Organising an Electronic Unit for Mass Production

Part I

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The growth of electronic instrument industry has been phenomenal over the last ten years. With the introduction of consumer electronic products like B&W and colour television receivers, it has won its laurels. In India, a lot of industries have sprung up in the organised sector for manufacturing B&W and colour television receivers, tape recorders, radios, two-in-ones, plain paper copiers, electronic typewriters and personal computers.

All these products are mass-produced the world over because of their mass marketability. Also, even professional instruments like electrocardiographs need to be mass-produced in India in order to offer competitive prices for the export market.

The scope of this article includes organisation, production aids, testers, software, production management, inspection and designing for mass production. Sales and financial aspects have been excluded from the discussion.

MPU ORGANISATION

Fig. 1 shows the organisation chart of a mass production unit (MPU). Here, except sales and design departments, all the other departments are under the MPU executive, the manufacturing manager. These two functions must be separated from the manufacturing manager in order to efficiently organise the unit. We assume that there is steady demand for the MPU product and any reasonable increase in production levels will be absorbed by the market. Checking the design aspects and trying to improve them do not concern the manufacturing manager although he may discuss the matters with the persons concerned. Similarly, we assume that the manufacturing manager is not to bother about arranging and controlling finance although he is required to keep the inventory to the minimum possible and ensure good production.

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Assembly line is controlled by the assembly manager who is responsible for shop scheduling, assembly and testing. Chief quality control officer takes care of incoming, on-line and finished product inspection. It is essential that both these inspection departments are under one person since there is bound to be difference of opinion regarding some quality aspects, particularly attributes if they are controlled by two persons. Material controller manages stores, planning, Kardex control and purchase.

As soon as sales targets are received, he plans for procurement. Accounts officer is there to make payments and account money received from head office. Maintenance department looks after periodical preventive maintenance and attends to breakdowns. Zero or minimum downtime of any machinery is the aim of this department. An administrative officer is also available for general, personnel and administrative routines.

PRODUCTION AIDS

Production aids are equipments which help manual, automatic or semi-automatic assembly in an MPU. If the operators' attention and intervention required in the assembly are very minimal, it is called automatic assembly; if the assembly requires frequent operators' intervention and still is better than manual assembly, it is termed semi-automatic assembly.

Programmable locators

There are several semi-automatic programmable locators with which either component insertion or wire-wrapping can be carried out in an easy and speedy way suitable for MPU.

A typical unit available from Assembly Automation can be used for component insertion as well as wire-wrapping.

Component insertion. The unit contains cassette memory, plug-in keyboard, universal board edge mounting rails, LED lighted parts, bins and DIP dispensers for the purpose.

