



**Doug Ford**  
Analog Design

Doug Ford Analog Design Pty Ltd  
ACN: 129 464 991

Web: [www.dfad.com.au](http://www.dfad.com.au)  
Email: [doug@dfad.com.au](mailto:doug@dfad.com.au)  
Phone: (02) 9896 8707  
Mobile: 0400 989 664

## HOW PRODUCTS GET DESIGNED

### **Introduction:**

This is a description of DFAD's role as an electronics design center, in designing products or projects for you. It also explains the interactions between all parties in the design and manufacturing process. These include:

- You, the principal, who pays for the development and reaps the rewards;
- Us, the electronics designers;
- The mechanical designers and product stylist;
- The purchasing officer (either us, or members of your staff);
- Component vendors, PCB fabricators, PCB assemblers, and packaging vendors;
- Compliance test houses

Although this description is focused on high-volume designs, most of the processes discussed here can equally be applied to one-off projects and short-run products.

The process of designing and introducing a new electronic product for mass manufacturing has four phases:

- Proof of Principle;
- Prototyping;
- Design for Manufacture;
- Production Test Equipment

DFAD will generally separately cost and quote each of the four phases.

Each phase may be used as a design milestone or checkpoint, or we can introduce additional intermediate checkpoints.

The tasks required in each phase, and the ownership of these tasks, are described below.

### **Proof of Principle Phase:**

The Proof of Principle phase establishes the practicality of the project, and provides you with a functional prototype together with sufficient information to allow me to cost and quote all of the design tasks, and to allow you to establish the viability of the project.

The following tasks should be performed in approximate chronological order:

#### **Product Brief / Specification:**

A detailed and unambiguous specification is required, such that all parties may agree on the desired design results.

Specifications should include:

- Basic functions of the product;
- Specific performance criteria (eg. consumption, noise, response, LED brightness etc);
- Physical size;
- Connector types;
- Level of fault tolerance and protection;
- Target cost of the product (total cost, electronics component cost, assembly & test cost);
- Production quantity (several, hundreds, or many thousands);
- Desired compliance standards to meet



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You will initiate the product brief, but the brief will often become collaboration between you, us, the stylist and the mechanical designers as questions are raised.

Since the duration of the Proof of Principle phase is often unknown, DFAD's involvement is charged at an hourly rate. Development of product briefs may require our input for an hour or so for simple projects, or for weeks in the case of complex military, aerospace or industrial projects.

### **Scope of Work:**

The Scope of Work statement defines the our role in the project, and assigns responsibility for various tasks and expenses. Examples include:

- Component procurement tasks and expenses: Your responsibility, or ours?
- Prototyping costs: You or us?
- Desired degree of "finish" of prototypes;
- Our level of involvement in compliance testing, in-house evaluation and field tests;
- Our level of involvement in commissioning installations and test equipment;
- The level of documentation you require;
- Travel expenses and arrangements: Your cost or ours?
- Provision of test equipment: Yours, ours, or both?

### **Design Job Costing:**

The Product Brief and Scope of Work statements provides us with sufficient information to allow us to cost the electronics design tasks, and provide you with a written quote for these tasks.

### **Feasibility Study:**

We examine the feasibility and practicality of achieving each specification in the brief (also known as a "sanity check"). Examples include:

- Does the specification for size conflict with the number and size of connectors?
- Does the specification call for more output power than the allowed power consumption?
- Are components available which will achieve the desired functions?

We liaise with the stylist, mechanical designers and purchasing officer during the feasibility study if required.

### **Circuit Simulation and Design:**

We devise electronic circuits to achieve the desired functions and performance levels.

We then check the performance of any critical circuit subsections by simulation and/or breadboard prototyping.

Complex or high performance breadboard prototypes may require printed circuit boards to achieve satisfactory circuit verification.

We can then draft a complete circuit diagram for the product/project with confidence.

### **Provisional Bill of Materials**

We can issue a provisional Bill of Materials (BoM) once the circuit diagram is drafted.

This BoM is an approximation of the final BoM. There may be numerous minor differences between this provisional BoM and the final product BoM, but rarely any gross changes.

