
DVD-8C

Print Reading For Electronics Assembly

Below is a copy of the narration for DVD-8C. The contents for this script were developed by a review group of industry experts and were based on the best available knowledge at the time of development. The narration may be helpful for translation and technical reference.

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Introduction

A beautiful, well-built house begins with a good set of plans. These plans list the materials required to build the house – along with drawings of what the house will look like after construction is completed. When a house is built without detailed drawings, the result may not be so pleasing.

Reading, interpreting and applying information from drawings, is a requirement in the electronics assembly industry. Some companies refer to these drawings as prints, and others simply call them documentation. To build reliable, operational products, there needs to be *accurate* documentation – such as the *bill of materials* and *assembly drawings*. And there needs to be *skilled* operators and technicians who can correctly read, interpret and *apply* the information.

In electronics assembly there are three areas where prints are usually required. These are circuit board assembly, wire harness assembly and final product assembly – also known as box build, or system build.

For example, during incoming inspection, the inspector uses the drawing to *examine* the bare circuit boards. Drawings are also used in the wire harness and cable assembly area as directions for assembling, routing and connecting the wires properly. In the box build area, prints are used to define all of the components and requirements for assembling the final product.

In this video, we'll be describing how the *bill of materials* and *assembly drawings* relate to the products you'll be manufacturing – and how to accurately *read* these prints so that what you're building reflects the correct revision level of the design. It's important to realize that each *company* performing electronics assembly may have their *own* documentation procedures on the

production floor. On top of that, each *customer* may have slight *variations* in the content and layout of the drawings *they* provide for their products. We'll be discussing the general concepts that should be applicable to everyone.

Circuit Board Assembly

Let's start with circuit board assembly. In this section, we'll be describing how to use the drawings to assemble components onto a bare circuit board. You'll be learning how to read the bill of materials and to apply that information to an assembly drawing. You'll also learn to read the assembly drawing and to relate that information to a circuit board assembly.

Every circuit board assembly comes with documentation that includes a *bill of materials* – sometimes called a BOM – and an *assembly drawing*. The bill of materials *defines* all the components used in the assembly – either specifying them by manufacturer and part number, or using an internal company part number. The bill of materials for a circuit board assembly includes all the electronic components, the circuit board itself and all other non-electrical components that are used on the finished assembly – such as nuts, screws, washers, stands-offs and spacers.

Let's examine a typical BOM in detail. Notice in the lower right hand corner there is a *title box* that tells us what this bill of materials is used for – an assembled printed circuit board. Beneath the title box is the *drawing number* and *revision letter* – in this case 61035, revision G. It's important to verify that the revision letter of the bill of materials matches the revision level of the assembly being manufactured.

The rest of the BOM is made up of a series of line items and columns that specify the components needed for the circuit board assembly. Columns in the BOM usually contain the item number, the description of the component, the part number, the quantity required and the reference designator.

We'll start with the description of the component. The description, in the case of a circuit board assembly, is usually in an abbreviated form. Let's look at item number 9 as an example. It is listed as CAP, 220, 50V, EL, 20%, LO ESR, SMD. CAP stands for capacitor. Capacitor values are measured in Farads, or units of electrical capacitance. 220 indicates that the amount of capacitance is 220 microfarads. Microfarads are the largest unit of measurement for capacitors. There are also picofarads and nanofarads – which are much smaller. 50V refers to 50 volts – the maximum operating voltage of the capacitor. EL stands for *electrolytic* – which is a specific type of capacitor. 20% is the *tolerance* of the capacitor. Tolerance refers to the acceptable operating range of the component. In this case, the capacitor is rated to operate at 220 microfarads. 20% of 220 microfarads is 44 microfarads. Therefore, this capacitor will operate properly in the *range* of 176 to 264 microfarads. LO ESR stands for *Low Equivalent Series Resistance* – a way of describing the resistance characteristics of the capacitor. Finally, SMD stands for *surface mount device* – meaning that this capacitor will be mounted on lands on the surface of the circuit board. So what we have here is a 220 microfarad, 50 volt electrolytic low ESR surface mount capacitor with a 20 percent tolerance.

Item number 10 describes another type of capacitor. This one is a 22 microfarad, 25 volt tantalum capacitor with a 20% tolerance – meaning it will operate in the range of 17.6 to 26.4 microfarads. This capacitor is contained in an EIA 7343 package.

For most production jobs, knowing how to understand the description of these electronic components isn't a requirement – but it never hurts to become more familiar with the components you're working with. For more information on component descriptions and component values, please refer to IPC's Component Identification Training and Reference Guide.

Now that we've examined the component description column, let's turn our attention to the column that provides the *part number* for the component. This entry can either be the manufacturer's part number, or an internal company part number used to identify the component for production purposes. As you can see, the part number for the resistor specified in item 65 is 11472.