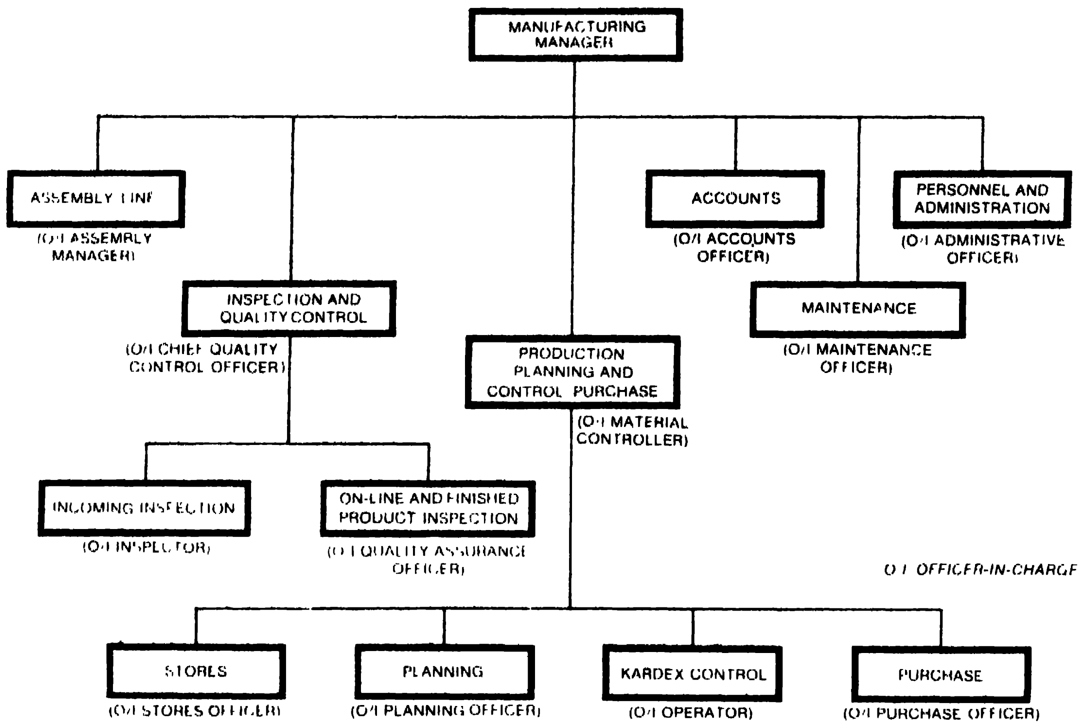

Fig. 1: Organisation schematic of a mass production unit.

The operator merely picks up the part from a bin indicated by its LED lamp and inserts it into the board where a light dot appears. The direction of the part is oriented according to a lighted symbol on the panel above. The only thing the operator has to recognise about the part is the plus end or pin 1 of a multi-pin part. Fig. 2 shows part of the unit. Component location lamp, corresponding orientation lamp and component bin lamp are sequentially switched to remove insertion errors.

Bench or floor model bin sets provide easy access to 50 or 100 different discrete parts. These bins are grouped in sets of five to provide a quick load/unload feature for convenient pre-kitting of jobs. Conductive bins for keeping MOS devices are available. Static protected IC DIP dispensers for up to 40 different devices are provided. Each removable tray fitted conveniently on the unit can hold up to 10 tubes of approx. 7.6mm, 10.1mm and 15.2mm wide ICs.

Programming for component insertion is extremely simple. It is accomplished by mounting a sample board in the machine and 'walking through' the assembly process. Horizontal and vertical keyboard controls are used to drive the light dot source behind the board to a particular component hole. For each part, a two-digit quantity for one board, bin number and orientation in 45° increments (flashing if polarity is required) are keyed in.

After 400 components have been completed, an audible signals that machine memory is full and this block of am has to be permanently stored. This is done by a fresh cassette into the built-in mini-cassette unit and pushing a 'write' button. If more steps are needed, programming may now continue for another 400 steps and so on until the board is complete.

Up to 16 boards can be assembled on the machine at one time with a single-board program automatically repeated at each board whose origin point has been designated. Board positions may be skipped at any time by eliminating the corresponding origins. During assembly, cassettes are read into machine memory in 400 step blocks. The operator uses a foot-switch to move from step to step within the block. An audible tone signals when a bin change occurs and a new part is needed. If a board is completed in 400 steps or less, the operator merely pushes 'reset' to start a new board at step 1. Controls are also provided for fast stepping and backward stepping.

There is no software requirement in the unit. Also, X-Y coordinate information about the parts to be loaded need not be fed to the unit.

A 'stretch-shrink' feature allows deleted steps to be removed or new steps added and the remaining steps renumbered automatically. Changes and additions are quickly made by advancing to the block and step of concern, switching to the program mode to make the new setting, storing this step, and again writing the block.

Wire-wrapping. A moving tool rest serves as a guide for the tip of a hand-held wrapping tool and automatically aligns with each wire wrap pin in a programmed sequence. The operator is thus freed from the tedious and error prone task of taking information from a written list and usually searching for the correct place to put the wire. Instead, the operation may be done with very little concentration and visual effort.

Here also programs stored on magnetic tape cassettes are read into machine memory, 400 steps at a time for execution. The operator uses a foot-switch to advance through the 400-step block. Digital displays and controls are provided to show step number, wire length or bin number, wire routing (if needed) and second end of wire indication. Controls allow back stepping, fast stepping and resetting to step 1. LED-indicated wire bin sets provide easy access to 18 or 36 pre-cut and stripped wires.