At this time we identify any critical or unusual components, and possible production issues for you.



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Your purchasing officer (or our equivalent) can use the provisional BoM to generate an approximate costing for the electronics assembly if we have sufficient knowledge of component costs.

### **“Proof of Principle” Outcomes:**

At the conclusion of the Proof of Principle phase, we supply you with:

1. A Bill of Materials for the prototype
2. Approximate material costing for the product, if requested
3. Circuit diagrams for the prototype.
4. Performance figures, predicted from simulations or breadboarding, if requested.
5. A list of possible areas of noncompliance.

This information will allow you to determine the viability of the project. You may decide whether to continue with the project as specified, or to abort the project, or to modify the specification.

### **Prototyping Phase:**

During the Prototyping phase, components are sourced and a small number of functional prototypes are built.

### **Critical Component Selection:**

Critical components must be selected and sourced before further design tasks can proceed. Critical components include:

- Switches and controls
- Indicators
- Connectors
- Highly specific electronic components

We mate the electrical specifications for these components with corresponding mechanical specifications issued by the mechanical designers and aesthetic criteria from the stylist. We pass the composite component specifications to the purchasing officer, who sources these components and verifies their availability and cost.

At this time the purchasing officer must arrange procurement and/or purchasing of sample components for prototyping. You should inform us if you have any preferred vendors for PCBs, components and general assembly.

### **Printed Circuit Board (PCB) Tasks:**

**PCB Design:** We generally draft the prototype PCBs required for the project, although clients with in-house capacity may choose to do so themselves.

**PCB Prototyping:** Most frequently, we arrange for fabrication of the prototype PCBs. However, you may opt to use your resources for these tasks.

**PCB Assembly:** We will generally assemble the prototype PCBs. Once again, you may opt to use your resources for these tasks.

Assembly of the prototype depends on timely supply of the components defined by the BoM and the Critical Component Selection tasks, and of any mechanical components which are to be supplied by the mechanical designers.



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**Verification Tests:** The designer tests and verifies the performance of the prototype, and performs manual corrections to the electronics hardware if required.

### **Prototype Enclosures:**

You may require a housing, platform or enclosure for the assembled prototypes. Depending on the level of finish you need, we can assemble the prototypes into a variety of enclosure types. Examples include:

- Off-the-shelf prototyping enclosures (plastic, sheet-metal or diecast boxes);
- Off-the-shelf professional electrical wiring enclosures or rack frames;
- Custom-designed CNC sheet metal enclosures;
- “Rapid-prototyped” polymer enclosures designed by the mechanical team.

### **Prototyping Outcomes:**

At the conclusion of the Prototyping phase, the designer will supply the principal with:

1. A Bill of Materials for the prototype, allowing more accurate product costing;
2. PCB source files, Gerber files and PCB fabrication instructions;
3. Selected measurements and performance figures for the prototype;
4. Assembled and housed prototype PCBs which conform to the specified level of “finish” and performance;
5. A list of known areas of noncompliance.

Once we release the working prototypes to you, you need to subject them to in-house subjective tests and/or third-party tests. Your tests on the prototypes may reveal issues which are not apparent during bench tests. Your tests may also suggest ergonomic, aesthetic, electronic or environmental improvements which may necessitate changes to the product brief or specification.

The principal should ensure that all variations and amendments are captured and listed at this point. If it is necessary to revise the product specification, some prototyping tasks may need reiteration.

Variations to the specification will result in variations from the quoted job costing. Prototype reiteration is always preferable to (and cheaper than) production retooling.

You should also submit a prototype to a recognised test house for pre-compliance tests at this time, to check:

- EMC emissions;
- EMC susceptibility;
- Electrical safety.

### **Design for Manufacture Phase:**

During the “Design for Manufacture” phase, DFAD develops the product from prototype to a design suitable for mass production.

All parties will require an estimate of the expected annual production quantity. The expected volume - hundreds, thousands, or hundreds of thousands - will dictate whether the product is designed for low-cost tooling but higher assembly effort, or more elaborate tooling with lower assembly effort.

