micross components

The CUSTOM and ASIC Can o' Worms

The Micross Components Guide to ASIC and Custom Product Design

Actually designing an ASIC.

Before launching into a diatribe on the technology, let's make one thing perfectly clear.

WITHOUT REAL INVOLVEMENT FROM THE CUSTOMER, THE DESIGN PROJECT IS DOOMED.

This cannot be stressed hard enough, just passing a design specification “over the wall” to the design guys does not endear oneself, nor will it lead to a successful conclusion of the design or project. Further more, without involving the rest of the chain, such as the test department, manufacturing department, quality department etc., you’re setting yourself up for certain failure. Design guys take note, we’re watching you as well, because your customers are manifold, and we’ll detail them later on.

From the start, the design should be controlled by a series of reviews, called design reviews, intended to bring all relevant parties to the table to discuss and agree to proceed onto the next stage. These design reviews are conducted and administered by the quality department, whose responsibilities include ensuring that all stages of the agree procedure are adhered to.

So what’s in these design procedures? First off, Austin Semiconductors offer a 6-stage design review, the nature of which can vary dependant upon the design technology, the project itself and the customer’s requirements. Each of the six design reviews has its own separate agenda, reflecting how far down the design flow the project has reached. A word of caution here; just because these are formal design review meetings, other, informal meetings, technical or otherwise, should be taking place, if doing nothing more than keeping the customer abreast of the project status. These design reviews are:

- Design Review 0 (DR0)
  - Pre-order & quotation stage
- Design Review 1 (DR1)
  - Initial kick-off and preliminary specification review
- Design Review 2 (DR2)
  - Pre-layout simulation review of final design
- Design Review 3 (DR3)
  - Post-layout simulation review of final design
  - Layout DRC, ERC & LVS review
- Design Review 4 (DR4)
  - Prototype review
- Design Review 5 (DR5)
  - Production review

The principal is that should a design review fail, it must be repeated with a successful outcome before the next stage can commence. Refer to the section on Design Reviews for further information.

Some design rules …

Garbage In, Garbage Out (GIGO)

If the design data is wrong, then don't expect the design to "make it all right".

You can't make a silk purse from a sows ear.

Roughly translated, you really shouldn't attempt to design the next generation 64-bit processor on a 5-micron metal gate process. (If you do, seek medication).

Be honest, tell the truth now, not later!

Adjust the customer's expectations back towards reality, tell him now what can and what can't be done within his budget. This can be tough, especially if your competition is promising the moon on a stick for sixpence, but rather walk away than have a dead-cert commercial failure on your back.

You can't always get what you want (from Mick Jagger, Rolling Stones)

*Be inventive, and work with the customer to come up with innovative solutions. This may often mean compromising the some parts of specification, or at least, work within the customers "**threshold of pain**". Again, walk away if the demands become too unrealistic or surreal.*

No customer involvement == no success

Initially, only the customer knows what he wants, you don't. Involve the customer throughout the design stages and you'll finally learn what it is he's after.

The design reviews, in depth.

The concept behind the Design Review procedures is to keep all relevant parties abreast of the project status. These DR's may be viewed as milestones within the project, and target dates should be used to ensure that the project does not slip. The DR reviews also offer an opportunity to formally voice concerns over technical, quality or commercial issues. An agenda is issued with each Design Review, and should serve as a guideline as to the topics that will be discussed, even if some of those topics to not appear to be relevant to the particular project. This is to ensure that nothing is neglected or missed, by erroneously making an automatic assumption as to its relevance. This may appear laborious and tedious, but it works!

At Design Review 0

Even before we can quote and estimate the design, we need to ascertain just exactly what we're intending to design and build, so a technical introductory meeting is needed with all parties to discuss, agree and resolve specific items. This is a type of check-list, which will be iterated for all subsequent design reviews as well.

DR0 agenda

- Design
    - Target Specification, description & schematics etc.,
- Planning
    - Development plan, proposed sample & production timescales.
    - Production quantities.
- Manufacturing
    - Package type & general specification.
    - Tester & tooling requirements.
- Commercial
    - Unit cost estimates, volumes, ASP, & NRE costs.
    - Special costs (Tooling, qualification).
- Safety & Reliability
    - Design safety & reliability requirements.
    - Product life-cycle requirements.
    - Environmental conditions.
    - Qualification requirements.

