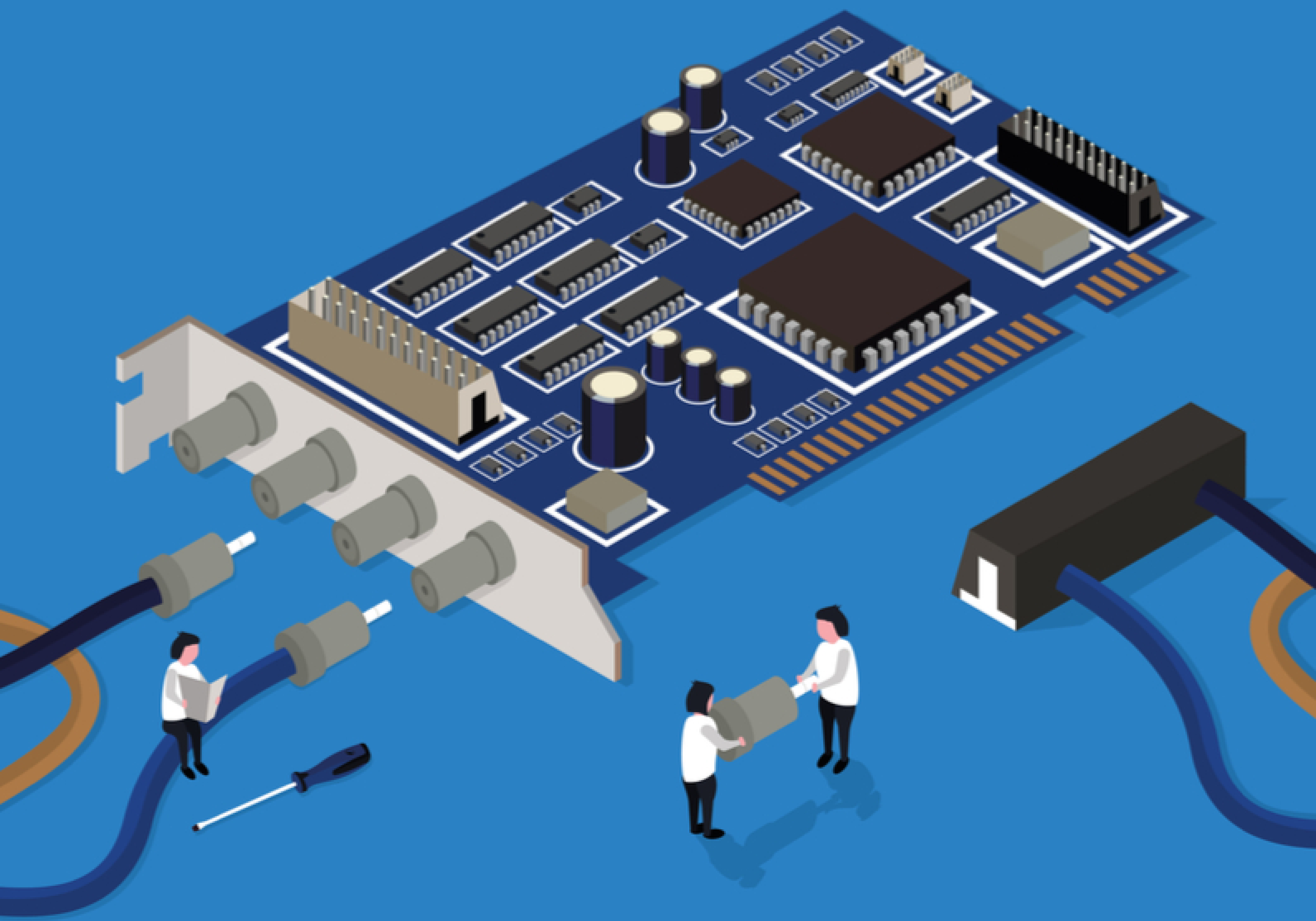
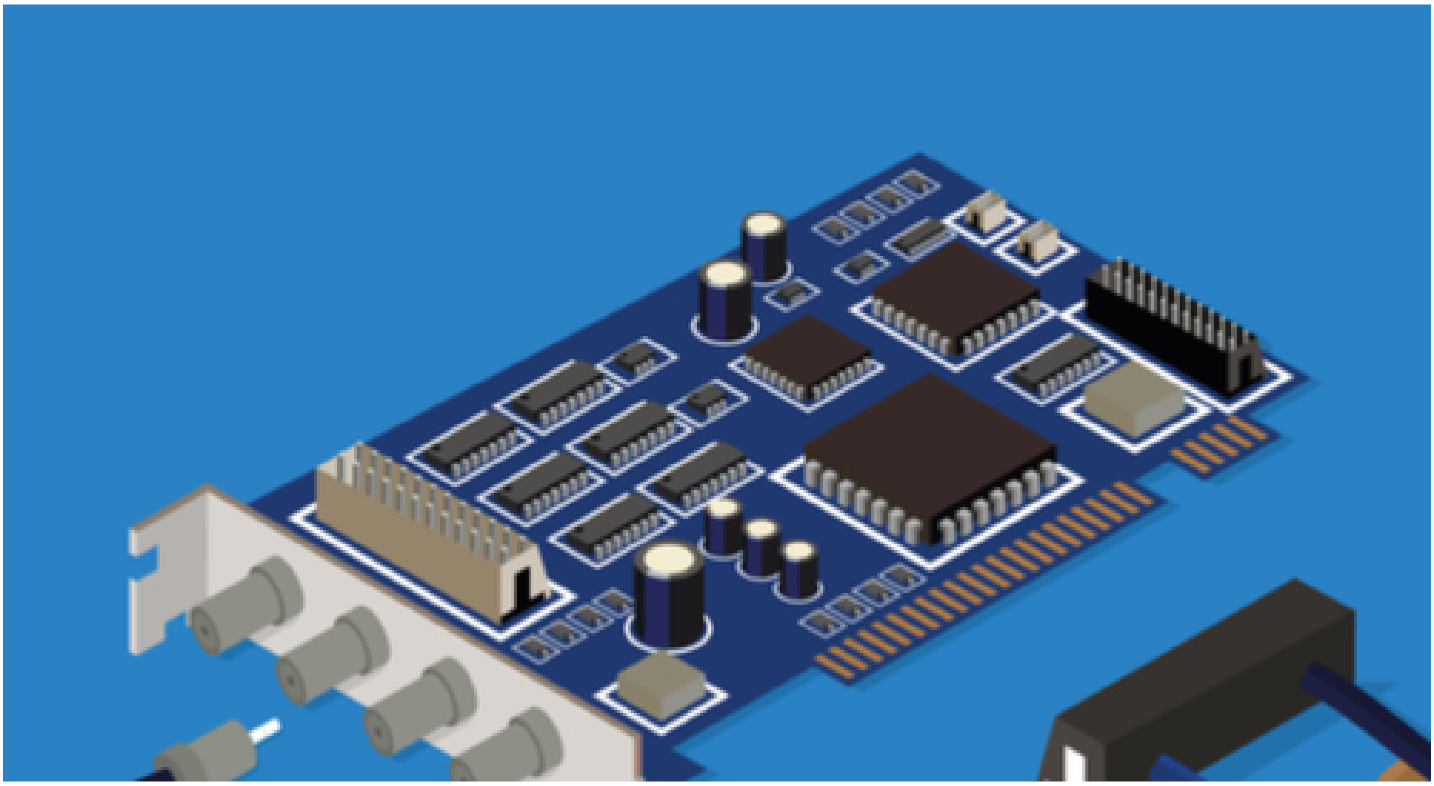
Altium®

