Manual ProtoMat M60

English, version 1.0

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Information on this manuel

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It is the duty of the system owner to care for and plan these measures as well as to control their execution. The owner especially has to ensure that

- **the system is only used as directed**
- **the system is only operated in perfect and functional condition. Especially the function of the safty appliances has to be checked regularly**
- **the necessary personal protectiv equipment for the operating, maintaining and repairing personnel is available and being used**
- **the operating manual is kept legible and complete at the place of operation**
- **only sufficiently qualified and authorized personnel operates, maintains and repairs the system**
- **this personnel is regularly instructed in matters of work safety and environmental protection and is informed on the operation manuel and especially the safety instructions**
- **all safety and warning notes or signs stay on the system and are legible**

Using this manual

I. Orientation

This manual is divided into the following chapters:

1. Safty notes
2. Introduction
3. General Information
4. Setup
5. Operating displays
6. Computer-controlled functions
7. Tools and accessories
8. Milling and drilling
9. Appendix
10. Declaration of conformity
11. Index

II. Conventions used in this manual

Bold text is used to emphasise important information.

Illustrations are numbered. Example: Fig. 5

› Prompts for actions are identified with an arrow.

Italic sections are used to indicate the reactions consequent on an action.

Words printed in italics mark proper names

Key inscriptions and menu terms are printed in **BOLD CAPITALS**.

III. Notes on the symbols used

Danger! This symbol is used to highlight danger to life or health.

Caution! This symbol is used to identify hazards which may cause damage.

Note: This symbol is used for notes intended to help you avoid faults in operation or to help you improve your procedures.

III. Legend

Copper laminate: special, very thin base material used only for laminating multilayer boards

Base material : Circuit board material coated with copper foil

Solder foil : special foil for cutting aperatures for the connections to be soldered

BoardMaster : Machine control software

CurcuitCAM : Software for data preparation

IV. Target Group

This manuel is written for people with basic knowledge in PCB production.

Table of contents

1.0 Safety notes

In order to be able to guarantee the safe operation of the system the user must have read this manual and especially the safety precautions printed in bold types!

- **Never reach into the machine while it is running!**
- **Remember that the machine changes speed automatically during the process!**
- **Only change the tool when the mill/drill motor is not spinning!**
- **Insert the tool into the clamping device as far as it will go!**
- **Never operate the control PC simultaneously when working with the device!**
- **Operator with longer hair must wear a hair net!**
- **If you modify the equipment yourself, the equipment's safety can no longer be guaranteed and no guarantee claims can be accepted!**
- **Please take note that some materials may produce cancerogenous dust or hazardous gases. Ask your supplier of the materials.**
- **Always work with the vacuum device!**
- **When using chemicals please take note of the safety notes on the containers or separate security sheets delivered with them!**
- **Keep the workplace tidy.**

2.0 Introduction

The LPKF *ProtoMat* M60 mill/drill unit is a circuit board plotter which can be used to produce prototype PCBs and gravure films, and for engraving aluminum or plastic.

Familiarity with the *BoardMaster* driver program of the LPKF *ProtoMat* M60 is essential for operation of the machine. Operation of the LPKF *ProtoMat* M60 is described in the LPKF *BoardMaster* Manual. The exclusive operating interface for the LPKF *ProtoMat* M60 is controlled from the serial port of a PC.

In order to make any guarantee claims, if necessary, it is absolutely vital to follow the instructions of this manual before putting the machine into operation. For machines exported to other countries of the European Community the guarantee conditions of the corresponding country apply.

2.1 Characteristics of the ProtoMat M60

Voltage	200-240V (or 100-120V)
Power consumption	200VA
Speed of high-speedcycle spindle max.	Approximately about 60000/min
Weight	ca. 25 kg
Drilling performance	max. 60 strokes/min
Resolution (smallest step)	0.0079375mm
Operating data:	
Humidity	60% max.
Temperature:	15-25°C

3.0 General Information

3.1 Scope of supply

- 1 LPKF *ProtoMat* M60 machine unit with integrated electronics
- 1 null modem cable (LPKF *ProtoMat* M60 control unit-computer), AT- Adapter 9/25-pol
- 1 set of accessories (Drafting Tape, Allen wrenches, alignment pins, tweezers, brush, 7 mm wrench, 2 red two-pin strips, 2 alignment drill 2,95 mm)
- 1 power cable
- Inserting tool for alignment pins
- This manual

3.2 Optional accessories

The following accessories can be supplied for the LPKF *ProtoMat* M60:

- Vacuum system with fine filter. The fine filter is essential in particular when handling materials containing glass fiber, such as for FR4 base material.
- Noise and dust guard hood
- LPKF *AutoSwitch*.
  Automatic switch for the vacuum cleaner. With this option can over the mill/drill spindle, the vacuum cleaner switch on and off.
- LPKF *AutoContac*
  Integrated through-hole plating using a dispenser and a special conductive paste capable of being soldered

3.3 Air-borne sound

The continuous sound level at the work place during operation is 71 dB (A). This value does not include the vacuum unit.

3.4 Installation

› Unpack the LPKF *ProtoMat* M60 carefully (for detaching the security screws see Fig. 1 on page 12). Then loosen the transport safety devices. These devices are marked red and are located:

- Locking of the X-axis - 2 aluminium elbow joints (safety device 2)
- Locking of the Y-axis - directly at the head to the left (safety device 3)
- Locking of the Z-axis - Allen screw (safety device 4)

Note: The equipment must stand on a flat and firm base in order to work properly!

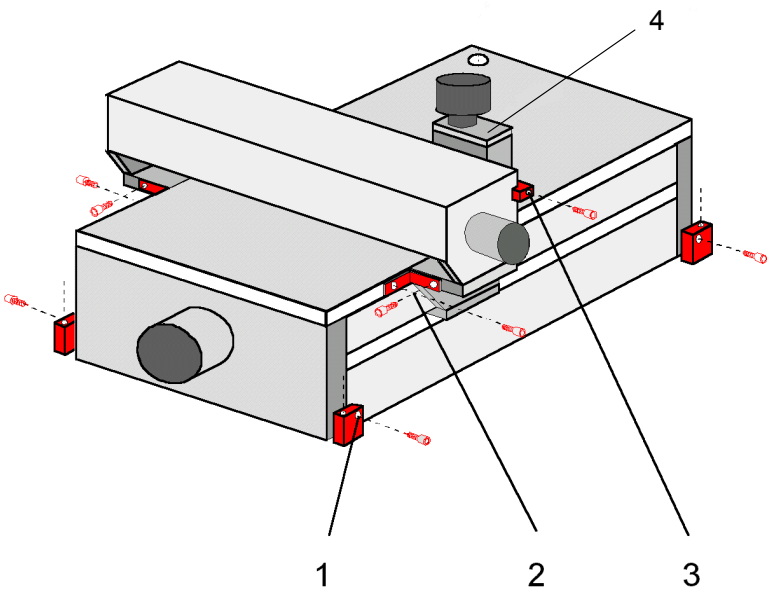
› Set up the circuit board plotter so that the connecting cables to the electronic unit can move freely.