The next column tells us the *quantity* of components required for the circuit board assembly. In this case, three of this type of resistor will be used. The last column in this bill of materials lists the *component reference designators*. These three resistors are identified as R40, R43 and R48. As you can see, resistors utilize the letter R as a CRD. If a circuit board contains 30 identical resistors, they might be identified as R1 through R30. The CRD pertains to the *location*, not the value or part number of the component.

C designations refer to capacitors. Transistors are identified by the letter Q – and inductors use the letter L. FL refers to filters – and the letter D refers to diodes. Sometimes diodes are identified by the letters CR. T designations are for transformers – and integrated circuits, or ICs, use the letter U. Notice that the *hardware* specified for the circuit board assembly does *not* use CRDs.

You can see the importance of component reference designators when we take a look at the actual *assembly drawing*. This is the print that shows the *components* and their *location* on the circuit board – and may include special instructions for assembly. Assembly drawings for the circuit board will also denote *where* and sometimes *how* hardware is to be mounted to the circuit board. Examining this drawing, you can see the CRDs, component outlines and component orientation. In addition, there will be notes, revision history and the title block.

The important thing to remember is that the assembly drawing shows the location of the components by CRD. The bill of materials relates the CRD to a specific component part number. For example, transformers T1 through T4 are called out on this bill of materials. We then locate transformers T1 through T4 on the assembly drawing. As you can see, the component side, or primary side of the circuit board is *imprinted* with the identical markings shown on the assembly drawing. Notice that transformers T1, T2 and T4 have already been inserted into the circuit board. Let's watch as we install transformer T3 in its proper location.

Now that you see how the bill of materials and assembly drawing are used to identify the proper components and their locations on the circuit board, let's examine another important topic related

to the assembly drawing – the direction, or *orientation* in which the component needs to be installed.

Some components have a *positive* and *negative* connection to the circuit board -- and the leads must be inserted into the circuit board in the correct position. This means that the positive and negative leads must be inserted into the positive and negative holes, respectively – as identified on the circuit board and assembly drawing. Components with this positive and negative connection have what is called *polarity*. This works the same way as the positive and negative terminals on a battery. For example, a flashlight battery has to be inserted with the terminals in the proper position for the flashlight to work. For components that have polarity, the positive lead is called the *anode* and the negative lead is called the *cathode*. The symbol for the positive anode is the plus sign and the symbol for the negative cathode is the minus sign. A plus or minus sign may be marked on the component, as well as on the assembly drawing and on the component side of the circuit board. Let's watch as polarized capacitor C12 is properly installed.

The direction in which a component is installed is also important for components with multiple leads – even if they do not have polarity. *Proper orientation* means that pin 1 of the component is in the same position as the pin 1 hole or land on the circuit board. The circuit board will usually have a *square pad*, or a *symbol* or screened outline of the component shape – to show correct orientation. IC manufacturers use a variety of methods to identify pin 1 on the component package. Markings may include a notch, a wedge, a dimple, a different edge or corner shape, a stripe or the actual number. When viewed from above, if the mark is at the top of the component, pin 1 is always to the *left*. The numbering of the other pins always proceeds in a *counter-clockwise* direction around the component. Connectors and larger array style components are marked in rows and columns. Always check your print for the pin orientation of larger components such as Ball Grid Arrays, or BGAs – and Leadless Components – as some suppliers mark their components differently. When a component is *not* oriented correctly, the assembly *won't* function as intended and will fail electrical tests. Let's watch as we install DIP component U2 in its proper orientation. Notice that the *dimple* at the top left of the component – lines up with the pin 1 designation on the circuit board.

Correct use of polarity and orientation is a *critical* requirement for circuit board assembly. Never guess. Failure to install parts correctly can destroy components and damage the circuit board. The result can be costly repair work, or even a scrapped assembly.

Now that you're aware how components are located and oriented using the assembly drawing, let's take a look at a few more features of a typical assembly print. Some circuit board assemblies will require special instructions and accompanying diagrams to make the process clear. This may include installing specific hardware, using lead free materials and special instructions for testing.

On this print there are some testing considerations. For example, note 8 instructs us to clip pins 6 and 7 of U12 and *remove* their leads from the two solder pads. And note 9 tells us to *tighten* M2.5 screws to 5 inch pounds – plus or minus zero point 5 inch pounds.

Finally, the assembly drawing will also have a box that provides the *revision history* for the document. Again, it is extremely important to verify that the revision level of the product you are building matches the revision level of the assembly drawing you are using.

Wire Harness Assemblies

Now, let's turn our attention to wire harness assemblies. The purpose of the wire harness is to interconnect electronic devices and provide power, control and data signals to the different parts of the electronic product. For example, the wires bundled into this harness are used to connect front panel switches to this circuit board assembly. In a more general sense, the wire harness acts as a *connection* from a source to a destination. Without this interface, our electronic product simply wouldn't work.

Let's examine the types of documentation you'll be using to build the wire harness assembly. In the same manner as circuit board assemblies, every wire harness will have an assembly drawing showing the physical form of the harness, and which also contains the bill of materials. This document will also specify the *gauges*, or thicknesses – the *lengths* – and *colors* of wire to be used – *and* the types of terminations. It also defines the physical breakout of the individual wires – meaning which wire goes where.