In the case of high-volume products, we are in frequent contact with all parties involved in the product design and manufacture. We liaise with the PCB vendor, since requirements and techniques vary between vendors. We also liaise with the assembler, since requirements and techniques also vary between assembly houses. We tend to have most frequent contact with the mechanical designers, since their housings and our electronics assemblies must be mated during production with the greatest ease and least effort.



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The Design for Manufacture phase is generally characterised by extreme attention to detail. However, all parties can apply imagination and creativity to reduce assembly effort and maximise product yield.

The stylist and mechanical designers collaborate closely during this phase to finalise the external aspects of the product. We provide them with information such as:

- Orientation and direction of operation of switches and controls;
- Labeling or function of indicators;
- Mandatory labeling requirements for compliance

### **Pre-Production Build:**

You really should arrange to build a moderate number of pre-production units. The pre-production build is your opportunity to debug all of those supply, assembly, handling and logistics issues.

These should be fabricated with the finalised PCB layout, finalised metalwork and off-tool samples of moulded plastic parts. Fabrication and assembly should be performed by the vendors who will be used for full production. We provide assistance (as defined in the Scope of Works) in setting up production jigs and assembly protocols.

### **Product Specification Measurements:**

The pre-production units should be subjected to characterisation tests of all important parameters. Data from these tests will be used in your product specification sheets and marketing information. This test data will also be used to determine test limits in production-test equipment.

Although we perform our own characterisation measurements, you may also enroll an independent test house, according to your preferences.

### **Production Test Equipment:**

The design of your production test equipment is a project in its own right. This task may require just as much electrical design effort as the product it is testing did.

Some production test jigs may consist simply of a battery and a multimeter; Other tests may require the use of million-dollar ATE systems with pneumatic nailed fixtures.

The assembly house should be involved at an early stage to give their input into test protocols.

We need to agree on a Brief and a Scope of Work for the test equipment, of the same nature as the product design brief. At a minimum, the following items should be specified by the Brief:

#### **What articles will be tested?**

- Assembled but unboxed PCBs?
- Finished, assembled products?
- Incoming components, such as microphones, speakers, mechanical parts?
- Wiring harnesses?

#### **What parameters will be tested?**

- Which DC or AC voltages and currents?
- Frequency responses, distortion, noise?



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- Waveshape?
- Impedance?
- Colour?

### **How will electrical connections be performed?**

- Manual connection/disconnection?
- Solenoid/pneumatic/hydraulic connection slides?
- Nailbed fixtures?

### **What kind of equipment will be used for test measurements?**

- Off-the-shelf instruments (oscilloscopes, DMMs, PSUs, signal generators, analysers)?
- Custom-built application-specific test equipment?
- Programmeable computer-based equipment with A/D acquisition?

### **How will test results be presented?**

- Meter readings, analyser graphs and oscilloscope waveforms?
- Pass/Fail, Red/Green lamps?
- Computer print-out?

Once the Brief (and corresponding Scope of Work) are defined, we can quote on the design, manufacture and commissioning of the Production Test Equipment.

### **In Conclusion:**

If you are only considering a small project, please don't be deterred by the apparent complexity of the various processes described here. It's our job to make it easy for you!

If you're considering a sophisticated high volume product, we hope you will forgive the fact that we've oversimplified the description of some processes.

Our job, as electronics design house, is to give you and your products the best possible balance between simplicity and sophistication in all areas.



## SCOPE of WORKS CHECKLIST

This checklist may help you to define the range of tasks you would like us to perform for you.

<u>PHASE</u>	<u>TASK</u>	<u>YES?</u>	<u>NO?</u>
<b>Proof Of Principle</b>	Involvement in product specification		
	Perform "Proof of Principle" analysis?		
<b>Prototyping</b>	Perform component selection for prototype?		
	Perform component purchasing for prototype?		
	Perform prototype PCB design?		
	Assemble and test the prototype PCB?		
	Build enclosure, housing or testbed for the prototype?		
<b>Design For Manufacture</b>	Develop the electronics for volume manufacturing?		
	Perform component sourcing?		
	Involvement required for pre-production run?		
	Involvement required during compliance testing?		
	Involvement required for preparation of technical documentation?		
<b>Test Equipment</b>	Specify test parameters?		
	Design the test equipment?		
	Build the test gear?		
	Commission the test gear?		

