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- 2D (BEM) field solver precision
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- Unique field solver computation of multiple differential technologies per stackup
- Heads-up impedance plots of signal and dielectric layers
- User defined dielectric materials library - over 16,250 materials up to 100GHz

ICD PDN Planner - analyze multiple power supplies to maintain low impedance over entire frequency range dramatically improving product performance

- Fast AC impedance analysis with plane resonance
- Definition of plane size/shape, dielectric constant & plane separation for each on-board power supply
- Extraction of plane data from the integrated Stackup Planner
- Definition of voltage regulator, bypass/decoupling capacitors, mounting loop inductance
- Frequency range up to 100GHz
- Extensive Capacitor Library – over 5,250 capacitors derived from SPICE models

# Why Autorouters Don't Work: The Mindset!

by Barry Olney

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Ask any group of PCB designers what they think of autorouters and the majority will say that they do not use them because they do not work. I have been battling this mindset for over 20 years now and it still persists today, even with the dramatic advances in routing technology. This way of thinking generally comes from those designers who use the entry-level tools that have limited routing capability. But even the most primitive autorouter may have some useful features. It's all about changing that mindset of the designer and having a crack at it.

I started laying out boards back in the Bishop Graphics days where layout began with a pencil sketch, on graph paper. Then, donuts and fine black tape were stuck to clear film, at twice the actual size, to produce the required connectivity. The 12 mil tape, which we re-

ferred to as "spiderweb," was the thinnest trace width (6 mils finished) manufacturable at that time. It was really a matter of just connecting the dots. Double-sided layouts were sometimes stuck to the same film to improve registration, using red and blue colors to photographically distinguish the layers. But routing has come a long way since then.

The first computer-based PCB design tools that emerged in the late 1970s were grid-based, ran on DOS or UNIX operating systems, and were very basic. Again it was still just connecting the dots, with a graphic trace from point-to-point to build up the layout, and then drawing the circuit on an XY plotter. Basic, but it was effective for the construction on single- and double-sided boards. The next step was to include a netlist for connectivity and then to draw the schematic graphically and extract the netlist to