› Connect the LPKF *ProtoMat* M60 to the computer with the null modem cable supplied with the system (COM1 or COM2).

› Plug the LPKF *ProtoMat* M60 control unit into the electricity supply

› Fit the Vacuum to the adapter (suitable for stay tube no. 111124 of a Nilfisk industrial vacuum unit).

fig. 1: Transport safety devices of the LPKF ProtoMat M60



1- Attaching the machine safely to the transport support
2- Securing the X-axis
3- Securing the Y-axis
4- Securing the mill/drill head

Note: Keep all transport safety device and packing and mount them accordingly if the machine is to be shipped.

4.0 Computer-controlled functions

4.1 Connection to a PC

The LPKF *ProtoMat* M60 has two serial interfaces. The first (SERIAL 1) is the INPUT to the system and is used for connection to the controlling computer (PC). The second interface (SERIAL 2) is an OUTPUT and is provided for future applications.

The LPKF *ProtoMat* M60 control unit's SERIAL 1 is connected to a serial interface on the computer with the RS232 cable supplied.

The RS232 cable (null modem) for the LPKF *ProtoMat* M60 circuit board plotter is wired as follows:

25-pin socket PC (COMx)			**25-pin socket Circuit board plotter (SERIAL1)**	
1	-		-	1
2	-	TXD	-	3
3	-	RXD	-	2
4	-		-	5
5	-		-	4
7	-	GND	-	7
8	-		-	20
15,17	-		-	24
20	-		-	8
24	-		-	15,17

The cable shield ground is connected only on the PC side (port).

The following parameters must be observed:

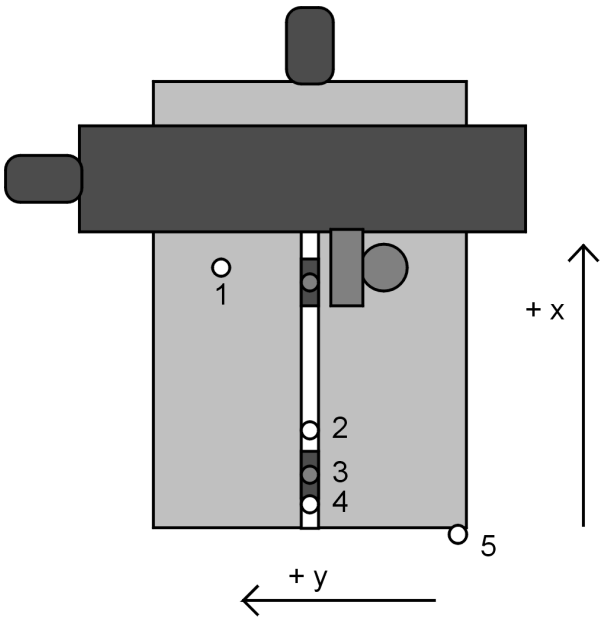
Baudrate	9600 (default setting, others upon request)
Parity	None
Datenbit	8
Stopbit	1
Hardwarehand-shake	
FIFO-Buffer	off

If the DOS driver is used the PC's serial interface is initialized with the DOS command **Mode Com1:96,N,8,1**. If *BoardMaster* is used, the port must be initialized under Windows using Main/Control Panel/Ports.

4.2 Machine orientation

Description of the main machine positions:

fig. 2: LPKF ProtoMat M60: the x-axis is the longer direction of movement



1- PAUSE position:
The machine will move to this point to load or turn the material to be machined.

2- HOME position:
This is the relative 0.0 position and MUST lie on the machine mirror (X) axis (two-pin system) and serves as the reference X=0,Y=0 position for the programm BoardMaster.

3- Two-pin slide with hole for alignment pin.

4- Reference pin for front two-pin strip

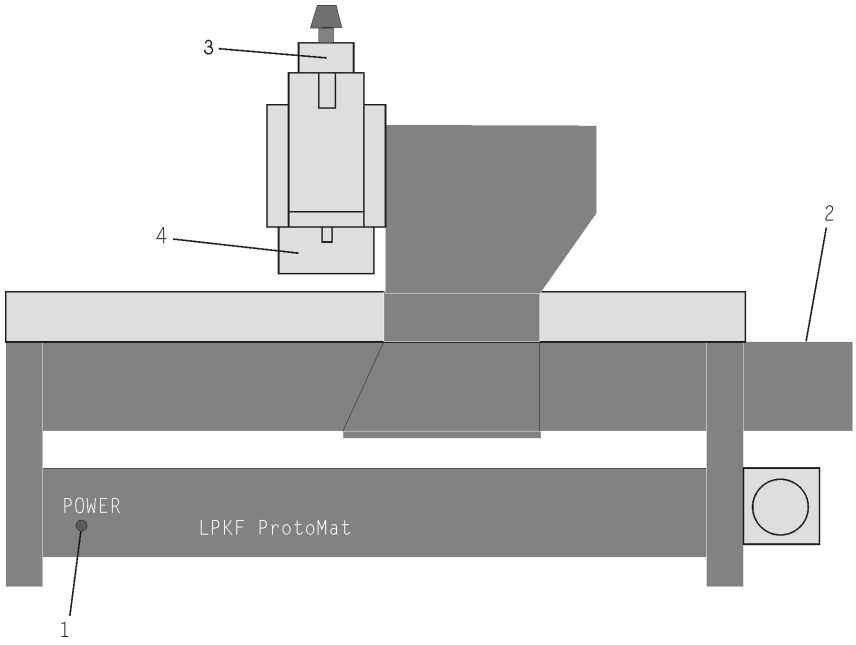
5- Tool change position (absolute zero position). The tool is changed here.

Danger! Keep fingers and any other items out reaching into the area of movement!