In addition, there may also be a *wiring diagram* and a *wire list*. The wiring diagram shows the routing of wires from the pins of one connector to the pins of another connector. The wire list provides the same information in *tabular* form. Another type of print is the wire cut list. This list provides the gauge and colors of wires used, the exact length needed and the required strip length.

Let's take a look at each type of document in more detail. We'll start with the bill of materials. All the materials required to build this basic cable assembly are provided in this print. This includes the connectors, wires and any hardware needed. It also includes other items such as thread locker, epoxy, and sleeving. Notice how the total length of wire needed is *specified* for each color of wire. For example, item number 16 specifies 29.7 feet of 16 AWG black stranded wire. The part number for this wire is 2104-8438.

Now, let's turn our attention to the assembly drawing. This print shows us the physical form of the cable – meaning what it looks like after it is assembled. As you can see, there are three connectors – P1, P2 and P3. The individual wires are mostly covered in heat shrink tubing. At this point, let's take a look at the wire list. Read from left to right, the wire list specifies the *pin identification letter* of connector P1; the *wire description*; the *wire length and part number*; the *pin name*; and the *termination point* to connector P3. For example, pin K of P1 uses a 25 inch piece of 14 AWG yellow wire, part number 2104-8440.

The wire list is used to create the *wiring diagram*. As you can see, this drawing illustrates the routing of every wire in the cable. As you can imagine, figuring out how to draw a wiring diagram so that it can be easily followed isn't so easy. And sometimes the lines can start looking like a big plate of noodles. That's why wire harness manufacturers use *form boards* for routing

wires – providing a visual method for identifying the beginning and end point of each wire, as well as specifying the type of termination required.

Another form of information used in wire harness assembly is the *wire cut list*. This document contains the cut and strip lengths for all the wires being used. These lengths will either be entered in automatic and semi-automatic wire processing machines, or will need to be measured when you are using manual tools to cut and strip wires. Let's watch how this manual method is done.

Box Build or Final System Assembly

Our last area of discussion is the documentation used for box build, or final system assembly. The clarity, accuracy and level of detail contained in these drawings is critical for the box build process. As with circuit board assembly and wire harness assembly, we'll be examining a bill of materials and an assembly drawing. And, depending on the complexity of the box build, there may also be detailed *assembly instructions* to put the final product together.

The bill of materials specifies the part numbers and quantities of all the hardware required to assemble the product. This includes the enclosure, or *chassis*; all the *subassemblies and components*; *cabling and wire harnesses*; and all of the *installation hardware*. Notice that circuit board and wire harness assemblies – our two previous topics – are included in the materials.

The assembly drawing illustrates the physical form of the product – identifying the location of all of the hardware, subassemblies and components. This print may also include partial, exploded, or color-coded views to explain specific details of the drawings.

Finally, the assembly instructions contain the step-by-step sequences required to actually build the product. These instructions are sometimes called *method sheets*. In addition to the detailed build information, the method sheets may specify the tools required for the assembly job and any precautions you'll need to observe. The completeness and accuracy of the documentation often will minimize the amount of difficulty and frustration there will be in the box build process. Sometimes the solution to a challenging situation is to work with your co-workers and supervisors to find the correct solution that will result in a quality product being built.

At this point, let's take a look at these box build prints for a small system. Notice that all of the necessary information is contained in the assembly drawing. The first sheet includes the bill of materials, revision history, special assembly notes and exploded view of how the product is assembled. The second sheet shows the wiring inside the box, the wiring diagram and the final product.

The bill of materials for this product is located above the title box and calls out a variety of items such as connectors, screws, washers, O-rings, an accelerometer and the printed circuit board assembly. Again, these materials are listed by item number, part number and quantities.

Notice that in the *exploded view*, each of the parts required for assembly is also referenced by the item number. As with the circuit board assembly drawings, there are also references to special

notes that provide extra instructions. For example, note 5 refers to bulkhead 2 and 3 and tells us that wires A through D must make one loop through a *ferrite ring* – which is item 19 on the BOM. Note 6 tells us to trim excess *zero insertion force*, or *zif* fingers, from the flex strip – identified as item 10 in both the bill of materials and in the exploded view.

In many instances, there will also be detailed step-by-step instructions that will explain the box build process. In addition to the assembly techniques, there will be torque specifications and a listing of any special tools that may be required.

Summary

This program has presented some examples of the detailed information contained in customer drawings – and how to interpret and apply the information. We started out by taking a look at how this documentation is used in electronics assembly, along with introducing you to the two main types of documentation – the Bill of Materials and the Assembly Drawing.

We then examined the types of drawings and related documentation you'll be using in circuit board assembly, wire harness and cable assembly and final system assembly. Interpreting and applying the information contained in product drawings is an essential skill for building reliable, high quality products. The more you *master* this process, the more *valuable* you'll be as an employee.