After Design Review 0

Once this stage has been concluded to everyone's satisfaction, a customer contact person will have been established, a Draft Specification been drawn up, with the appropriate feasability & technology studies, if needed, and followed by a quotation to the customer.

At Design Review 1

This obviously presumes that the quote has been accepted, and an order has been emplaced to proceed with the design work. Whilst it is fully understood that the specifications may be subject to change, this is really where we start “pouring concrete” over those documents, in an attempt to have a firm base to commence the actual design activity. The DR1 meeting begins to establish what is required, when, for whom and by whom. There are several topics on the agenda, but in general the technical discussions have taken place ahead of the DR1 review, and the technical assent to the proposed methodology has been given.

DR1 agenda

- Design
  - Target Specification, description & schematics etc.,
  - Wafer fab technologies, design rules, special issues
- Planning
  - Task allocation & resources
  - Development plan, sample & production timescales
  - Production quantities & schedules
- Manufacturing
  - Package type, package approval status & general specification
  - Tester, tooling & assembly requirements
- Commercial
  - Die size estimates, unit cost estimates, wafer costs & yields
  - Capital & Tooling costs
- Quality, Safety, Reliability & Risk assessment.
  - Quality plan
  - Risks - Identification & Assessment
  - Design safety & reliability requirements, with life-cycle definition.

After Design Review 1

Once the DR1 review has been successfully completed and signed up to by all parties, design work can begin in earnest. This stage of the process involves the electrical design, be it schematic capture or HDL descriptive software generation, the design takes shape on paper until the simulation results match the requirements of the customer. This can be a long, iterative process, with the generation of many test benches to simulate and prove the design concept and realization. Once the designer has satisfied himself, and the customer, that the design is stable and ready for layout, then he can initiate the next design review.

At Design Review 2

Here, the design is formally presented, including all data that supports the belief that the design will operate in the required manner. This will include simulation and test bench stimuli data under all parametric and environmental conditions, more than sufficient to convince both the customer and the other members of the peer review at DR2 that the design will work. Mere plausibility is insufficient, and there should have been a technical meeting with the customer prior to the DR2 such that both parties can come to the table and "sign-up" to the current state of the design. If the technical data falls short or is inadequate, then the DR2 should not proceed unless there is another pressing need to do so.

DR2 agenda

- Design
  - Specification, description, block diagrams & schematics etc.,
  - Simulation data.
  - Performance against specification, any special issues.
- Planning
  - Progress and outstanding actions.
  - Development plan, with sample timescales.
  - Production quantities & schedules.
- Manufacturing
  - Package type, package approval status & general specification.
  - Assembly requirements, piece parts & travellers.
- Commercial
  - Die size estimates, unit cost estimates, wafer costs & yields, any changes ?
- Quality, Safety, Reliability & Risk assessment.
  - Quality plan review & update
  - Risks - review, any new risks identified ?.

After Design Review 2

This is the stage at which the electrical data, as a netlist or a schematic, is transcribed or translated into a physical layout for mask manufacturer, either manually or by using auto-layout software. All electrical and mechanical checks should have been performed: DRC (design rule check), ERC (electrical rule check) and LVS (Layout versus Schematic) should pass cleanly (apart from known fiducials). Back annotation and parasitic extraction should be covered and re-simulated with matching or acceptable results. After post-layout simulation and chip finish (which includes identification and fiducial objects), the design should be in a state ready for "tape-out", at which stage the designer will initiate the next Design Review stage.

At Design Review 3

Often referred to as the CDR, or Critical Design Review, this is the review that takes place before the “big red button” of committing to fabrication is pushed. Of all the design reviews, this is the most important and intensive. Once this review has completed, commitment of mask manufacture and wafer fabrication will be made, spending and allocating real money to the project. If anyone feels uncomfortable about proceeding with the design, this is the “11th hour” meeting and review at which to voice those concerns. There must have been an in-depth technical meeting beforehand, to review and agree all the technical issues, where comprehensive post-layout simulation should be presented along with the full DRC/ERC and LVS results.