Programming consists of mounting a sample board and driving the pointer to each pin in the desired sequence with keyboard controls. The machine will automatically calculate the required wire length. Alternately, a wire length or bin number may be entered manually from the keyboard. LED arrow symbols may be programmed to light or flash to indicate wire routing and second end of wire information. Each step is stored in machine memory by pushing the 'store' button. By a combination of fast slewing and stepping 2.54mm per keystroke, an operator may quickly drive from one pin to any other that is on the same 2.54mm grid pattern without worrying about exact alignment. Off-grid positions can also be handled.

As in the component insertion operation, after 400 steps have been completed an audible tone warns that machine memory is full and this block of program must be permanently stored. This is done by inserting a fresh cassette into the built-in mini-cassette unit and pushing a 'write' button. Programming may now continue until the board is completed. Each cassette holds four 400-step blocks. Average programming time for a given board is less than the time required to manually wrap the same board. Fig. 3 shows the wire-wrapping arrangement.

Wire-wrapping tools

In an MPU product, the need for a faster, more reliable and inexpensive method of making electrical connections has become a necessity. The solderless connection by wire-wrapping technique is now a standard method of making connections to terminals in high density MPU products. The strength of a wire-wrapped connection is considerably in excess of that of a solderless one. It is less easily stripped from the terminal and is less subject to breakage. The contact areas of a wire-wrapped connection remain gas tight when exposed to temperature changes, corrosive atmospheres, humidity, and vibration.

A wire-wrapped connection is made by coiling plated copper wire around the sharp corners of a terminal under mechanical tension. By this, the oxide layer on both wire and terminal is crushed or sheared, and a clear, oxide-free metal-to-metal contact is obtained (Fig. 4). The terminal must have at least two sharp edges.

A distinct advantage of wire-wrapping is the ease with which a wire may be removed from a terminal to correct errors or modify wiring. An unwrap tool is slipped over the terminal, engaging the first turn of the connection. By rotating the tool, the connection is removed within seconds without damage to the terminal.

Generally, bare wire is wrapped around the terminal. Alternatively, in addition to the bare wire, a portion of insulated wire can also be wrapped around the terminal. Fig. 5 shows these two situations.

There are four types of wire-wrapping tools: (i) pneumatic, (ii) electric-powered, (iii) manual, and (iv) battery-powered.

Pneumatic wire-wrapping tool is air-powered The flexible air hose in the tool is connected to a compressor. The tool-head rotates at about 3000 to 4500 RPM. It receives air at about 80-100 psi through a hand-operated switch. Any wire size between 0.2 mm and 1 mm can be used.

The electric-powered wire-wrapping tool is available for 110, 48, 220 and 240 volts AC/DC operation. A motor rotates the tool-head at about 4000 RPM at the flick of a switch. Some manufacturers incorporate a back force device to prevent over-wrapping which might otherwise occur with small wire diameters. Optionally, it is provided with a reversing switch for power unwrapping. Also, wire cut-and-strip attachment is available for PVC insulated wires.

Manual wire-wrapping tools are designed to produce wire-wrapped connections by merely squeezing the trigger. Each squeeze of the trigger provides ten revolutions of the bit on the tool-head. Fewer wraps can be achieved by adjusting the strip length of the wire.

Battery-powered wire-wrapping tool uses two C-size rechargeable nickel cadmium batteries. This light weight tool can unwrap if the batteries are put in reverse. Anti over-wrapping device is optionally available.

All types of wire-wrapping tools find use in an MPU in different stages of production. One has to take the following

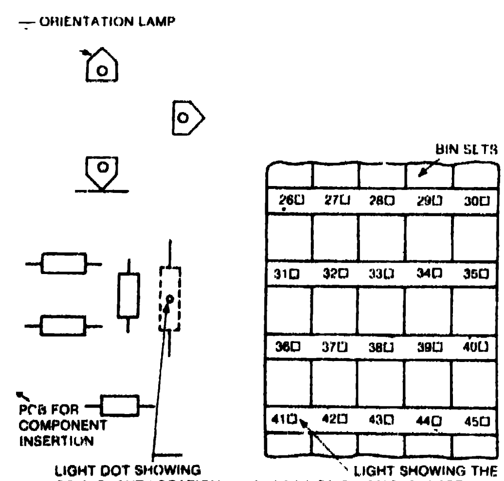

Fig. 2: Programmable locator—component insertion arrangement.