Modular Design





MODULAR DESIGN

PCB Design is a complex field and every step you take to design and develop a board has its own set of best practices. But what will truly move the needle in your design process? Modular Design tools that keep your team not only focused but *in the flow.* Altium PCB design tools start each iteration with ultimate productivity in mind. Join us in an exploration of Modular PCB design and get an inside look at what has made Altium Designer *the designer's EDA tool* right from the very start.

Join us as we discuss a variety of topics to help you with Modular Design, including:

- Modular approach to simplify PCB Design Process
- Modular approach to PCB Design for internet of things applications
- Modular Design Tips for Obsolescence Management
- How Tesla Rethought Lithium Ion Cells Through Modular Design and Vertical Integration

HOW TO USE A MODULAR APPROACH TO SIMPLIFY YOUR PCB DESIGN PROCESS

PCB design can end up taking more time if it is not planned out properly when moving from conceptual spec to actual design. There are a lot of factors to consider at once. For example, where to place major components to optimize space and performance, and which one to drop first. You'll also need to consider where subsystems fit and which placement will result in the cleanest traces. These initial decisions can be daunting and lead to either procrastination or having to completely start over. Read on to find a solution for this!

On my first trip to the Yosemite, I bit off more than I could chew. Big mountains, bad planning, and I found myself at the mercy of a squeeze chimney. One emergency bivvy later, my project had to be scrapped and I was back in the valley staring up at the mountain I couldn't conquer. PCB design can end up like my failed climbing endeavor if it is not planned out properly when moving from conceptual spec to actual design. There are a lot of factors to consider at once. For example, where to place major components and which one to drop first. You'll also need to consider where subsystems fit and which placement will result in the cleanest traces. These initial decisions can be daunting and lead to either procrastination or, in my case in Yosemite, having to completely start over.

To help break through designer's block I simplify the design concepts by modularizing them into virtual components.

