplish their higher capacitance in two ways. They use a unique porous substance, typically activated carbon because of its low cost, that has an incredibly high surface area versus volume. This activated carbon is applied to the electrodes of the capacitor, causing a marked increase in the surface area of the capacitor. To further increase the capacitance, the distance between the two electrodes is decreased by practically eliminating the dielectric, which is usually on the order of microns to millimeters thick. Instead of a standard dielectric, the activated carbon is placed in an electrolytic fluid. When a charge is applied, the electrodes are polarized with the electrolytic fluid acting as an extremely thin dielectric, a couple molecules thick. The combination of these two improvements have lead to commercial EDLC style supercaps with greater than five thousand farads of capacitance.

The predominant type of supercap in use is the electric double-layer capacitor, frequently shortened to EDLC.

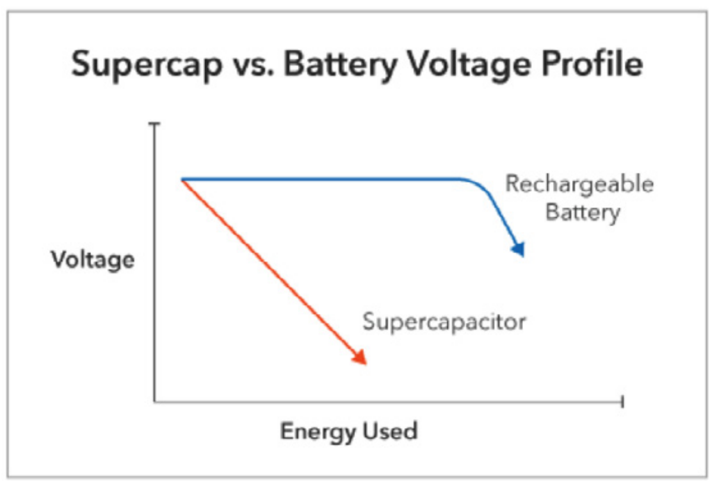
Supercaps share the same strengths of electrolytic capacitors. They can be charged and discharged hundreds of thousands of times, orders of magnitude more frequently than batteries. They are extremely simple to charge, without fear of overcharging or complicated charging schemes that are frequently found with LiPo or NiMH batteries. They also have low equivalent resistance, or ESR, compared to batteries though it is slightly higher than standard electrolytic capacitors. This low ESR affects multiple aspects of the functioning characteristics of the supercaps. It means that they can charge and discharge very quickly, that there is minimal self-heating while doing so, and that they're significantly more efficient in returning the energy placed in them, nearly 100% efficient. The ability to charge and discharge quickly gives supercaps a very high power density. Of course, this can also be considered a drawback in certain cases as a shorted supercap can discharge all of its energy in an extremely fast, nearly explosive release. At minimum, sparks can easily be generated, which may be problematic in industrial or chemical laden sites.

The drawbacks of supercaps are also very similar to standard electrolytic capacitors. While supercaps have energy density several orders of magnitude greater than their standard cousins, supercaps still fall below one tenth the energy density of electrochemical batteries. It is important to note the difference between power density and energy density in these cases. Energy density has a time factor, with units of watt-hours per kilogram where power density has units of kilowatts per kilogram. Due to the high discharge rate, supercaps have very high power density and are able to provide huge amounts of power. However, they are unable to sustain that discharge rate and their overall watt-hours are relatively limited. Supercaps also have the concern of relatively low cell voltages, requiring multiple supercaps in series to achieve higher voltages, though at the expense of diminished capacitance. This in turn leads to loading and balancing issues. Also, supercaps have relatively high self-discharge rates, losing most of their charge in a matter of days or weeks. Finally, supercaps have a linear voltage drop-off as they're discharged, unlike

The ability to charge and discharge quickly gives supercaps a very high power density.

most batteries that are designed to maintain the same voltage through the majority of the discharge cycle.