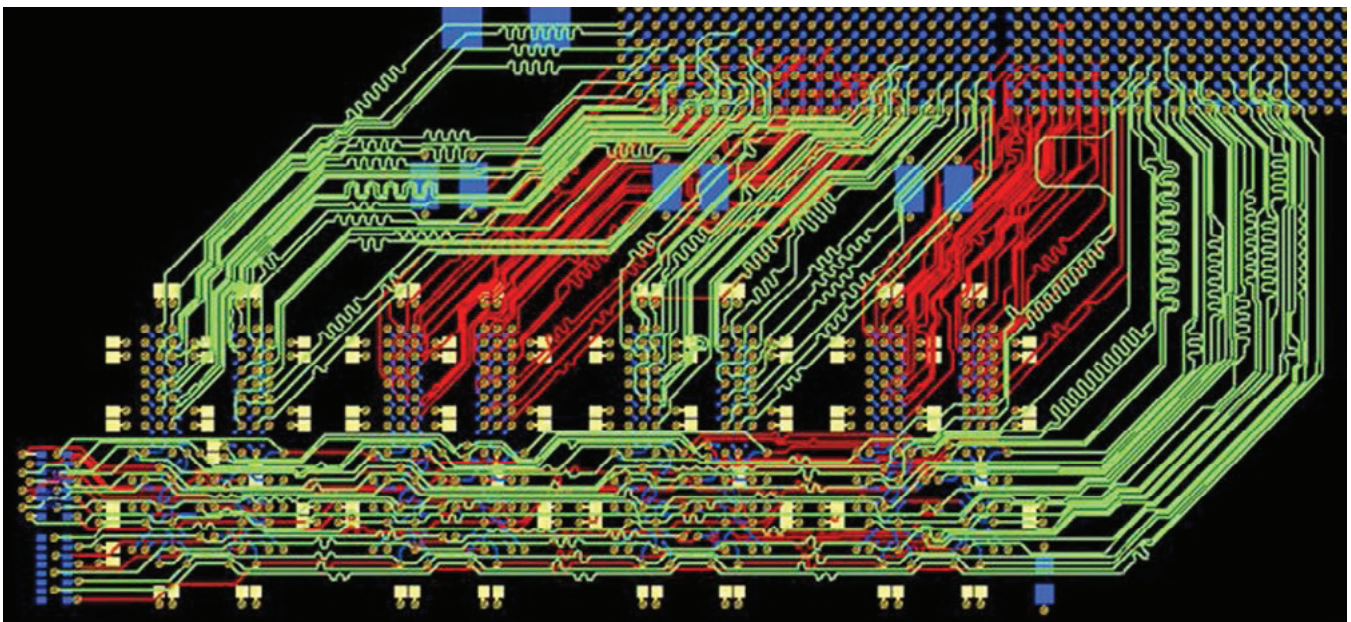


Figure 1: DDR3 memory fly-by address/clock and point-to-point data/strobe tuning.

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the PCB database. This improved database integrity dramatically.

PCB routers were developed using either the grid-based, gridless, shape-based or geometrical approaches. The first were maze and line searching routers that use an imaginary gridded workspace, while a gridless router uses a workspace with available polygon areas to accommodate the new paths. In a shape-based router, each entity on the board is represented as polygonal geometry with no reference to a specific routing grid. This enables the router to cope easily with boards in which there are SMT devices and fine-pitch BGAs with a variety of pitches and odd shapes. Also, unlike a grid-based router, a shape-based autorouter does not have to work at a particular resolution, so routing of high-density or fine-pitch boards is not significantly slower than for lower density work. Put another way, routing time depends only on the available memory, the number of objects on the boards and on the number of connections to be routed. Later, topology routers allowed designers to plan the strategy for a set of nets with attributes to define routing layers, bias and rules.

The first autorouters were not very capable, limited by computing power and lack of memory. They added too many vias, wasted space due to the strict XY bias, and the quality was

poor compared to manual routing. I recall that I used to set up our Advanced Technology Designer Star router to run on the MicroVax mainframe over the weekend, only to find it 50% complete by Monday morning. However, autorouters evolved, like all technology, to include angle routes, reducing vias, push-and-shove algorithms, rip-up and retry, spreading and gloss passes. But so also has interactive routing.

Probably the most popular shape-based router, 20 years ago, was Cooper & Chyan Technology's Spectra router. The Spectra router was used by many PCB layout tools and interfaces to the router still exist today. Design constraints and routing strategies were setup in a "do file" which contained the sequence of commands. The routing was not graphically visible but the routing status was indicated and updated. Cadence's Spectra for OrCAD is still available today.

In the mid 1990s, Intergraph Electronics (VeriBest Inc.) came up with arguably the best routing technology still available today. Mentor Graphics has made considerable improvements to the router since acquiring this technology, and it is now available in both the Xpedition and PADS flows. They provide a selection of routing tools with each optimized to perform a particular function.