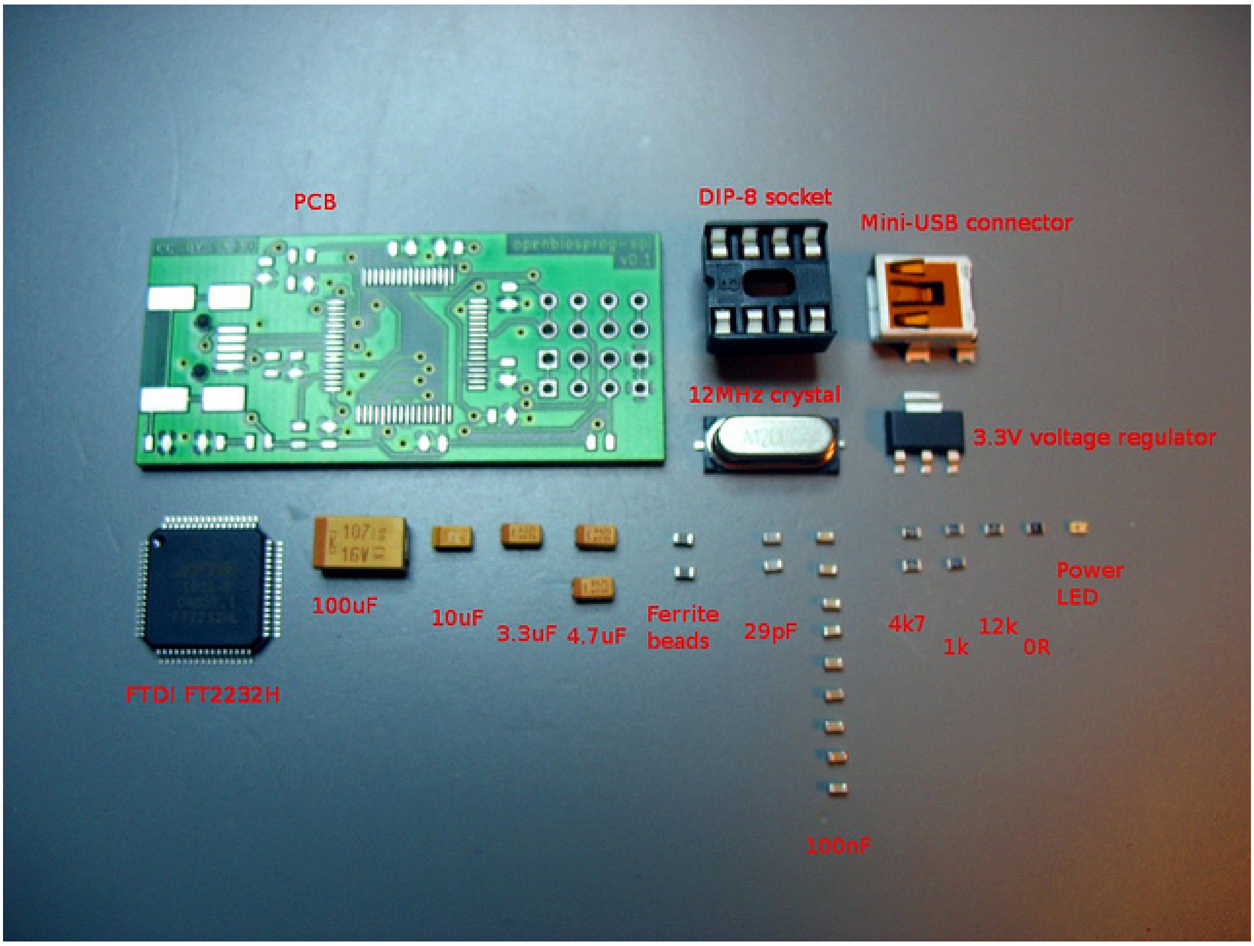


Image source: Flickr User Uwe Hermann *(CC BY 2.0)*

BREAK THE MOUNTAIN DOWN INTO STEPS

Much like how a climber would approach a mountain; break your PCB design into manageable "pitches" and tackle each one individually until you've reached the top. To get your design started, find areas in the design that are self-contained or have a well-understood interface. These sections will eventually need to be designed in detail, but in the beginning, we only need to identify their presence on the board. Once they have been identified, you can temporarily block them off using a placeholder, which we will refer to as a "black box". Much like planning a climbing route, this will let you focus on the big picture and then you can go back and tackle each individual section. Using placeholders in your design to prioritize sections of your layout is commonly referred to as “modularizing your design”.

If you think about it, many of the actual components we use in our designs are black boxes for two reasons:

1. They present a well-defined interface in their pinouts and specs.

2. We know that their performance is predefined and specific to their interface. As a result, we do not need to define how they function in their interface.

Imagine how complicated your project would become if you had to represent the internal workings of all op-amps, CPU’s, regulators, etc. It would be enormously complex.

We can expand upon this concept of placeholders to kick start the design process. Often you’ll have a jumping off point for figuring out how to break down your design into manageable pitches if you stay organized. Remember your project documentation? Those flow charts, design overviews, and user documentation should present the function of your design at a high level. Like your modular PCB layout, these documents focus on the big picture of your design and are an excellent resource for initially modularizing your PCB layout.