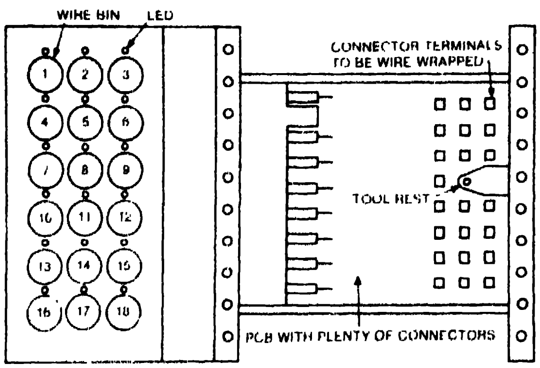

Fig. 3: Programmable locator—wire-wrapping arrangement.

precautions while using these tools:

1. The tool should be kept on the terminal until the wrap is complete. Early removal can result in spiral and open wraps.
2. Tool should not be pressed hard. Excessive pressure can lead to over-wrapping.
3. Each wire size has a tool bit and corresponding sleeve. Wrong bit and sleeve can cause loose wraps.
4. The stripped end of the wire should be pushed in all the way.

If too many interconnections through wires and flat cables are present in an MPU product, then probably aids such as automatic wire-strippers and flat cable and tubing cutters are required.

Automatic wire-stripper. In such a unit made by Eubanks, a keyboard is used to select wire length, number of pieces produced and delay between cut and strip actions. Cut and strip assemblies are powered by compressed air. The microprocessor in the instrument can be programmed from the keyboard to store as many as ten separate combinations of lengths and batches, any of which can be called up at will. Three types of stripping blades are used: V-type, radiused V-type and die-type.

V-type blades are adjustable to accommodate a range of wire sizes. They are used for soft insulations such as PVC.

Die-type blades are made to fit both the conductor and the insulated diameter of the wire. They cut through most—but not quite all of the insulation. The thin remaining section of insulation is broken by being pulled against the blades by the strip assembly clamps, thus minimising the possibility of nicked or scraped wires.

Radiused V-type blades have a radiused cutting edge in the throat of the vee that fits the conductor. Unlike die-type blades, they can be used to strip wires with different insulation diameters.

Blades are available for stripping teflon, kynar, vukene, tefzel, mil-ene, kapton, rubber, glass, PVC and other wrapped or extruded insulations. Wires need not be of single conductor only. They can be coaxial, cable, power cable, telephone cable etc.

Flat cable and tubing cutters cut plastic tubing, wire, ribbon cable, tape and other linear material to preset lengths accurately and at high speed. It uses a stepping motor to drive the feed rolls. Cutting lengths are variable from 0.5mm to 2539.9cm in increments of 0.5mm. Both wire lengths and batch count are entered through the keyboard.

Soldering station. For repair work in an MPU, small soldering stations should be installed in various stages. Almost all latest products carry MOS and CMOS devices. These devices warrant use of 24-volt low leakage, grounded iron in the soldering station although it may receive 230 volts AC. It is better if temperature control (100°C to 500°C) is also provided.

Desoldering aids. Nowadays most equipments carry plated-through hole (PTH) PCBs and multilayer PCBs from which components cannot be removed easily for repairs. Heating the solder which holds the component and vaccum-sucking it is the method to be adopted. Desoldering stations do this job nicely. Installing these at all essential points in an MPU is a necessity.

The desoldering station is fitted with a vacuum pump which does not require external supply of air. The vacuum pump is activated by a foot-switch. A pistol grip iron which carries a see-through solder collector and a hollow desolder-bit heats and sucks the solder from the PCB. Temperature to the soldering iron is controlled through a switch. This facilitates widest variety of desoldering applications. In general, a 30-watt soldering iron is provided. The suction hose is made out of heat-resistant material which eliminates the possibility of accidentally piercing the hose with the heated tip.

Manual desoldering pumps are also available in plastic construction as well as metal construction. In the metal construction type it will be conductive through the full length of the tool. The tip is a special bronze alloy composition designed for long life and static electricity discharges automatically through the hand of a grounded operator. In this manner it becomes suitable for removing sensitive CMOS components. Suction is by a spring loaded piece of plastic or metal which gets released by hand trigger. It is obvious that a soldering iron has to be used in conjunction with this manual desolder pump to melt the solder for sucking it. Teflon tip is also used in the manual desolder pumps.