4.3 Displays and connections

Description of the front panel:

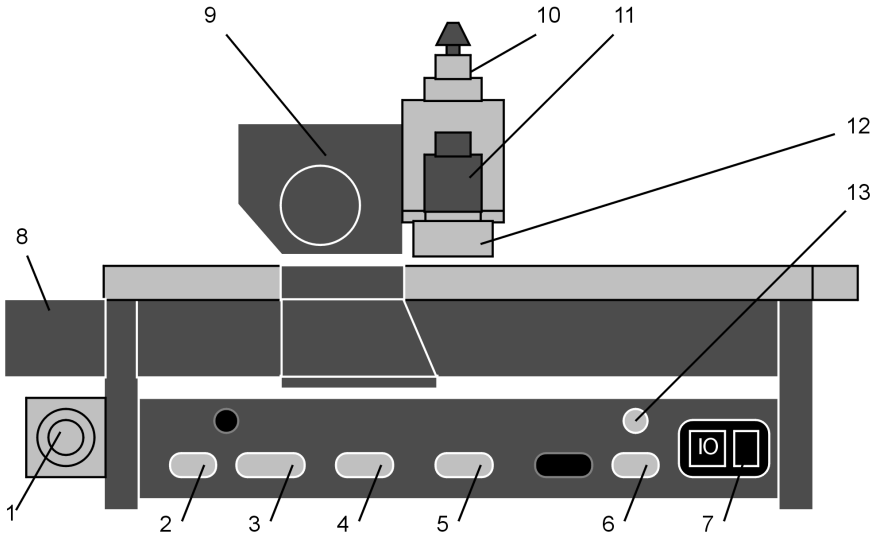
fig. 3: Front LPKF ProtoMat M60



1- Operating display of the integrated machine control SMCU
2- X motor
3- High-speedcycle spindle motor
4- Working depth limiter

Description of the rear panel:

fig. 4: Rear view of LPKF ProtoMat M60



1- Vacuum connection
2- Output Serial interface (9-pole) for controlling optional equipment
3- Input Serial interface (25-pole) for connection to PC serial port
4- X motor connection
5- Y motor connection
6- Mill/Drill head connection
7- On/Off switch, power cord connector and fuses
8- X motor
9- Y motor
10- High-speedcycle spindle motor
11- Solenoid
12- Working depth limiter
13- Connection of high-cycle spindle

4.4 Use of BoardMaster

Data required to drive the plotters are generated in *CircuitCAM* and are stored in files with HP-GL format or as LPKF binary files (LMD format). *BoardMaster* is used for reading the files, decoding plot commands and modifying them for the specific LPKF System being driven. The drivers use the HP-GL or LMD data and add important, machine specific functions such as scaling, motor control, etc. The LPKF *ProtoMat* M60 circuit board plotters respond to HP-GL commands. The drivers provide additional capability such as step and repeat, move, rotate, etc.

All LPKF circuit board plotters are driven via an asynchronous interface (RS232C). In the case of the LPKF *ProtoMat* M60, it is operated at **9600 baud, 1 stop bit, 8 data bits, no parity and hardware handshake**. The configuration of the computer's serial interface has to be accordingly set within the system control of Windows. The FIFO-buffer has to be switched off.

5.0 Setup

5.1 Before switching on

Caution! Be sure the voltage set at the machine corresponds with the line voltage: If not, continue at „Fuses, commuting the device voltage“ on page 45.

Before switching on, all items are to be removed from the machine and its range of movement. Alignment pins are not allowed to jut out from the base material. Alignment pins serves to fix, and by the twirl of the base-material as reference point of the brush mirror.

Danger! Never reach into the machine while it is running!

5.2 Turning the system on

The following switching on order is useful, but not essential:

1. Computer
2. LPKF *ProtoMat* M60
3. Start the *BoardMaster* program

If for some reason it should be necessary to switch the machine off and on again, then change to the **MACHINE/SETTINGS** window of the *BoardMaster* program and click on **OK**. Through all necessary initialization parameters like speed ranges, dwell times positions and so on are again transmitted to the machine.

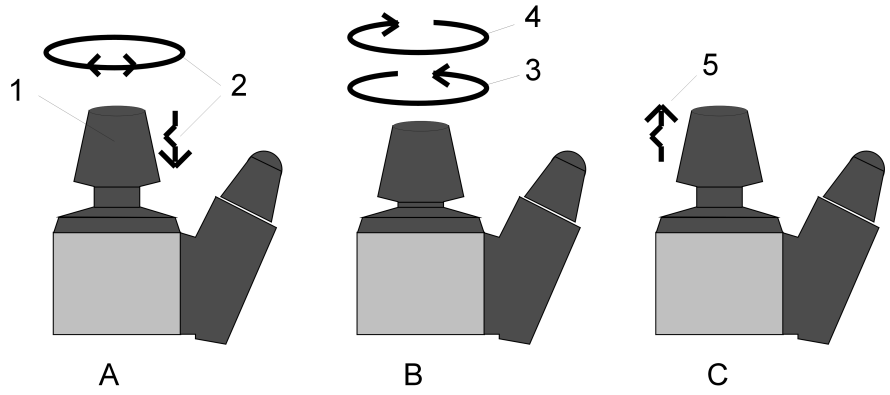
5.3 Switch-on instructions for high-speedcycle spindles

A tool must always be placed in the shaft of the high-speedcycle spindle when the machine is switched on. The collet must always be closed and the knob of the high-speedcycle spindle must be in itsist top position, otherwise the spindle is blocked and the motor driver can be overloaded.

Caution! The Danger of spindle can be damaged if it operated without a tool inserted!

Danger! Do not operate with the tool clamp before the spindle is standing absolutely still!

fig. 5: Operating the collet of the high-speedcycle spindle



A) Knob in normal position, spindle is running freely. Push the knob (1) down until it is engaged in order to open or close the collet. Hold the head up to avoid damaging the tool in the collet. Tight so that a tool that might be inserted will not be damaged. If necessary, turn the knob slightly to the right or to the left (2) when pushing it down.

B) **Caution**: In this position collet and spindle are blocked and the drive electronics may be damaged if the motor is turned on. In order to open the collet, turn the knob counter-clockwise (3). To close, turn the knob clockwise (4). Do not turn the knob too tightly.

C) Bring knob back to normal position (top) (5). The spindle can now run free again. Spindles of some manufacturers are jumping back into the normal position by themselves.

Caution! Only operate the spindel with the vacuum cleaner switched on.

Note: During set-up take note that the bearings of the high-speedcycle spindle have to be run in first after a longer period of standstill (several months) or after transport. During initial set-up the spindle should run at 10 000 rpm for several hours.

Normal warm-up of 3 to 10 minutes (at 20 000 rpm) of the spindle is automatically controlled by *BoardMaster*. The duration of this warm-up depends on the length of time the system has been off. During warm-up no speeds exceeding 20,000 rpm will be allowed. Programmed speed above 20,000 rpm will be allowed after the warm-up time.

5.4 Changing a tool

For changing a tool there is to be considered, that the tool after the opening is introduced up to the plot in the tool clamp, before the tool clamp is closed again. Befor handling the tool clamp you must read chapters „Switch-on instructions for high-speedcycle spindles“ on page 17.