Regardless of whether you have these documents or not, I recommend repeating the following steps until the design concept is simple enough to complete:

- Find a subsystem or functional group you can modularize

- Identify all the components that are part of the group

- Identify the inputs and outputs (i.e. the interface) of the group

- Create a black box to represent the group and its interface

- Substitute the black box for the identified components in your design

Once you have defined your modules, take a first pass at your schematic or PCB using black boxes just to get an idea of how they interrelate. It will be straightforward to build out the whole design. With that done, you can begin designing the contents of the individual black boxes. You may choose to modularize the subsystems within them as well. Modularization works at any level.

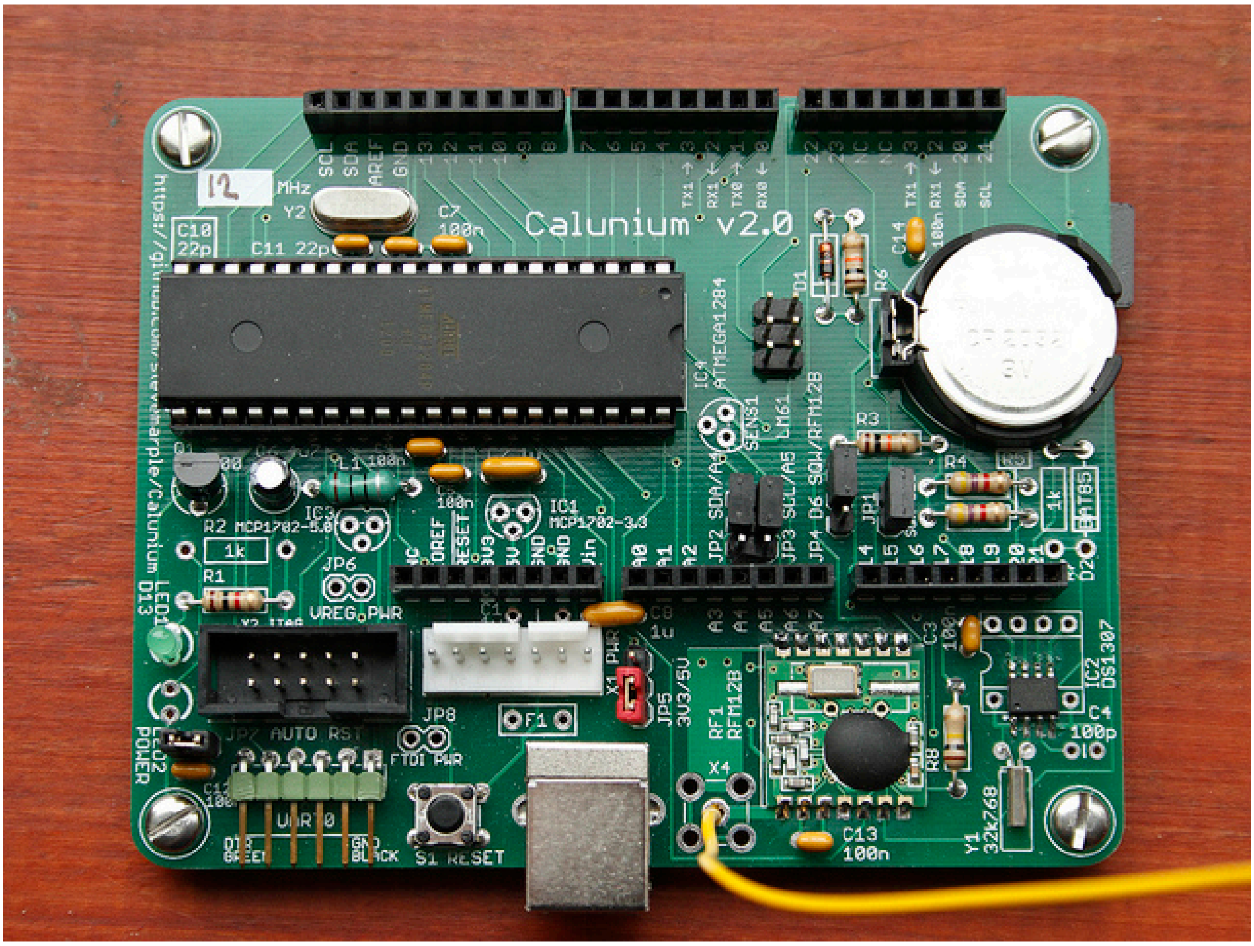


Image source: Flickr User Steve Marple *(CC BY 2.0)*

MODULARIZATION TOOLS AND TECHNIQUES

Most design software will include features that help you modularize your design. This allows you to represent your modules in the project environment in whatever way makes the most sense to you and your team. Here are a few ideas that are commonly available:

DRAWING TOOLS

Use the drawing tools to place shapes on your board. This can be a simple box or something more creative--whatever helps you stay organized. You can also use the line drawing tool to show connections to other parts of the design.

CUSTOM COMPONENTS

Some design software lets you define custom components in case you don't find everything you need in their component libraries. You may even be able to define the electrical properties of the component accurately enough to include it in a working schematic.

NOTES

Use text to represent your black box, or add written text to a drawn shape. It may also be helpful to annotate why you made this placement and to define the black box's intended function. Be sure to point to the part of the design the note applies to with an arrow.