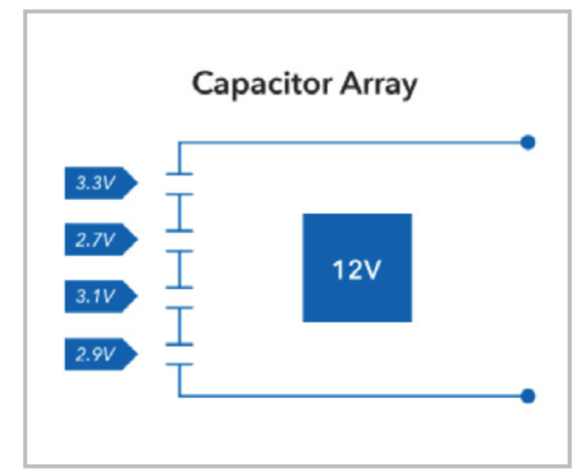
With many of the benefits of a capacitor but an energy density more similar to that of electrochemical batteries, supercaps fill the gap between the two. This has become increasingly important over the last twenty years or so as the role of supercaps has expanded to fill the new requirements introduced by electric or hybrid vehicles. In the quest for higher efficiency, regenerative brakes have moved from being integrated in only large vehicles such as trains to being placed in some of the smallest



cars on the road. Regenerative brakes turn the kinetic energy of the car into electricity instead of heat as done with typical brakes. In its most simple form, regenerative brakes use the back-EMF from a motor to provide resistance to the turning of the wheels, slowing the wheels, while also turning the motor and creating electricity. This electricity is then immediately turned around and used to positively accelerate the car when ready to go once again. The concern with this scheme is where to store that electricity during that very short period. Standard capacitors do not have the capacity and batteries struggled with both the speed required to store that high surge of power as well as doing full charge/discharge cycles dozens of times in traffic, severely shortening the life of the battery. In this situation, supercaps are the ideal solution, relying on the strengths of the supercaps faster discharge rate and not being affected by the drawbacks related to self discharge. This type of system is not only found in commercial vehicles but has also recently been found in Formula One racing. In F1, nearly all of the cars use regenerative braking, either relying completely on a mechanical system involving flywheels, or making use of a motor generator, utilizing supercaps for the storage.

While regenerative braking is relatively new in commercial vehicles, supercaps continue to be important in other power applications as they have been for years past. In any case where there are peaks and valleys in the electrical system, supercapacitors can act to smooth and regulate the voltage to keep levels within standards. In large manufacturing plants, there are motors that are so large they can bring down entire electrical grids for small cities if they are not turned on carefully. As part of the process of turning it on, a supercapacitor can be placed close to the input of the motor to help maintain the line voltage as the motor is ramping up. In a similar vein, uninterruptible power supplies that are focused more on voltage sag can perform better with supercapacitors as they can respond to voltage drops faster than batteries. Supercaps have also been used, thus far in a limited fashion, as temporary storage for alternative energy sources such as windmills. Windmills have very highly volatile power output and can change in their output by tens of megawatts per minute. Supercaps can be used to provide power in the interim while a secondary power sources can be brought up.

All of the applications discussed require much higher voltages than those offered by supercaps, which, as mentioned, is overcome by putting the capacitors in series. Beside the drawback of reduced capacitance, cell imbalances are a very large issue. When a voltage is applied across several capacitors in series, that voltage is not always spread out evenly across all of the capacitors. This is similar to how battery packs that have cells in