5.5 After switching on

When it has been switched on, the equipment moves to limit switches -X and -Y, and the system then halts in the tool change position. It is then able to accept commands from the machine drivers. If the equipment does not move when it has been switched on, check the following:

1. Is the POWER LED on (is on only after successful initialization)?
2. Are all cables properly inserted ?
3. If necessary, check the fuses at the input power connection!

5.6 Function test with BoardMaster

Danger! Make sure that nothing is no other persons are in the machine operating area when the first functional test is taking place!

First check that the serial interface used is set to **9600 baud, 8 data bits, 1 stop bit, no parity bit and hardware handshake and FiFO-buffer off**. Also check that **CHANNEL** and the correct interface have been selected in *BoardMaster* under **MACHINE CONNECT...** Consult the *BoardMaster* Manual if you need help.

Now using *BoardMaster*:

› Before the motor can be switched on, the milling head has to be moved out of the tool-change position a few inches using the cursor key.

› The correct tool must be declared (clicked on) in the window **TOOL-ASSIGNMENT**

› turn on the motor, to click of  (first the motor will turn at a maximum of 20,000 rpm, warm up phase)

› raise/lower the head, to click of 

› switch off the motor, to click of 

› move the head manually using the cursor keys on the *BoardMaster* function bar.

If the equipment does not move, check the interface configuration, the connecting cable as well as the PC interface.

5.7 HOME-Position and two-pin system

The HOME position must be on the machine's X axis (two-pin system) to guarantee alignment of a double sided board. The data for the bottom side of a PCB is mirrored around the X axis and therefore the board must also be rotated around the X axis to maintain registration. Inaccuracies in the HOME position result in a displacement during machining of double-sided boards after the rotation.

Note: The two-pin system is parallel only for the current position of the two-pin strips. The front two-pin slide must be placed against the pin in the groove (reference). If base material of different sizes is used, an additional hole must be drilled in the strip of the back for every format. To do this, move from the home position in direction of the rear strip, displace it to the desired position and drill an additional hole by hand, using the 2,95 mm drill. The position of the new holes should recorded or marked at the plotter. This will help when drilling the reference hole in various size material.

5.8 Programming the HOME position

The home position needs to be programmed on new equipment and when the system has been moved.

The HOME position of the LPKF *ProtoMat* M60 must be precisely on the mirror (X) axis (the two-pin system with the red plastic slides) for machining double-sided base-material. To do this, proceed as follows:

› Start *BoardMaster*

› Click **CONFIGURATION** in the menu bar.

› Now select **SETTINGS..**

› Activate **UNLOCK** so that you can make entries in this window.

› Make sure that SMCU is selected.

› Now **INITIALIZE** must be clicked.

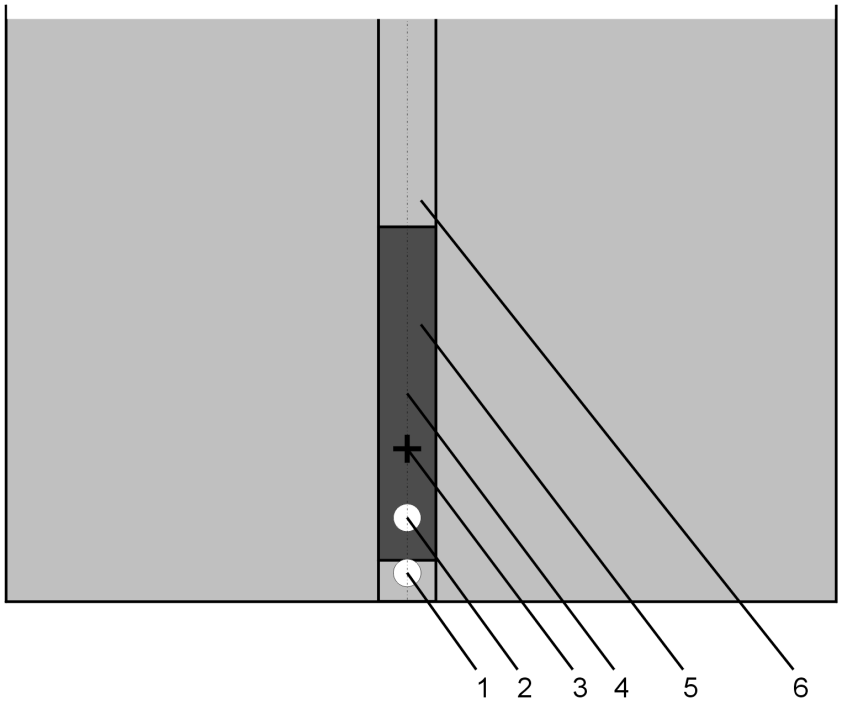
The equipment travels to all four end positions, and then stops in the ZERO position (tool change position). The movement range thus determined is displayed under **SIZE** *and stored when the* **MACHINE SETTINGS..***dialog box is left. For more detailed information see the BoardMaster Manual.*

A two-pin system has already been set up at the factory. The HOME position x and y coordinates is delivered with the machine on the enclosed paper (see driver diskette). They should now be entered under Home in *BoardMaster*.

If the coordinates are not known, the two-pin system must be drilled again. To do this, see the section „Making a new two-pin system“ on page 22.

Click **OK** to close the **MACHINE SETTINGS** dialog box and quit *BoardMaster*. The new values are saved in an .INI file wich is read each time *BoardMaster* is called.

fig. 6: Front stripe of the two-pin system



1- reference pin
2- front alignment pin
3- HOME position, min. 10 mm distance to the alignment pin
4- mirror axis
5- two-pin stripe
6- two-pin groove

5.9 Checking and correcting the HOME position

Caution! Bevore beginning you must read the chapters „The mechanical working depth limiter“ on page 29 and „Changing a tool“ on page 18.

› Make alignment holes in double-sided base material.

› Fix the material and the drilling base (2 mm) on the base plate with the help of the alignment pins (see too the section „Securing the PCB on the machine bed“ on page 28).

› Drill a hole at the HOME position with a 0.7 mm drill.

› Move the mill/drill head to the PAUSE position.

› Turn the base-material around (about the X axis).

› Move to the HOME position, move to the tool change position and insert a universal milling cutter. When the tool has been changed, the mill/drill head automatically returns to the HOME position.

› Mill a channel over the hole manually in the X direction, without moving in the Y direction.

› Check visually that the milled channel passes precisely through the center point of the hole.

› If the milled line does not run exactly through the center point, the HOME position must be corrected by half the difference. This can be done directly by changing the home position in **MACHINE SETTINGS..** dialog box.

› After making a correction, the movement should be repeated as a check.