The fanout of a high-pin-count BGA is the

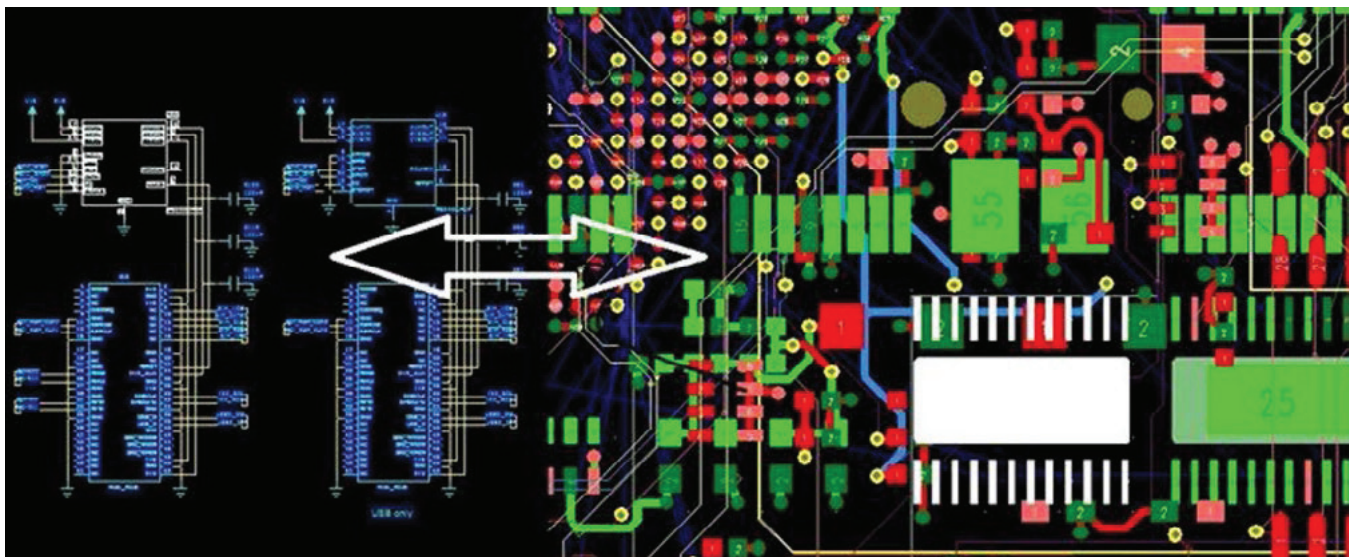


Figure 2: Cross-probing between schematic and PCB.

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primary contributor to the number of layers required for routing. An effective fanout solution should provide low inductance supply connectivity, minimal cross-over of signals, reduced crosstalk, breakout on multiple layers and layer reduction. The increasing pin count and decreasing pitch of BGAs proves a challenge to both PCB designers and routing technologies. Placement, orientation of interconnecting devices, swapping of I/O pins to reduce crossovers, together with the fanout to internal layers, are also key factors of routability.

The design constraints need to be established before an attempt to route is initiated. These include:

**1. Stackup planning:** This should be defined at the time of design entry to improve signal integrity, reduce crosstalk from adjacent layers and provide clear, uninterrupted return paths for all critical signals. There are many stackup options using a myriad of high-speed materials and these should be chosen based on the pre-layout simulation. The stackup should also be designed based on the technologies incorporated on the PCB to include all the single ended and differential impedances used. This determines trace width and clearance of each layer for each technology.

**2. Via spans:** These should be selected based on the stackups construction and the density of the BGAs to provide a fanout to internal layers. Blind and Buried vias need to be considered in order to fanout from 0.8 mm or less pitch BGAs.

**3. Signal integrity:** SI should be considered early in the design process to eliminate crosstalk, extended return current paths, and EMI.

**4. Power integrity:** PI should also be analyzed up-front to determine the number and values of bypass and decoupling capacitors required to reduce the AC impedance to an acceptable level, given the switching regulator properties. Plane resonance should be analyzed to determine the best possible plane definitions.

Design constraints can be established based on the above requirements. These are entered at the schematic level and carried through to the PCB database to control the router. The router needs rules to determine the most effective path but too many rules can also bog it down to such an extent that it will not perform. Care must be used when creating and prioritizing rules.

Once the schematic has been completed, the FPGA I/Os need to be evaluated for crossovers and pins swapped where necessary, to assist the router as much as possible. You could do this manually, but it is very time-consuming. Alternatively, Mentor's IO Designer FPGA-PCB co-design tool integrates synthesis and I/O optimization.

To obtain a high route-completion rate, component placement is extremely important. If the board is difficult to route, it may just be the result of poor placement, slots/gates positioned all over the board, or perhaps the sequence of pins on components are flipped. We need to help the router as much as possible by opening route channels and providing space for vias.