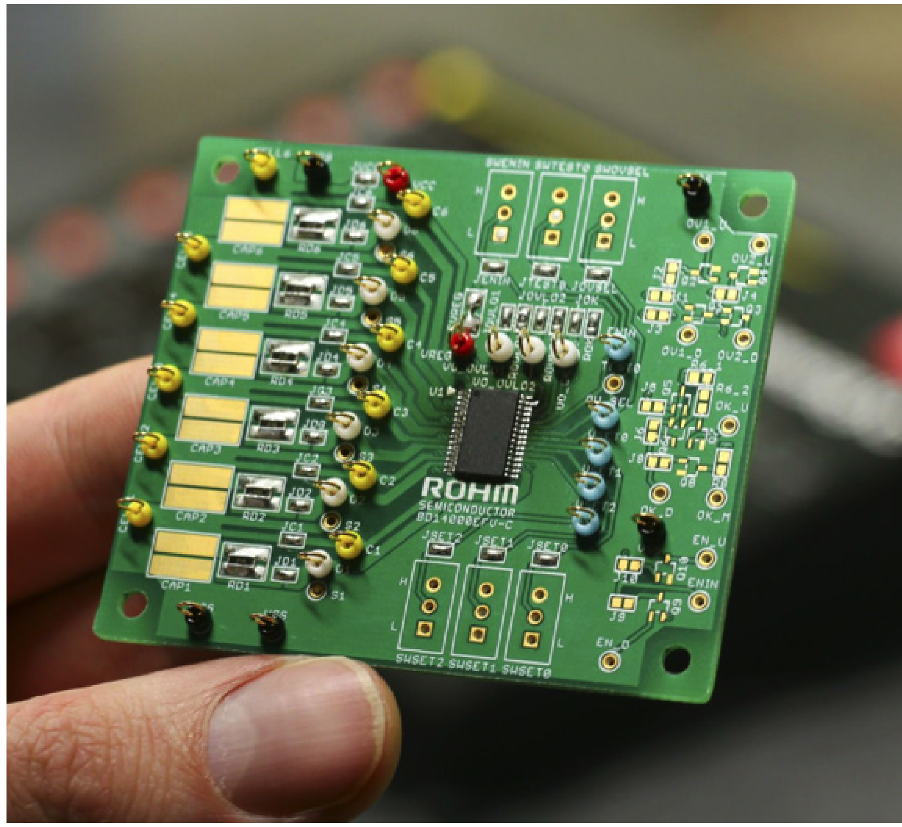
Regenerative brakes turn the kinetic energy of the car into electricity instead of heat as done with typical brakes.

series will have special connectors to the charger so that each cell receives the correct charge. Due to minor differences in their ESR, their location in the series of capacitors, as well as other variations in the capacitors, some capacitors will regularly receive a higher voltage while others receive a lower voltage. This both reduces the overall capacitance available to the rest of the circuit and puts the supercaps out of their operating thresholds, significantly reducing their useable life. The overvoltages on the certain supercaps can lead to a catastrophic failure, putting the entire string of supercaps out of commission. While a failure is unlikely to be literally explosive, there is the possibility of harm from such a situation. More frequently, the side effect will be an unexpectedly shortened lifespan, requiring inconvenient and costly repairs. Depending on the implementation, the failure may be unnoticed until such time as the supercaps are required. In cases such as uninterruptible power supplies, this could result in equipment damage and data loss.

Where there are peaks and valleys in the electrical system, superca-pacitors can act to smooth and regulate the voltage to keep levels within standards.

As, even in the best of scenarios, supercap cell imbalances are a serious concern as most designs incorporating supercaps have custom made circuits that proactively check the cell voltages and make certain that none of them are in an overvoltage condition. While this is effective, it is time consuming because, up until this point, every design has been done from scratch. The entire design process from brainstorming to producing and testing has been completed by the product engineers, using large portions of development time. Seeing the trend of increased usage of supercaps but still no good solutions to the balancing issue, ROHM has created the first single-IC EDLC cell balancer, the BD14000EFV-C. This IC has been made to replace all of the custom circuitry that has been used up to this point.