TO-DO'S

Create reminders for yourself to design the contents of your black boxes using "to-dos". To-do items should be available to you anywhere in a project. They can be assigned to an owner, categorized, and marked as complete when they are done.

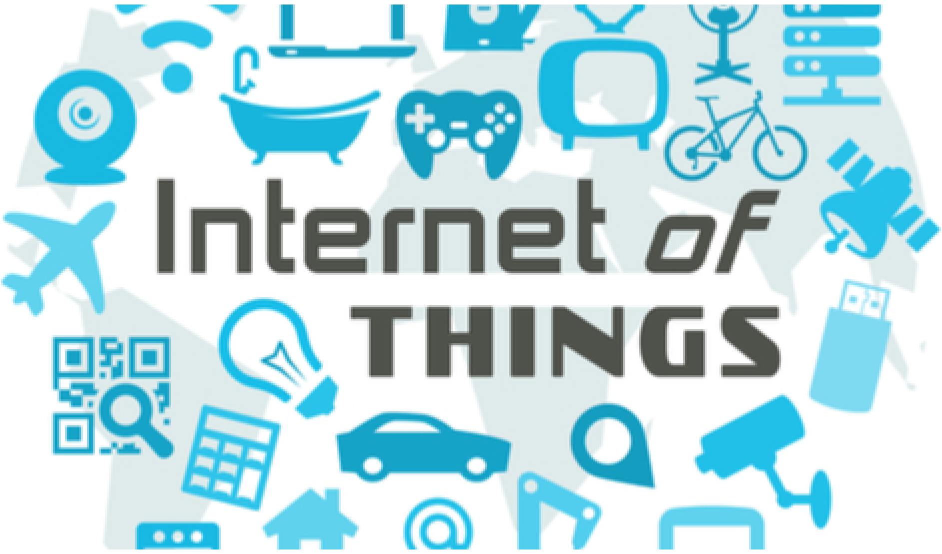
CLEAN UP WITH EASE

Since my first experience in Yosemite, better route planning has led to significantly less discomfort. The same goes for modularizing your PCB design and, lucky you, there are even programs to help you out with this. Altium Designer can help modularize your design, and track and report on your progress. This way you can spend less time anxiously plotting how to get out of a bad situation and more time designing an excellent product.

WHY YOU SHOULD TAKE A MODULAR APPROACH TO PCB DESIGN FOR INTERNET OF THINGS APPLICATIONS

As engineers, one of our worst nightmares is doing the same pointless thing over and over again. Adopting a modular design philosophy for Internet of Things PCBs will save you from that monotony. Optimize your design process and save time, money, and sanity, by reusing your PCB designs. Read on to find out more!

While in college I did several projects with Arduino boards. I started with the basic Arduino Uno, but later bought several different Arduino shields for various projects. The standard design of Arduino has helped them become one of the top entry-level embedded system platforms. Arduinos are often used to prototype IoT devices, which are mostly modular. Since the IoT is inherently extensible, PCB design for IoT devices should be as well. Adopting a modular design for your IoT PCBs will help you design more efficiently, and reduce manufacturing costs for your PCBs.



The Internet of Things!

OPTIMIZING WORKFLOW

As engineers, one of our worst nightmares is doing the same pointless thing over and over again. I once interned in a testing lab where I ran the same test on a broken machine every day for 4 months. My supervisor hoped I could find some kind of correlation in the data I collected, but there was none. That machine is still being tested by some poor intern, spitting out bad data. With a traditional design mindset, you'll end up doing the monotonous work of designing 10 similar boards, for 10 similar products. I may wear monotone colors, but that doesn't mean I enjoy monotony. Extensible design means producing one board that works for all 10 products. You can benefit from this design philosophy by streamlining your PCB's design, tailoring, testing, and sales.

- Design - What do a WiFi toothbrush and a WiFi chair have in common? Yes, they are both useless, but that's not what I was going for. They both use similar components, maybe WiFi, RFID, etc. Most IoT things will include fairly predictable features that use predictable components. So, instead of designing a PCB for a toothbrush, and then a PCB for a chair, make one that does both. Then you'll have supplied two bad ideas with a single board.

- Tailoring - So, what if your customer now wants to make a WiFi shoe? It will probably have similar functionality to the WiFi chair, but different structural requirements. Well, I'm sorry, but you'll have to make some alterations so your basic board will work. However, it's often easier to change an existing board than to make an entirely new one.

Taking a modular approach to your IoT designs lets you be efficient and chill.

- Testing - It's much easier to test 20 of the same board than to test 20 unique boards. Though, it is easier to test 20 unique boards incorrectly. Do you really trust those guys in Quality Assurance to rigorously test such a wide variety of boards? Just make the designs as close to each other as possible and reduce the risk.

- Sales - Would you enjoy using a new design program every couple weeks? No? Well, embedded systems engineers won't like it if you make them use a new board every couple weeks. If you make your design standardized, like Arduino's, embedded systems engineers will choose it simply because they already know how it works.