5.10 Making a new two-pin system

The alignment holes in the red two-pin strip become larger over time due to use and top to bottom alignment will suffer. You must then drill new holes in the slides. If after a certain time there are too many holes in the slides, the two-pin strips must be changed.

Danger! Take note that sharp tools are involved and that they may be hot. In order not to hurt yourself because of chips always work with the vacuum system switched on!

To make a new two-pin system, proceed as follows:

› First press both two-pin strips into the machine groove, with the front two-pin strip pushed against the reference pin to the front of the groove. The distance between the two two-pin strips should be about the size of the base material in the X axis.

› Fit a drill measuring 2,95 mm in diameter so that the distance between the base plate and the drill point is about 0.5 mm (Under the base material you can put a 0.5 mm thick base). This is the only time a tool is not inserted into the collet as far as it will go. The speed of the drill must be changed to 25.000 rpm in *BoardMaster*.

› Move the plotter head in +x direction for about 30 mm and define this positionas the new HOME position (set HOME, see **MENU CONFIGURATION**)

› Move the mill/drill head to HOME and then to the front two-pin strip (Pull the alignment pin before, in order to avoid the drill from breaking off). Then manually drill a hole about 4 mm deep in the approximate center by pressing down the drill head (before, choose in menu bar **DRILLING PLATED**). Afterwards, do not move the mill/drill head position in the Y direction.

› Move in the X axis a known amount to the second, rear two-pin strip (from the first hole, 287 mm) and drill a hole about 4 mm deep there too. By no means move in the Y-direction.

› Now position the drill tool in the drill chuck as far as it will go.

› Move the mill/drill head to the side. Insert two alignment pins in the holes now made in the two-pin strip. Check that the pins are firmly inserted as any play affects alignment accuracy.

› Mark old holes with a felt pen so they cannot be confused with the new ones.

› Position the previously drilled base material and drilling base over the alignment pins. The holes in the base material and the copper clad should have been drilled using the system and at the same distance apart as the alignment pins so the plastic strips do not have to be moved.

› Now fix the base material thus positioned with adhesive tape on all four sides.

5.11 Producing a PCB with BoardMaster

The job to be carried out must already be loaded or prepared in *BoardMaster*. For example, the data from the *CircuitCAM* tutorial can be used.

A further requirement is that the HOME position was programmed precisely as described.

Caution! Bevore beginning you must read the chapters „The mechanical working depth limiter“ on page 29 and „Changing a tool“ on page 18.

Danger! Take care when handling the tools! Danger of cutting! Do not forget to switch on the vacuum system during machining!

› Move to the PAUSE position using *BoardMaster* (**GO TO..., PAUSE**).

› Fix the base material using alignment pins as described in the section „Securing the PCB on the machine bed“ on page 28.

› Using *BoardMaster*, move to the left corner (-x, -y) of the base material so that the working depth limiter does not quite touch the adhesive tape.

The project must be visible in BoardMaster as light gray on the dark gray machine surface.

› If applicable, move the project by means of **PLACEMENT** so that the graphics data is completely on the material. In the menu the position can be selected manually. It can also be clicked on the icon  on a corner of the projekt, so that the machine exactly approaches this point.

› Select the first machining phase i.e. **DRILLINGPLATED**.

› Drill data is selected with **ALL+**.

Selected data is shown brighter.

› Switch on **AUTO-MOTOR-ON** () (motor key on right in *BoardMaster*).

› Press **START** .

BoardMaster requests the tool needed for the machining phase by traveling to the tool change position and then switching the motor off automatically.

The tool can be removed by using the enclosed tweezers from the shaft of the motor.

› Insert the ordered tool up to the limit and fix it.

› Acknowledge the tool change with **OK**.

The motor switches on and the first hole diameter of the drill phase is carried out.

› Once the holes of the current diameter have been made, the next tool is requested and changed in the same way.

› When the drill phase is complete, mill phase **MILLINGBOTTOM** is selected after any through-plating.

› The milling depth should now be set. To do this, click **UNIVERSAL CUTTER** in the **TOOL** combo box.

The head travels to the tool change position.

› Insert the universal milling cutter and, with the arrow keys, move over the base material, but not over the project, in *BoardMaster*.

› Set the step size manually (approx. 10 mm) 

. Switch on the milling/drilling motor  . Move down the raise/lower plotter head  and move with the arrow keys  . Check the milling channel (if necessary, with handmicroscope) and correct the milling depth correspondingly (see chapter „The mechanical working depth limiter“ on page 29).

› Switch on **AUTO-MOTOR-ON** () (motor key on right in *BoardMaster*).

› The mill data for the component side is now selected with **ALL+**. Machining is started with **START**.

› Move to the pause position and turn the material.

› Select and carry out the **MILLINGTOP** mill phase.

› If required, select the **CUTTING** mill phase and machine with a contour milling cutter.

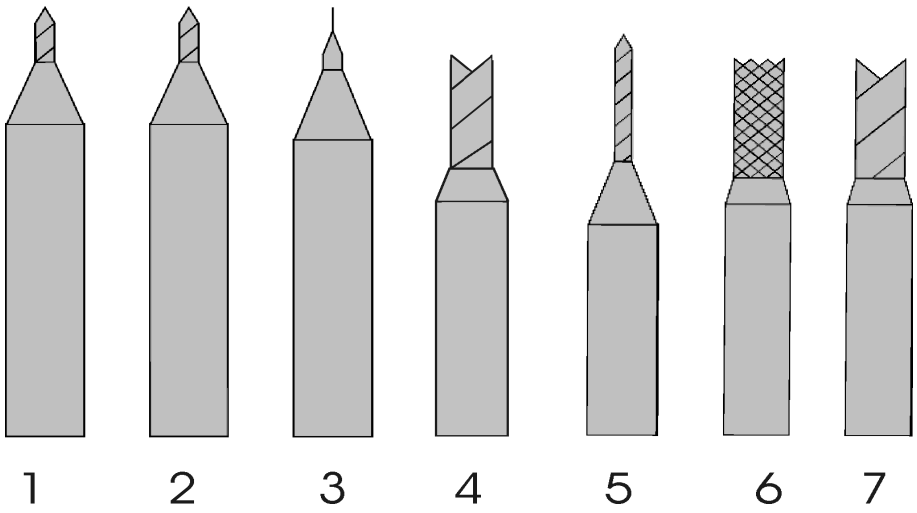
› Move to the pause position, remove the PCB and proceed as described in the section „Cleaning the PCB“ on page 37.