In the classic high-speed design flow, timing specifications and simulation results are compared to determine placement and routing constraints. Given a length constraint, a designer can control signal integrity by controlling the PCB trace topology of the various parts of an interface. Included in this topology are any terminations.

Interactive placement is best done by cross-probing, as in Figure 1, and dragging the components one by one from the schematic to place on the PCB, taking functionality and design constraints into account. Once the correct placement and orientation of the major devices is complete, the IO Designer can then be invoked to make some sense of the rats nest.

The trend now, is to put control of the autorouter back into the hands of the designers to enable clean, highly desirable results. The Sketch router can optimize the trace fanouts at both ends of the netlines, avoiding additional vias when completing the routes. It can also gloss the finished route to look much like a manual route. The idea is to give the designer control over the location of the routing, along with some style

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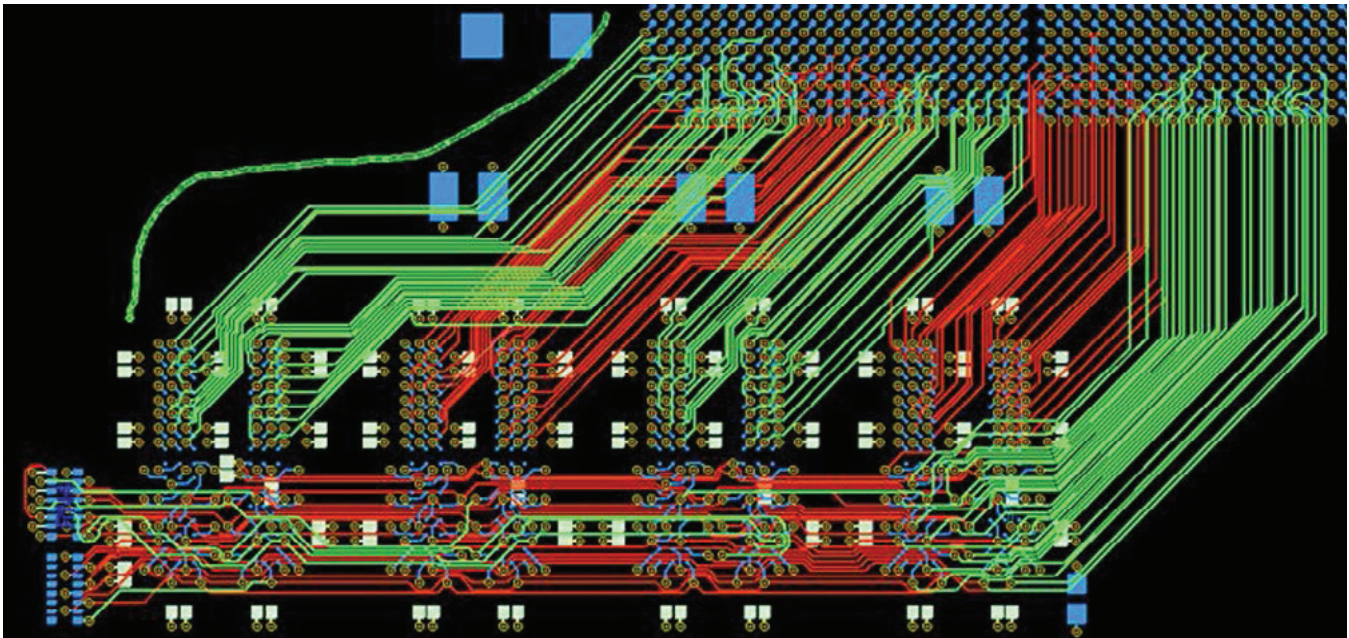


Figure 3: Sketch routing of DDR3 memory.

options, using a simple and fast methodology. Figure 2 shows sketch routing using multi-drop topology for address/clock and point-to-point for data/strobe on DDR3 memory. Once the basic routes are connected, the matched length traces are then tuned as in Figure 1.