Device handler. Some devices have to be handled very carefully to avoid electrical and mechanical damages. For example, MOS devices will fail if exposed to static discharges. To avoid this, an automatic device handler has been

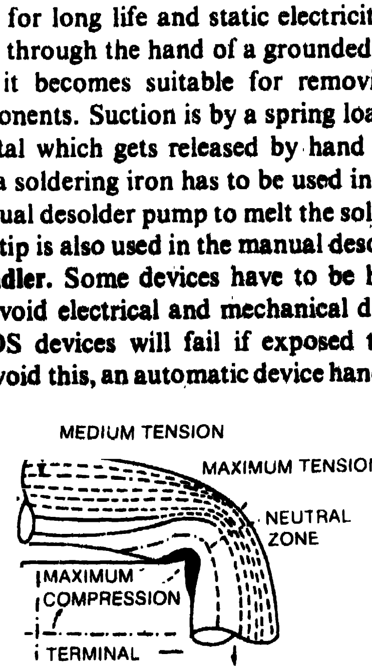

Fig. 4: Wire-wrapping mechanism.

designed. The speed achieveable is a desirable quality in an MPU.

A typical handler fits dual-in-line ICs into sockets of testers, removes them after the tests are over and then discharges them into one of the predesignated output reservoirs. Speeds as high as 3600 devices per hour can be achieved. Handler and test system should be properly grounded. Errors possible in manual handling of devices are totally eliminated here. In fact, this automatic handler can be a part of the test system.

Lead bender. There are hand tools for rapidly bending component leads to preset dimensions. Pointers on the tool accurately set the lead distance to match hole to hole locations on the PCB. Setting and bending adjustments are made by simply turning a thumbwheel to the desired spacing.

Lead wires are securely held during forming to prevent lateral stress on component body. Components are always positioned centrally, for equal leg length. A commonly available model will bend 0.4mm to 1.4mm diameter leads with an easy squeeze of the handles (Fig. 6).

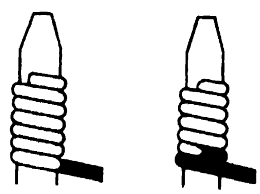

Fig. 5(a): Bare wire wire-wrapping.
Fig. 5(b): Part of insulated wire wrapped.

Cut-and-clinch tool. After inserting the component into the PCB, the extra lead lengths are cut. The components should be held to their respective locations before soldering. Hence while cutting the leads, they should be clinched flush to the PCB as shown in Fig. 7. Cutting and clinching in one stroke burnishes the lead which will improve subsequent solder wetting.

Manual cut-and-clinch tools are available for the purpose. In order to reduce operator fatigue and speed up board processing, air-powered pneumatic lead cut-and-clinch tools can be used. This also provides single motion cut-and-clinch action and improves solderability by swaging the metal. This requires an opening air pressure of only 50 psi.

Manual IC insertion tool. Most of the present day ICs come in DIPs with either 7.62mm (0.3 inches) or 15.24mm (0.6 inches) width spacing.

Manual IC insertion tools in which a twist of the handle compresses the pins to proper spacing thereby aligning bent-out pins are available. Then one has to simply place the tool on the IC socket on the PCB and depress the plunger for instant and accurate insertion. Most of the tools feature chrome plating throughout. This plating and terminal lug for attachment of ground strap provide reliable static dissipation.

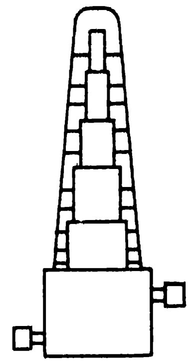

Fig. 6: Simple lead bender.

DIP IC lead straightener. Sometimes, leads of the ICs are found bent even when received from the supplier or while handling. It is essential that we have ICs with straight leads to facilitate automatic insertion, testing etc. Simple, manual DIP IC lead straighteners accepting all standard 8-40 pin ICs on 7.62mm and 15.24mm centers are available.

Fig. 8 shows the construction of the aid. One has to simply attach IC carrying tube and slide ICs through forming rollers.