6.0 Tools and accessories

6.1 Tools

The tools for the LPKF *ProtoMat* M60 come in two different lengths. Tools used to machine the material surface (milling and engraving) are 36 mm long for 1/8" and tools used for drilling or contour milling are 38 mm long for 1/8" collets. The following tools are available.

fig. 7: LPKF tools for circuit board plotters



1- LPKF Universal cutter:	for milling of isolation-canals and to the front panel-engraving of 0,2-0,5 mm, according to depth setting, length 36 mm.
2- LPKF Micro-cutter:	for milling isolation channels of 0.1 - 0.2mm (depending on the depth setting), length 36mm
3- LPKF HF-cutter:	produces rectangular isolation channels of 0,15 mm, 0.25mm or 0,4 mm width, length 36 mm
4- Double chamfered cutter (0.8; 1; 2 mm):	for engraving of aluminums and to the milling of wide isolations, different diameters, length 36 mm.
5- Spiral drill:	Cylindrical special tool to the drilling of base material (reinforcedf), different diameters.
6- Contour milling cutter:	to the contur routing of conductor plates as well as molding machines of outbreaks, with chip removal downward (downcutting), different diameters, length 38 mm
7- Double-edged cutter (0.8; 1; 2 mm):	to the contur routing as well as milling machine of outbreaks in aluminums, HF-and microwave-materials. Length 38 mm

Caution! Execute a tool change only in defined positions!

The tools must always be inserted in the tool fixture as far as they will go. Otherwise the working depth will be incorrect. In certain circumstances, this can even result in damage to the machine base plate.

Tweezers are supplied for tool insertion and removal.

6.2 Materials used for machining

In general all base materials supplied by LPKF can be used for machining. You are free to machine all other materials at your own risk. Take into consideration the notes of the manufacturers.

However, the most basic phenol resin qualities (FR 2) can adversely affect milling quality.

Glass fiber reinforced epoxy material (FR 4 or G 10) can be a health hazard due to the milling dust produced (allergies, risk of cancer). Tool service life is also substantially reduced.

Danger! Never work without extractor!

We recommend epoxy material without glass fiber (FR 3). With top milling quality and a high tool service life, no disadvantages with regard to FR 4 are known other than a slightly reduced mechanical strength bearing capacity (breakage). This drawback should not be of any significant importance for prototype boards plates unless particularly heavy components are to be mounted. The adhesive quality of the copper on the base material is mostly slightly reduced which might lead to the removal of smaller pads.

Normally, a total thickness of 1.5 mm and a Cu thickness of 35 µm are used. With 17 µm material even fine milling channels can be engraved at a higher packing density. For galvanically through-hole-plated, double-sided PCBs, 5 - 17 µm Cu thickness is used to prevent an excessively thick copper layer after galvanic copper application.

With 70 µm material, compromises must be made when setting milling depth. I.e. a deeper milling depth results in wider milling channels of 0.5 to 0.7 mm.

Special base materials with a thicker copper layer of up to 300 µm can no longer be machined with the LPKF universal milling cutter. Contour milling cutters or special tools are needed for this. In these cases, we would ask that you consult us and send sample material so that tests can be carried out if appropriate.

Teflon materials can be machined, but the following points must be borne in mind:

- As the material is very soft and therefore often extremely uneven, a constant milling width often cannot be maintained unless, so the material is should be smoothed first.
- Because the material is so soft, it is not possible to mill such as fine isolation tracks as in epoxy material.

Danger! Machining Teflon might produce hazardous gases! Protect Teflon from overheating!

The following material has proved particularly successful as material for HF and microwave applications: RT/Duroid types 5870, 60XX, RO 4XXX, oder TMM-X.

A drilling base is indispensable for all machining processes on PCB material. With it, PCBs cannot be drilled through without damaging the machine. The drilling base can be made simply of cardboard and should be 2 mm thick.

Material supplied by LPKF and suitable for machining:

FR3-material:	engraving, drilling, milling
FR4-material :	engraving, drilling, milling
Engraving film:	engraving

Material suitable for machining but not yet supplied by LPKF:

Different HF applications:	engraving, drilling, milling

Danger! Keep from overheating, hazardous gases may be produced!

Danger! When working with materials containing glass fibers there might be produced cancerogenous dusts. Therefore only work with vacuum system switched on!

Danger! When working with unknown materials cancerogenous dusts or hazardous gases may be produced. Ask your supplier or the manufacturer before starting with the machining.

7.0 Milling and drilling

7.1 Securing the PCB on the machine bed

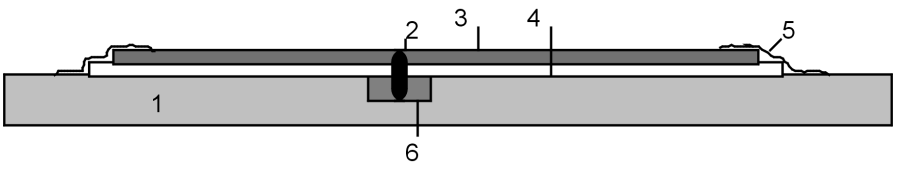
› Make 3.05 mm alignment holes in the base material and backing material spaced the same distance as the alignment pins. This can also be done with any upright drilling machine. Take into consideration that the diameter decreases during galvanic through-plating process so do not plate these holes.

› Move the mill/drill head to the PAUSE position. Insert alignment pins in the front and rear two-pin strips but, even so, check that the front two-pin strip is pushed forwards against the reference pin in the machine groove.

› Position the pre-drilled base material and drilling base over the alignment pins. The format of the base material should be selected in a way that the two-pin slides do not have to be moved by more than 10 mm, as otherwise the two-pin system precision decreases.

› Now secure the base material in position with drafting tape (masking tape is not recommended because it leaves a residue) on all sides. This prevents the corners of the PCB turning upwards.

fig. 8: Securing the PCB



1- Machine bed (aluminum base plate)
2- Alignment pins, 3 mm in diameter
3-Base material, approx. 1.6 mm thick
4- Drilling base, 2 mm thick
5- Drafting tape
6- Two-pin strip

The alignment pins hold the PCB in position. This is essential particularly for contour milling. They are also the reference when turning double-sided PCBs.

Caution! Switch on the vacuum system! Take into consideration that the vacuum filter might need to be changed! It is important that there is no dirt (adhesive tape remains, drilling or milling chips) between the individual layers so that the base material can be laid absolutely flat. Small particles under the base material would adversely affect milling depth uniformity.

7.2 The mechanical working depth limiter

Danger! Keep your fingers away from the movement area of the machine during operation!