DR3 agenda

- Design
  - Specification, description, block diagrams & schematics etc.,
  - Layout and post-Layout Simulation data, performance issues.
  - LVS, DRC, ERC, Customer checks, die fiducials, Bonding data.
- Planning
  - Progress and outstanding actions.
  - Update of development plan, with sample timescales.
  - Update of Production quantities & schedules.
- Manufacturing
  - Bonding diagram, branding data, BOM defined, wafer testing.
  - Sample & production travellers for Assembly, Test and Qualification.
  - Test information and specification
- Commercial
  - Die size estimates, unit cost re-estimate, fab timescales, any changes ?
- Quality, Reliability & Risk assessment.
  - Quality plan review & update
  - Risks - review, any new risks identified ?

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After Design Review 3

Once a satisfactory DR3 review has been completed, there are a number of items to be addressed. Firstly, the output to the foundry must be prepared and sent, along with all foundry release documentation. The output may be a tape, CD or even an e-mail attachment, but the data must be checked and validated by the foundry upon receipt. The data may be a certified net-list or a GDSII data file, either way verification at the far end is necessary. Naturally the requisite purchase orders

and T&C's must have been emplaced beforehand.
The preparation of test information for subsequent prototype evaluation and production testing must also be compiled and released along with the Test Specification, which should have been finally agreed with the customer during the DR3 review. The test program and software development can now commence ahead of the delivery of wafers or die product. The build and assembly of environmental hardware should also be started at this stage.
The final issue of the bonding diagram, along with any other assembly notes and data should be released, once again, all this should have been signed and sealed during the DR3 review. As you can see, there is a lot of preparation work required before the DR3 review procedure can begin

Once the prototype silicon has been delivered by the foundry, wafer inspection, sawing, and prototype die packaging swiftly follows; everyone is curious about the device and whether it meets it's design target. Prototypes that are un-tested, often called cut-and-go devices, are sent both to the customer and the test department simultaneously for application and specification verification. Sometimes the customer really only can use working prototypes, so there can be a delay in sending prototypes to the customer until the test department have completed debugging the test software and hardware. Customer evaluation and compliance testing can then take place. At this point it is relevant to point out that prototype devices are just that, prototypes, and generally do not have a certificate of conformance suitable for use as production devices. Firstly, the silicon will have been "fast-tracked" as an engineering batch, and the fast assembly process may not have all stages completed. The prototype devices may also be in a package that differs from the final intended package, either at the customer's behest, or due to package MOQ and delivery issues.

What is described above is the "normal" route, if there ever was such a thing, as each project can differ. Options such as wafer probing, special packaging or delivery options are regularly included.

At Design Review 4

Once the prototypes have been evaluated by all relevant parties, a prototype review (DR4) can take place, where all the gathered data is presented.

DR4 agenda

- Design
  - Specification, description, block diagrams & schematics etc.,
  - Samples meet specification, problems identified ?
- Planning
  - Progress and outstanding actions.
  - Update of development plan, with production timescales.
  - Update of Production quantities & schedules.
- Manufacturing
  - Any problems/changes from Assembly, Test and Qualification ?
  - Characterization data from samples.
- Commercial
  - Yield issues ?
- Quality, Reliability.
  - Quality plan review & update

After Design Review 4

Once the DR4 review has taken place to everyone's satisfaction, then production may commence. In practice, the customer may not feel it necessary to attend this meeting, as he's got working silicon as prototypes, now he wants the real thing, fully characterised and qualified, to meet his production targets.

In the factory, there is still some work to do to ascertain that all production and qualification stages are emplaced for incoming wafer delivery, saw and inspect, wafer probe, device packaging, electrical test, environmental screening and final delivery to the customer. Any additional process tests and yield analysis routines required either internally or by the customer have to be proved.

At Design Review 5

This review tends to be a “factory-only” affair in practice, unless there are some real customer issues, such as field failures or application changes. In house, the concern is generally focussed on maintaining quality and reliability of the product, monitoring any changes in yield or device characteristics, so the DR5 may be called at any stage during the product to address issues, or just to ensure that the build documentation conforms to good working practice. A DR5 review may also be used to review the results of a long-term reliability exercise or to evaluate any changes in processing in an attempt to enhance final yield.