No one really enjoys doing more work than they have to unless they're just a huge nerd. Ok, lots of us are huge nerds, but let's save ourselves the extra work anyway. Modular design will save time and work from design down to sales.

Doing the same repetitive tasks is the worst!

OPTIMIZING CASH FLOW

If you need to convince your manager to let you start with extensible design, send them this section.

Optimization in the design process automatically translates to cost savings in man hours. Time not spent rehashing the same old designs is time spent designing boards for new useless products. Another major cost saving area is in board manufacturing. Manufacturers dislike fabricating low quantities of board designs, a preference they show with high pricing. The more similar your PCBs are, the less they'll cost to manufacture.

Your PCB design software should help you keep old designs with a new fangled feature called "save." However, CircuitStudio has a somewhat more advanced "comparator" feature that can help with a modular approach to design. With the "comparator" function CircuitStudio allows you to compare different designs against each other. This makes tailoring modular designs and adding features from one design to another a breeze.

Life is short, don't waste developing the same circuit over and over. Modular design will help you use your designs and time more efficiently. It will also help your company save money in man hours and manufacturing costs.

Has modular design left you with lots of time on your hands? Chat with an expert at Altium.

HOW TESLA RETHOUGHT LITHIUM ION CELLS THROUGH MODULAR DESIGN AND VERTICAL INTEGRATION

Lithium Ion batteries provide high performance and fast recharging, making them ideal for electric vehicles. However, their cost has always been a barrier to adoption in the world of electric vehicles. Tesla has sidestepped this issue by adopting a highly scalable modular approach. Every battery package they construct is made out of hundreds of one single standard cell. Tesla is taking their battery production in-house, constructing the Gigafactory to build this one battery unit in high volumes. Through this simplified approach, they've been able to not only bring better battery technology to electric vehicles but have also vertically integrated their manufacturing.

I learned a lot about lithium-ion (Li-ion) batteries when I was working for a smartphone company. With every phone redesign, we built a new battery pack from scratch. The phone gets thinner, so the battery must as well. Sure, that's a time-consuming effort, but it's the only way to get the best battery performance. In a perfect world, there would be a standard Li-ion battery that could work within all our phones. This sort of modular approach is more efficient and cost-effective, and easier to produce in-house. This is why Tesla has taken a modular approach doing for their electric vehicles (EV); they simplified production and battery recycling by using a single battery unit.

The 18650 lithium-ion cell. By combining thousands of these into one battery pack, Tesla created a standout power solution.

LI-ION BATTERIES: POWERING THE ELECTRIC VEHICLE OF THE FUTURE

Tesla Motors, the standout EV maker, has created a winning strategy for developing battery solutions. This is a key issue for all EV manufacturers since batteries are the most expensive part of the vehicle. Older and cheaper battery technologies, like Nickel Metal Hydride, result in shorter range and longer recharge times. Unlike other car manufacturers, Tesla made the bold choice to take the Li-ion route early on. They have taken advantage of Li-ion's potential through a modular battery design.This means that their cars exhibit gas engine-like performance, design flexibility and the fastest charge times available.

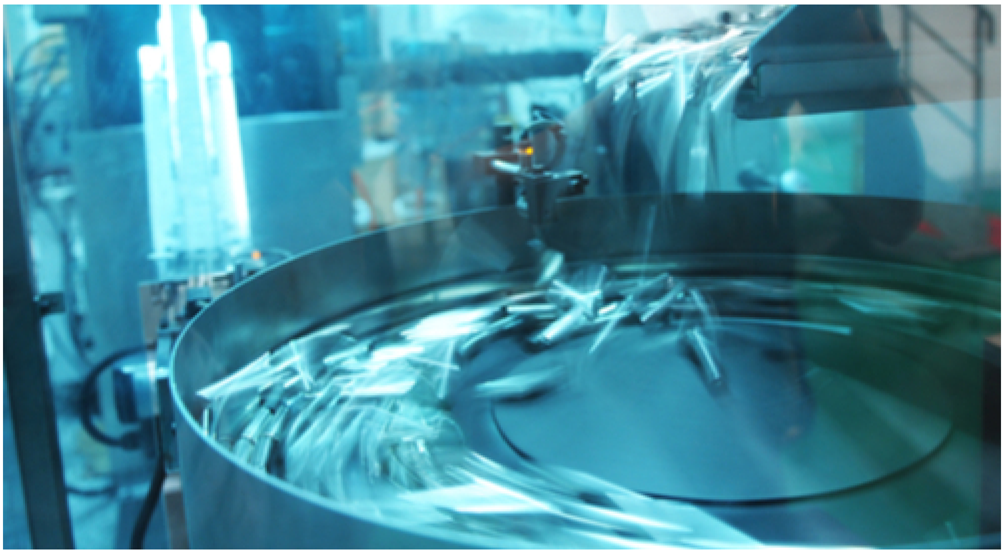
Guided by Elon Musk's mantras of simplification and modular design, Tesla has created a novel technique for their battery technology. They dropped bulky and expensive "bespoke" battery designs that reminded me of ones I struggled with on my smartphone projects. Their breakout product, the Model S luxury sports hatchback, set the stage for their brilliant design approach. Tesla decided to base their work around a single off-the-shelf unit, the "18650" size cell. To build the Model S battery, they wired hundreds of them into one flat slab-shaped pack. This shape was chosen so that the battery could sandwich into the car's floorplan, effectively merging with the frame. This approach allowed them to achieve the capacity and performance they wanted, without the commitment of developing a custom battery.