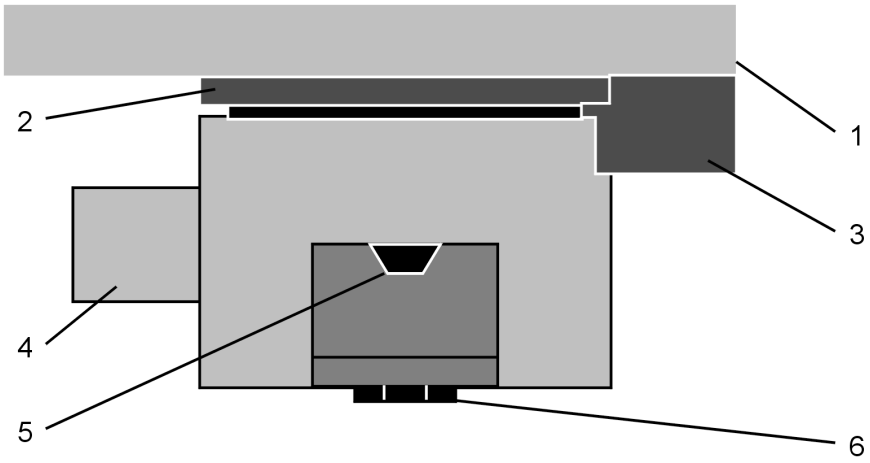
When milling isolation channels in PCB materials, it is extremely important to keep a constant milling depth. With the LPKF *ProtoMat* M60, this done by the mechanical working depth limiter.

This provides the following benefits:

- The depth limiter rides on the surface of the material. The working depth limiter follows warped PCBs.
- The material is held down within certain limits by the working depth limiter.

The head is lowered with a solenoid and raised with a spring.

fig. 9: The LPKF ProtoMat M60 working depth limiter

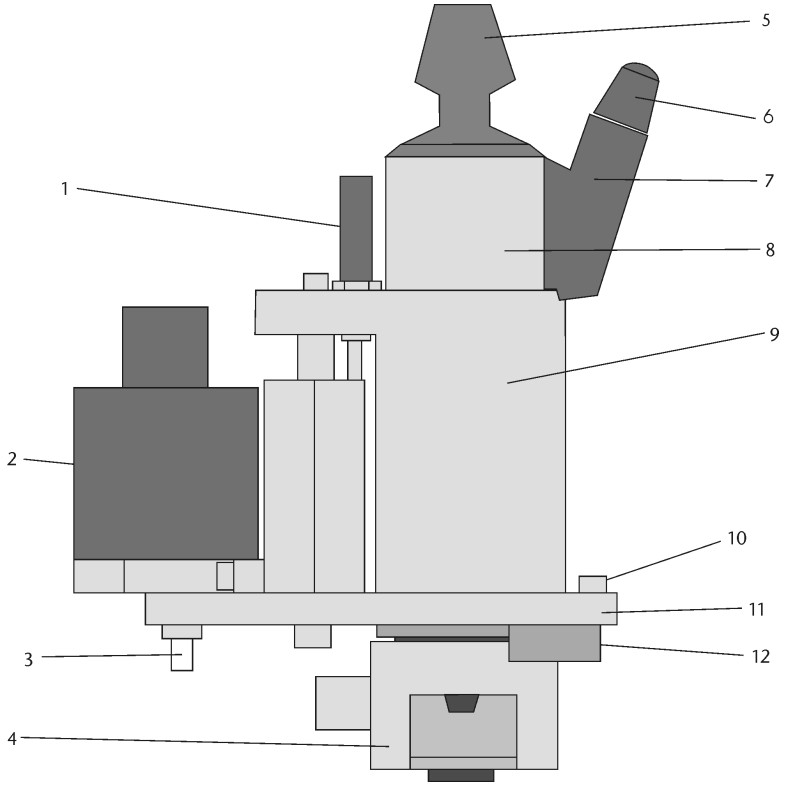


1- Holding plate
2- Knurled nut used to set milling depth
3- Holding block for working depth limiter
4- Suction nozzle
5- Tool fixture (collet for manual clamping)
6- Scanning ring in the working depth limiter

Milling depth is set by adjusting the knurled nut (2) on the working depth limiter. When the wheel is turned clockwise, the milling depth is increased, while it is reduced when turned counterclockwise. The milling depth is altered by about 4 µm per step. Turning the knurled knob in counter-clockwise direction is difficult when the head is lowered.

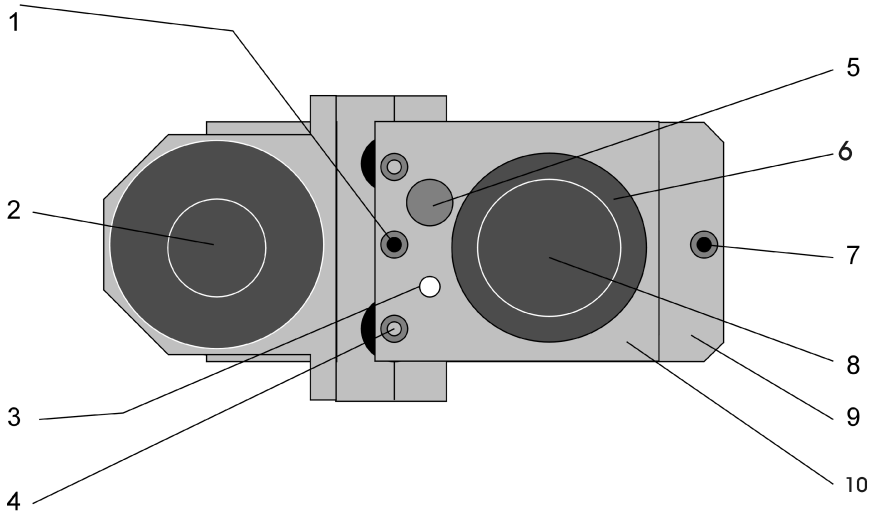
7.3 Functional elements on the mill/drill head

fig. 10: Mill/drill head front view



1- Shock absorber
2- pneumatic cylinder
3- Adjustment bottom head stop (Attention! Do not move!)
4- Working depth limiter
5- Knob for manual clamping
6- Connector for high-speedcycle spindle
7- Socket for high-speedcycle spindle
8- High-speedcycle spindle
9- Holding block
10- Adjustment screw for working depth limiter
11- Base plate for high-speedcycle spindle
12- Setting screw for knurled nut (Attention! Do not move!)