DR5 agenda

- Design
  - Yield issues, customer returns ?
- Planning / Project
  - Outstanding actions.
  - Update of Production quantities & schedules.
  - Characterization / Qualification complete.
- Manufacturing
  - Any problems from Assembly, Test and Qualification ?
- Commercial
  - Yield issues ?
- Quality, Reliability.
  - Quality plan issued.

After Design Review 5

There is no real “After DR5”, as the production is a continuous process, so DR5’s, as already alluded to, may be called at any stage during the production. The only requirement after a DR5 review is that the recommendations and actions are implemented as soon as practicable.

Some relevant considerations to getting it right !

Reliability

- Application requirement
  - Operational life & Infant Mortality
  - Hazardous environment (to device)
  - Mission criticality ?
- Environment
  - When device active ?
  - Long term storage ?
  - Operational and shelf storage
- Choice of Foundry
  - Appropriate technology ?
  - Suitable design rules for application ?
  - Characterised silicon for intended use ?

Risk Assessment

- Chances of Success …
  - Avant-Garde design
  - Unusual techniques
  - Poor information
- Design criticality
- Failure Mode Analysis
- Life-Cycle requirements
  - Application
  - Environment
  - Use of device outside of design rules
- Testability & Manufacturability

Packaging

- Ceramic / Plastic / Metal etc.,
- Package and lid match
- number of pins
- Electrical characteristics & performance
- Attach method …
  - Eutectic
  - Ag-Glass
  - general Adhesives
- Bonding rules ...
  - Au or Al ?
- Bond wire length and angles ?
- Pad sizes and spacing
- Current carrying capacity
- Lead finish

Design verification

- Digital
  - Verilog or VHDL netlists ...
    - Verilog often preferred by foundries
    - VHDL often preferred by Designers
  - Pre- and Post-Layout checking
  - SDF file creation
    - Min-Typ-Max simulation
  - Test benches
    - Fault coverage (stuck-at faults)
    - Automatic & Application Test Vector Generation
  - ATE Tester Vector Generation
    - ATE Tester semantics
    - Critical Path Timing data
  - Test specification
    - Guardbanding

- Analog
  - SPICE netlists …
    - Many SPICE flavours, netlist conversion ?
  - Pre- and Post-Layout checking ...
  - Parasitic back extraction

- Sweep & Monte Carlo simulation
- Test benches
  - Multiple SPICE test benches
- ATE Tester semantics
- Test specification
  - Test set-up and parametric measurements critical.
  - Tester noise floor
  - Tester measurement resolution & accuracy

- Mixed Signal. As both Analog & Digital, plus
  - Signal / data-path partitioning
  - A/D & D/A interfacing techniques
  - Separate power/ground supplies ?
  - Test bench set-up now very critical ...
  - Mixed-mode simulation
  - Analog/Digital test synchronisation
  - Testability
  - Intermediate test and capture points / nodes
  - Test equipment capability
  - Special test bench set-ups
  - Test Specification !!!
  - Guardbanding

Manufacturing

- Test
  - Testability of design
  - adequate test coverage
  - Test socketing
    - Suitable for temperature extremes
  - Test throughput --- realistic tests
    - Test time vs. test coverage
- Manufacture
  - Acceptable yield profile
  - Special processing
- Project control
  - Project maintenance
- Cost reduction
  - Test time reduction
  - Flow control
  - Volume purchasing
- Commercial
  - Projected yield
  - Gross Die / Wafer
  - Die yield at test
  - Yield after packaging
  - Packaging costs
  - Post processing …
  - Device testing
- Environmental screening
- Life testing

Finally, the most important ingredients ...

Customer Involvement
Pragmatism
Honesty

In summary

Design reviews are for ...

Customer partnership
Project & QA control
Ultimate accuracy

These stringent controls have given us AND our customers first time success in all ASIC projects !

Alun D Jones
Technical Director
Micross Components Ltd.,
Oriel Court, Omega Park
Alton, Hampshire, UK
GU34 2YT

Tel : +44 (0) 1420 594180
Email : alun.jones@micross.com
Web : www.micross.com