PCB holders. PCB holders ideal for assembly, testing and repair on a conveyor belt in an MPU are essential. Holder frame rotates full 360° and the steel backed foam cover opens from either end to expose component side of the PCB. Close and lock cover is provided to hold components in place. The cover can flip over frame on pivot to allow for work on the PCB like soldering, cutting, crimping, repair etc.

Generally, the following features are provided:

1. Spring-loaded guides to accommodate various board sizes.
2. Angled board position for ease of use plus minimum fatigue.
3. Adjustable foam-lined retaining cover that adapts automatically to various sized components.
4. Removable center bar to facilitate mounting of several small boards or one larger board.
5. Detachable frame which can be used as a carrier to transport the stuffed board to the next work station or process.

Simple vice-PCB holders are also available. The vice carries nylon jaws which makes delicate yet sure grip action possible. A swivel base with a pivotal holding system is provided. The PCB can be positioned and fixed with locking lever in any random position up to 90° pivotal and 360°

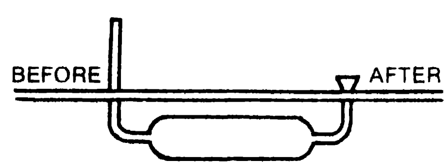

Fig. 7: Clinching before and after.

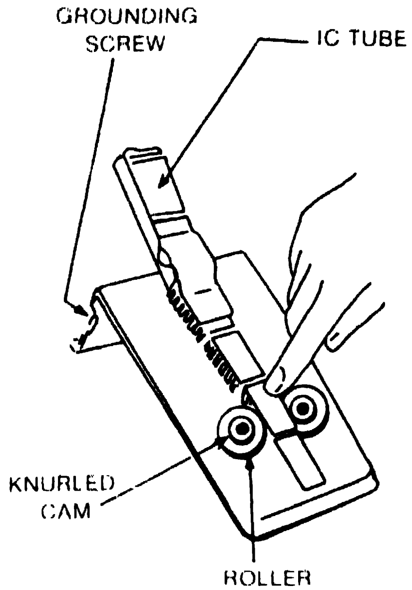

Fig. 8: DIP IC lead straightener.

rotational. Rubber bellows keep tilt mechanism free from dust and contamination. A self-locking hinged foam cover is available for holding components when the PCB is flipped over for soldering.

Air screwdrivers. In order to reduce operator fatigue and improve speed of work in an MPU, air screwdrivers are employed. These are engineered to handle a broad range of fastening and unfastening applications and are powered by air.

Generally, they are built with gear type driving mechanism that generates exceptional power with air. Common features are automatic start with a forward push of the bit upon contact with the screw, instant reverse and torque adjustment for close tolerance, and repeatable torque control. One should choose air screwdrivers as they create less noise.

Automatic component insertion machine

Apart from saving labour, uniform performance resulting in increased reliability can be achieved by using automatic component insertion machine.

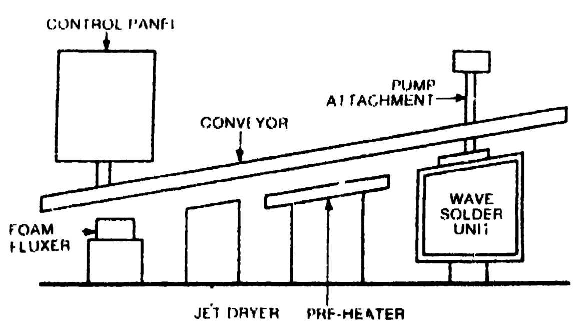

Fig. 9: Layout of automatic wavesoldering machine.

For automatic insertion, the components should be uniformly packaged for presentation to an assembly head. Since not all the components lend themselves to this method, one has to study and decide about the components insertable by the machine.

Most of the axial components are lead-taped by component manufacturers to facilitate automatic insertion. Some special components, or very small components which cannot be lead-taped are packaged in continuous plastic strip. Body taping is generally used for large, heavy axial components. These are placed on reels with interliner ready to be fed into an insertion mechanism.

Methods based on bowl feeding or magazines are adopted for radial lead components. Dual-in-line components like ICs and connectors can be very easily inserted automatically. Numerically controlled insertion machines are available which give insertion rates up to 5000 per hour.