Fast recharging is just one additional plus with Lithium Ion cells. Tesla's SuperCharger system, shown here, can provide 100 miles of range on 30 minutes of charging. Image credit: Taina Sohlman/shutterstock.com

GIGAFACTORY: SCALING LI-ION BATTERY PRODUCTION TO EPIC PROPORTIONS

The Model S proved that the "many small batteries" approach was a compelling and cost-effective strategy. Accordingly, Tesla went on to deploy the same technology in the follow-up Model X, and will use it again in the forthcoming Model 3. With this approach, the batteries for a whole series of EV's are based on one single modular cell. Bringing the production in-house just means producing that one building block in high volume. Moreover, Tesla can refine the battery cell according to their needs, rather than persuading their vendor to make changes. This is the brilliance of their design approach. Restrict yourself to one single building block, and vertical integration becomes a lot simpler.

Tesla has decided to follow through on their in-house modular strategy. The Gigafactory is their new battery production plant currently under construction. This enormous facility is projected to build 50 gigawatt-hours per year by 2018 and will vertically integrate the complete battery production process. The Gigafactory will mass produce an individual battery unit similar to the 18650, taking in all of the production steps short of mining the raw lithium itself. The facility will also produce the battery packages as well, assembling hundreds of cells into the aforementioned "slabs." Furthermore, the Gigafactory will be a green facility. This means that it will reprocess old Li-Ion cells into new production.



By producing every battery out of hundreds on one cell, manufacturing is dramatically simplified.

Combined with the advantages of vertical integration, the modular Li-ion battery brings Tesla ever closer to the "inflection point" of battery cost. Eventually, Li-ion battery production will be cheap enough per unit to outpace the powertrain costs of gas-powered cars. Prices on EV's would permanently drop through economies of scale. It's a long road ahead before that happens, but the takeover of the EV is certainly in sight. Tesla is turning Li-ion batteries into something truly empowering.

Even if you're not setting out to beat Tesla at their own game, battery design and implementation is an unavoidable challenge for PCB designers. The related power conditioning, control, and charging circuitry have to work with intense specifications and power requirements. However, with a state-of-the-art 3D design environment these components can stop being a threat to project success. PCB design software, like Altium Designer, provides cutting-edge, intuitive tools to build high performing power management PCB's.

Plus, with add-ons like Altium Vault, you can keep track of components, like lithium ion cells, and save yourself the time needed to design every board from scratch. Transform your workflow with an Altium solution today.

TAKE YOUR SHOES OFF: MODULAR DESIGN TIPS FOR OBSOLESCENCE MANAGEMENT

I've noticed that there are two kinds of people in the world: those who have a large armoire full of lightly-used shoes to choose from for their daily activities, and those who have a few (too) well-worn pairs of shoes that they are squeaking out until the toe-holes become intolerable. I am among the latter, and unfortunately for my current pair of sneakers - it is getting time to replace them. But there's always a golden-period to replace old shoes: finding the point in time where the weariness of your current pair is just more cumbersome than the stiffness of a new pair that has yet to be broken in.

Unfortunately, knowing when to replace your shoes seems more of an intuitive process than one which could be tracked and managed like in electronics. Though, end-of-life component obsolescence management is still a common challenge in electronics design. When individual components become obsolete before the product reaches the end of its life cycle, there is a clear transition problem. For example, microcontrollers are frequently replaced by newer versions due to their short end-of-life (EOL) cycles of five years or less. Because of their limited lifespan, long life-cycle products like industrial dataloggers and vehicle parking payment machines face the continuous challenge of outlasting their microcontrollers and requiring regular replacements.

If you're unprepared, migrating to a new microcontroller can be a painful process that involves close coordination (and potential miscommunication) between hardware and firmware developers. However, following these three important modular design tips can help you develop a smoother microcontroller transition process:

1. MODULARIZE SCHEMATICS DESIGNS TO MINIMIZE CHANGES

If hardware redesign is required for MCU migration, modular schematics can save lots of time. The convenience of keeping all of your schematics in a single design file simply isn't always worth it! Replacing an obsolete microcontroller with a new one can be potentially problematic if the two are not pin-compatible. In this case, the microcontroller cannot be replaced until other components have been manually moved around and every single connection has been reconnected.

A modular schematic design is a far better option that provides the flexibility of organizing the microcontroller on single schematic sheets and using nets or ports to connect to other modules. With this approach, you would only need to alter the microcontroller schematic module. This is much neater and more efficient than non-modularized schematics.