### Example 1:

Your circuit has been in production for twelve years, and you want us to design a PCB which uses contemporary components but with identical performance to its ageing but functional predecessor.

Your SCOPE OF WORKS checklist may look like:

<u>TASK</u>	<u>YES?</u>	<u>NO?</u>	<u>REASON:</u>
Involvement in product specification		No	Spec already exists
Perform "Proof of Principle" analysis?		No	Product already exists
Perform component selection for prototype?	Yes		Contemporary components required
Perform component purchasing for prototype?	Yes		Your option (may equally be "no")
Perform prototype PCB design?	Yes		Part of our main design task
Assemble and test the prototype PCB?	Yes		Your option (may equally be "no")
Build enclosure, housing or testbed for the prototype?		No	Product already exists
Develop the electronics for volume manufacturing?	Yes		Part of our main design task
Perform component sourcing?	Yes		Your option (may equally be "no")
Involvement required for pre-production run?		No	Your production facility is capable
Involvement required during compliance testing?		No	Your option (may equally be "yes")
Preparation of technical documentation?		No	Product already exists
Specify test parameters?		No	Product already exists
Design the test equipment?		No	Product already exists
Build the test gear?		No	Product already exists
Commission the test gear?		No	Product already exists



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**Example 2:**

You have a concept for a new product. You are already manufacturing existing product, but you need additional engineering resources. Your SCOPE OF WORKS checklist may look like:

TASK	YES?	NO?	REASON:
Involvement in product specification	Yes		You know the functional specs, but performance level is ill-defined
Perform "Proof of Principle" analysis?	Yes		You need confidence that it's technically feasible
Perform component selection for prototype?	Yes		One of our main engineering tasks
Perform component purchasing for prototype?		No	You have a purchasing officer
Perform prototype PCB design?	Yes		One of our main engineering tasks
Assemble and test the prototype PCB?	Yes		One of our main engineering tasks
Build enclosure, housing or testbed for the prototype?	Yes		One of our main engineering tasks
Develop the electronics for volume manufacturing?	Yes		One of our main engineering tasks
Perform component sourcing?		No	You have a purchasing officer
Involvement required for pre-production run?	Yes		Measurement of prod'n parameter spreads
Involvement required during compliance testing?	Yes		Correct any problems before full production
Preparation of technical documentation?	Yes		Application notes, marketing data, product specification sheet
Specify test parameters?	Yes		New test system required
Design the test equipment?	Yes		New test system required
Build the test gear?	Yes		New test system required
Commission the test gear?	Yes		New test system required

**Example 3:**

You need just two (rather complex) specialist industrial assemblies designed and built. Most of the functional specifications are well defined. Your SCOPE OF WORKS checklist may look like:

TASK	YES?	NO?	REASON:
Involvement in product specification	Yes		You know most of the functional specs, but clarification is needed.
Perform "Proof of Principle" analysis?	Yes		You need confidence that it is technically feasible
Perform component selection for prototype?	Yes		One of our main engineering tasks
Perform component purchasing for prototype?	Yes		One of our main engineering tasks
Perform prototype PCB design?	Yes		One of our main engineering tasks
Assemble and test the prototype PCB?	Yes		One of our main engineering tasks
Build enclosure, housing or testbed for the prototype?	Yes		The largest of our tasks!
Develop the electronics for volume manufacturing?		No	N/A; Only two required.
Perform component sourcing?		No	N/A; Only two required.
Involvement required for pre-production run?		No	N/A; Only two required.
Involvement required during compliance testing?	Yes		(Presumes that on-site compliance testing is required)
Preparation of technical documentation?	Yes		Full set of construction records required
Specify test parameters?		No	N/A; Only two required.
Design the test equipment?		No	N/A; Only two required.
Build the test gear?		No	N/A; Only two required.
Commission the test gear?		No	N/A; Only two required.

[end]