When high volume of only one PCB is involved, as in the case with TVs one can afford to employ what is called 'multiple-station in-line insertion machine.' Here, a series of assembly stations are installed. Each station is fitted with an automatic insertion mechanism which takes care of one type of item. PCBs are conveyorised and time-paced. As the PCBs move on the conveyor, they get loaded with components step by step.

Automatic wavesoldering machine and cutter

This is the most important production aid in an MPU. This receives the PCBs after component insertion into a conveyor. PCB leaves the conveyor after soldering. Fig. 9 shows the inside layout of a typical automatic wavesoldering machine.

The conveyor is either a fixed width type that engages the pins of a PCB carrier or an adjustable width type that engages the PCB directly in titanium fingers. Both types are set at a fixed incline of 6^0. The conveyor has a drive mechanism with variable speed control from 0 to 3m/min. A tachometer on the control console gives readout of conveyor speed. Maximum PCB width that can be processed is limited to 25.4cm or 38.1cm. The PCB carrier supplied has adjustable holding bars which can be set to accommodate any size PCB up to the maximum. The finger type has an adjustable rear rail which can be set to handle PCBs from 2.54cm to maximum width.

The foam fluxer deposits a thin layer of flux on the underside of the PCB, resulting in minimum residue after the soldering operation. The heat of the solder removes most of the flux and the remaining contamination can be removed by a cleaning operation. Low pressure compressed air is diffused through the aerator tube to form a quick wetting flux layer of uniform bubble size. An adjustable air knife removes excess flux to minimise dripping and wastage.

The jet dryer blows hot air on to the PCB to accelerate evaporation of the flux solvent. In addition, the hot air provides a mild initial thermal conditioning of the PCB.

The preheater is a radiating platen which provides an intense heat source to overcome the heatsink of the PCB and raise the flux to its activation point prior to the soldering operation.

The wavesolder unit generates a solder wave which ensures good soldering when the PCBs travel along the conveyor through it. The unit is constructed of stainless steel. There is a pump attached.

In some automatic wavesoldering machines, the PCBs pass over a heated air knife after soldering, displacing bridges, icicles and unwetted solder joints, leaving wetted joints undisturbed.

In-line lead cutters are available which take PCBs after wavesoldering and trim in a single pass of all lead wires. The cutters have two or three high speed blades. PCBs are fed individually into a roller-type automatic palletless conveyor. Adjustment for desired lead length is provided.

Automatic PCB cleaners

There is an aqueous cleaner/dryer which has a conveyorised system of six cleaning and drying stages: (i) prewash to remove gross contaminants, (ii) heated recirculating wash, (iii) heated recirculating rinse, (iv) final rinse of tap, conditioned, or deionised water, (v) and (vi) flash drying sections of tri-vent blower, air knife, and upper and lower radiant panels. This cleaner/dryer when used soon after wavesoldering operation with water-soluble flux helps improve MPU output.

There is a vapour degreaser which is designed for chlorinated, fluorinated and azeotropically blended degreasing solvents. It can be used soon after wavesoldering with rosin fluxes. Cleaning is accomplished by lowering the stainless basket containing the PCBs to be defluxed into the vapour zone. On contact with the parts, solvent vapours condense and cleaning begins. Contaminants are removed by the solvent and drain away with it. Then, still within the vapour blanket, the PCB basket is moved to the cold tank for rinsing. Fresh-solvent flushing by the spray wand completes the process. Solvent is recovered and recycled.

Conveyorised assembly/testing

Various assembly and testing stations of MPU must be conveyorised. Conveyors can be manual, automatic or a judicious mixture of both.

Robots. One can describe a robot as a reprogrammable multifunctional manipulator designed to move material, parts, tools or specified devices through variable programmed motions for the performance of a variety of tasks:

1. They can replace unskilled labour for transferring materials.

2. They can be used on conveyors and rotating tables.

The base of the robot can rotate 330^0, the shoulder and elbow 140^0 and the wrist a full 360^0 with wrist pitch of 180^0. Robots are fast replacing human labour in countries like Japan and USA. Slowly we will also find them to be useful in Indian MPUs also.

(To be continued)