The BD14000EFV-C is a useful resource for designers as it has multiple over-voltage detection functions as well as the ability to detect any abnormal modes, such as uncharacteristic deterioration of the supercap cells. This chip has been designed specifically for EDLC style supercaps with voltage specifications between 2.4V and 3.1V. These capabilities are found in a very small form factor of a 10 x 7.6mm HTSSOP package, which has been found to be nearly 40% smaller than implementing the circuitry with discrete components. By reducing all of those components, upwards of twenty or thirty, bill of materials are simplified and supply chain concerns are reduced. Also, with variations even within the tolerances of the components, there will be a certain degree of inconsistency in the balancing circuitry that may leave certain cells vulnerable. On top of the performance increases, the reduced development time means that products can get to the market faster, shaving precious weeks or months off of the design and testing. Supercaps have been filling a crucial role that is expected to continue growing quickly over the next few years hand in hand with hybrid or electric cars as they become more popular. As the demand increases, more advances are expected to make supercaps even more energy dense and therefore more useful in all aspects of society, particularly alternative energy sources such as wind or solar. In the development of these phenomenal pieces of technology, it's important to create the circuitry that properly utilizes and protects them so that they can best fulfill their role. EE



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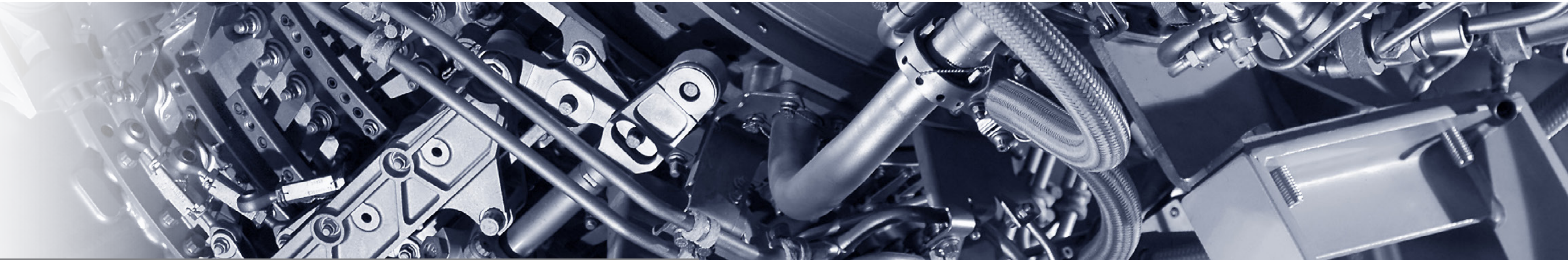
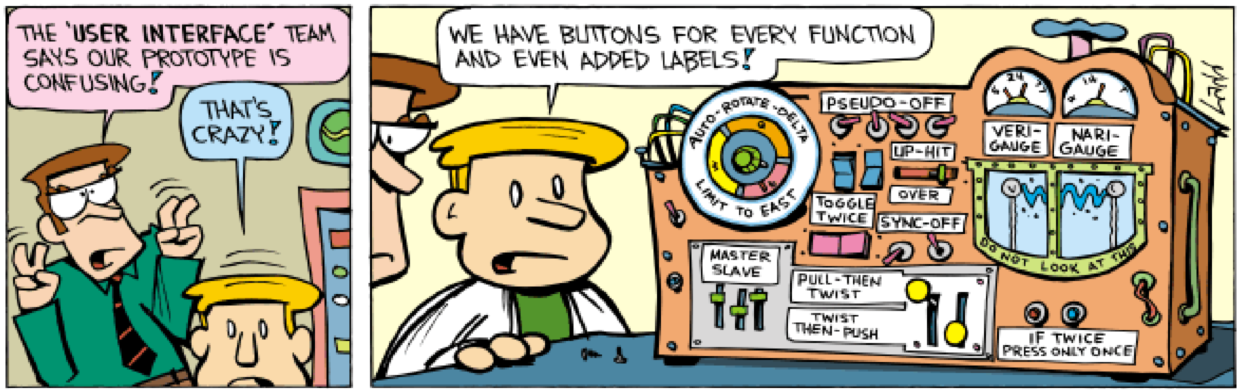


Return-to-ZERO

LAB Hoarders

User Interface



Football Funds