So why don't autorouters work? I guess you will have to ask yourself that question! They certainly do for me. The trick is to control the router with constraints, cross-probe with the schematics, check as you go, tune and fix critical traces and allow the autorouter to do all the hard work. Believe me, once you know how to control your router, it will definitely save a great deal of time and frustration. PCB layout is a means to combine your artistic side and your creative skills with the power of automation, but you need to uncover the right mix to make it work.

### Points to Remember

- Even the most primitive autorouter may have some useful features. It's all about changing that mindset of the designer.
- The first computer based PCB design tools that emerged in the late 1970s were grid-based, ran on DOS or UNIX operating systems and were very basic.

- PCB routers were developed using either the grid-based, gridless, shape-based, or geometrical approaches.
- A shape-based autorouter does not have to work at a particular resolution, so routing of high density or fine pitch boards is not significantly slower than for lower density work.
- The first autorouters were not very capable, limited by computing power and lack of memory. They added too many vias, wasted space due to the strict X/Y bias and the quality was poor compared to manual routing.
- The most popular shape-based router, 20 years ago, was CCT's Spectra router.
- Xpedition is arguably the best routing technology still available today.
- The design constraints need to be established before an attempt to route is initiated.
- The router needs rules to determine the most effective path, but too many rules can also bog it down.
- To obtain a high route-completion rate, component placement is extremely important. If the board is difficult to route, it may just be the result of poor placement.

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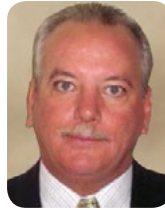
- The trend now is to put control of the auto-router back into the hands of the designers to enable clean, highly desirable results.
- The Sketch router can optimize the trace fanouts at both ends of the netlines, avoiding additional vias when completing the routes. **PCBDESIGN**

### References

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5. Sketch router information: [www.pads.com/professional](http://www.pads.com/professional)



**Barry Olney** is managing director of In-Circuit Design Pty Ltd (ICD), Australia. This PCB design service bureau specializes in board-level simulation, and has developed the ICD Stackup Planner and ICD PDN Planner software. To read past columns, or to contact Olney, [click here](#).

## Back to the Future: Serviceable Spacecraft Make a Comeback

Ever wonder about the future of space science? Hop inside a time machine that transports you back 40 years and you may get a good idea about where things are headed. History, it would seem, has a funny way of repeating itself.

Serviceable spacecraft—like the NASA-developed Multi-Mission Modular Spacecraft (MMS) and, of course, the iconic Hubble Space Telescope that NASA conceived and developed in the 1970s with servicing in mind—are once again de rigueur.

Case in point: As required by Congress in a law passed in 2010 and then amended five years later, NASA is requiring that proposed flagship astrophysics missions support servicing, even if their orbits are up to a million miles away. The agency also released a Request for Information (RFI) seeking ideas for a spacecraft design that it could use for both its proposed Asteroid Redirect Mission (ARM) and as a vehicle for refueling a government satellite in low-Earth orbit.

“The 40-year cycle is starting all over again,” said Benjamin Reed, deputy project manager of the Satellite Servicing Capabilities Office (SSCO) at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

WFIRST-AFTA, which NASA plans to equip with an 8-foot (2.4-meter) mirror and a slitless spectrometer and imager, will study dark energy, the mysterious form of energy that permeates all of space and accelerates the expansion of the universe, while providing cosmic surveys. It also will carry a coronagraph that will allow the observatory to image giant exoplanets and debris disks in other solar systems.

Other conceptual missions that various groups currently are studying in preparation for the 2020 Astrophysics Decadal Survey also could operate in more distant orbits. One possible scientific objective would be to find Earth-size exoplanets in the habitable zone in our solar neighborhood and then identify chemicals in their atmospheres that may indicate the presence of life.

To achieve these ambitious goals, WFIRST and the other conceptual observatories ideally would operate from Sun-Earth L2 (SEL2), a thermally stable sun-Earth orbit roughly a million miles away.