It also helps if you create a table within a spreadsheet to ensure the pins are mapped correctly to the new microcontroller. This reduces the possibility of mistakes while revising the new PCB. But if a component's end-of-life is affecting any of your products, you might want to consider using the item lifecycle management feature of Altium Vault to better track and synchronize your design.

Segregate your schematics by module to minimize changes in new MCU migration.

2. DEVELOP PORTABLE CODE FOR EASY MIGRATION

Creating good code is more than just crunching pages upon pages of programming instructions and getting the hardware to work. Good firmware programming involves establishing a systematic hierarchy to plan out the coding module and minimizing changes to the source code when migrating to a new microcontroller. The more portable and structured the code, the better.

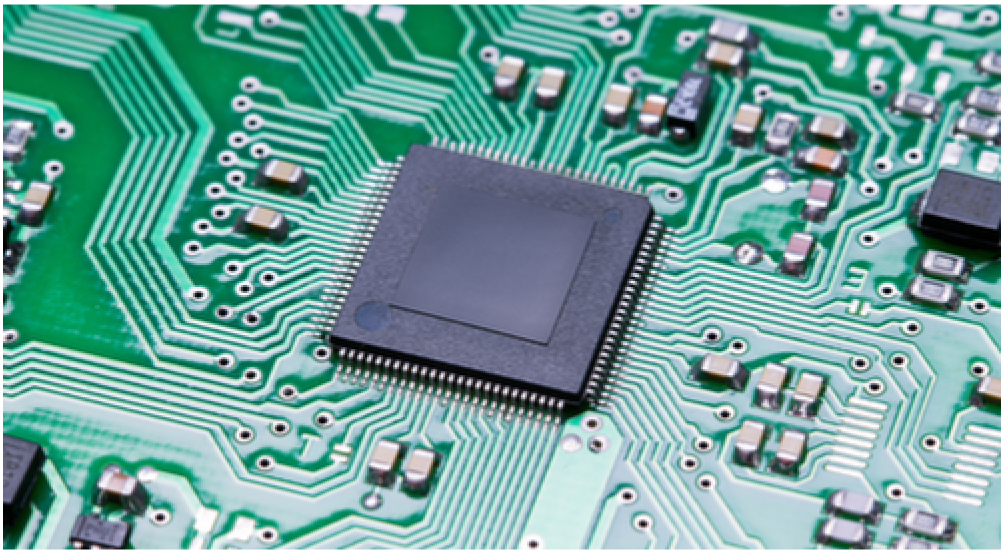
The source code of a system can be divided into hardware levels such as Inputs, Universal Asynchronous Receiver-Transmitter (UART), and Timers. These hardware-level modules configure and interact with the microcontroller's register. Source codes dedicated to the system algorithm are placed in a separate section. For example, the Database, Modbus, and Data Logging modules aren't hardware-dependent and can be placed separately.

The bottom line is that when transitioning to a new microcontroller, only the source code related to the internal portion of the microcontroller needs to be modified. This approach minimizes the time needed to amend the firmware to suit the new microcontroller. With the right structure, the porting process can begin while the hardware team is simultaneously revising the design.

3. CHOOSE PIN-COMPATIBLE MICROCONTROLLERS TO SAVE TIME

Ensuring efficient PCB layout can be the most efficient way to save time and energy when migrating to new microcontrollers. The most tedious part of migrating to a new microcontroller is the process of remapping each and every signal to other components within the circuit. When the microcontroller has hundreds of pins, minor mistakes can complicate the transition process. Therefore, it is wise to check with the manufacturer if the obsolete microcontroller requires a pin-to-pin replacement.

I directly experienced an EOL issue when one of my designs contained the NXP ARM7 based LPC2368 microcontroller. Luck was on my side, though, because the newer microcontroller was pin-compatible with my existing design and saved me the immense trouble of revising the PCB itself. With that said, there are certain circumstances where pin-compatible versions are not available, in which case the hardware design needs to be revised.



A pin-compatible microcontroller could mean no hardware revision is required.

PREPARE DESIGNS WITH OBSOLESCENCE MANAGEMENT SOFTWARE

Efficient PCB design is challenging to achieve without a streamlined workflow, access to design history, and component customizability. Ideally, the designer needs to be able to monitor independent and modular changes to all components while ensuring overall synchronization. Offering end-of-life management through optimized modularity and less repetitive work per transition, obsolescence management software can minimize surprises and extra work down the line. The PCB design software CircuitStudio offers a comprehensive, cutting-edge solution.

Want to better prepare your design for end-of-life component obsolescence? CircuitStudio could be the perfect tool to prepare your design for common issues like microcontroller transition. Talk to an expert at Altium now for more tips.

ADDITIONAL RESOURCES

Thank you for reading our guide on Modular Design. To read more Altium resources, visit the Altium resource center here or join the discussion at the bottom of each original blog post:

- How to Use a Modular Approach to Simplify Your PCB Design Process
- Why You Should Take a Modular Approach to PCB Design for Internet of Things Applications
- How Tesla Rethought Lithium Ion Cells Through Modular Design and Vertical Integration
- Take Your Shoes Off: Modular Design Tips for Obsolescence Management