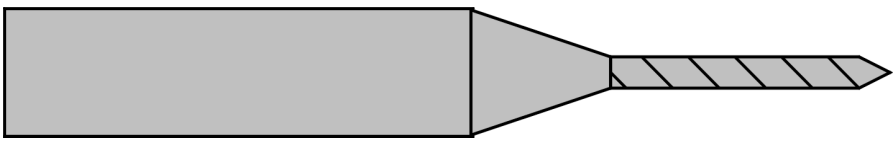
fig. 11: Mill/drill head, view from above



1- Adjusting nut for head stop, top
2- pneumatic cylinder
3- Hole for transport safety devices and options
4- Axis guide
5- Shock absorber
6- High-speedcycle spindle
7- Fixing screw for working depth limiter
8- Knob for high-speedcycle spindle
9- Base plate
10- Bracket for high-speedcycle spindle

7.4 Drilling

fig. 12: Spiral Drill



Caution! Before drilling make sure that the PCB is positioned tightly. Switch on the vacuum cleaner!

You must check the PCBs are drilled with special PCB drills. It is important always to lower the head at a constant speed. This is achieved by setting the tool as close as possible to the material to be drilled. A setting nut can be used to make this adjustment. An excessive lowering speed can result in burrs, particularly where holes have a small diameter.

Only one PCB can be drilled at a time. It is not possible to stack PCBs one on top of the other. No drill cover plate is needed. All drills are 38 mm long. For further notes see „Practical tips“ on page 38.

7.5 Isolation milling

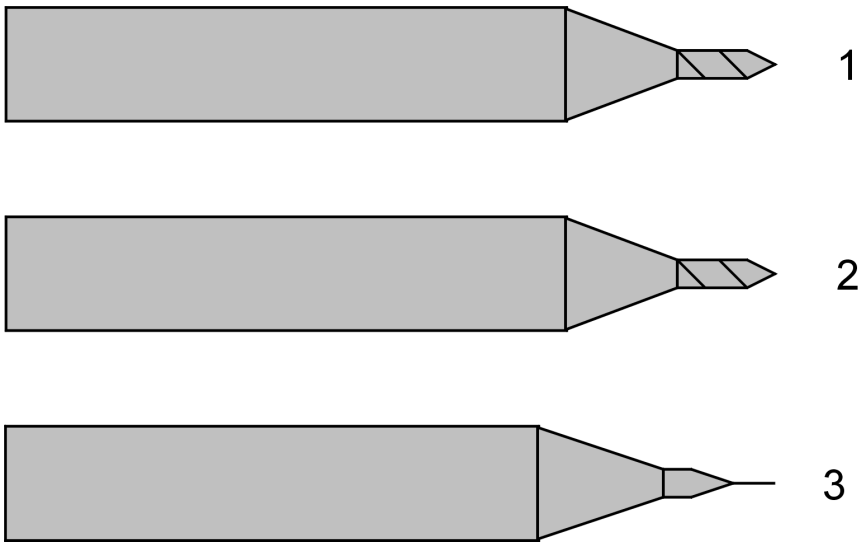


fig. 13: LPKF universal- (1), micro- (2) and HF-cutter (3)

Caution! Before milling make sure that the PCB is positioned tightly! Switch on the vacuum system!

Before milling, it must be ensured that sharp LPKF universal milling cutters (36 mm long) are used. The milling width is set to between 0.2 and 0.5 mm depending on component thickness.

It is advisable to degrease the base material with cleaner spray before machining (degreaser for electronic components), so that milling dust can be removed more easily by the extractor.

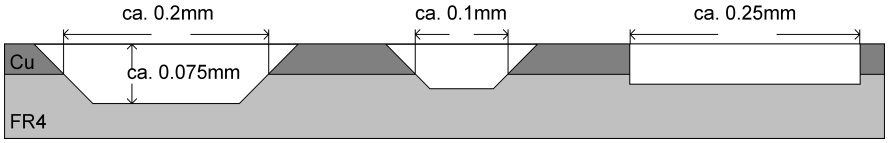
The milling depth must be set as large (deep) as possible in all cases. If only the extreme milling cutter tip (<0.2 mm isolation) is used, the tool wears more quickly than with deeper drilling.

The LPKF micro-cutters can be used to produce even smaller isolation channels, but their service life is about 10% less than that of the above-mentioned universal cutters.

Caution! Do not confuse micro-cutters and universal cutters - both of them can only be recognize using a microscope.

A cutter has been specially designed for HF-technology. It produces a rectangular cross section.

fig. 14: Milling channel of LPKF universal, micro- and HF-cutters



For further notes see „Practical tips“ on page 38.

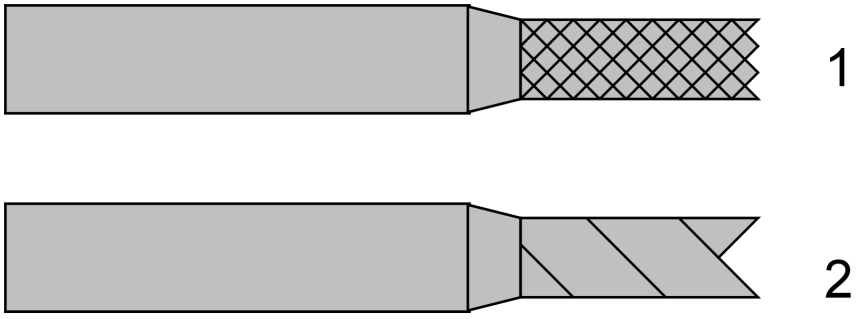
For the advantages and disadvantages of various materials, see the section „Materials used for machining“ on page 26.

After machining, the PCB has to be cleaned. This can be carried out either in a brush machine or alternatively manually with board cleaners (LPKF accessories). In either case, the PCB must be rinsed thoroughly with water to remove any copper dust produced by brushing.

After rinsing, the PCB must be dried thoroughly (air drier) and then protected against oxidation by a solder varnish.

7.6 Contour milling in PCB material

fig. 15: Contour cutter (top) and two-edged cutter (bottom)



The speed of movement has to be lowered for contour milling. This may differ from material to material. Only use special contour milling cutters (38 mm long): if possible 1 or 2 mm.

The 1 mm contour milling cutter should only be used for internal holes (smaller internal radius). It breaks relatively easily so set the feed speed to minimum.

The 2 mm contour milling cutter is substantially more robust, but does not remove as much material as the 3 mm milling cutter.

With contour milling using a 3 mm milling cutter, a large quantity of material is removed. Moreover, the high-speedcycle spindle can be overloaded if the speed of movement is too high.

For outline milling of soft HF-base material so-called double-edged cutters are being used instead of the outline cutters.

Caution! All speed ranges and feed rates given in BoardMaster refer to FR4 material. When other material is used, it is advised to work with reduced feed rates at first.

Danger! Take into consideration that cancerogenous dusts (due to glass fibers) might be produced when FR4 material is machined. Therefore always work with the dust exhaustor switched on. Always use the superfine filter.

Danger! When machining some materials (e.g. teflon) hazardous gases might be produced!

7.7 Milling wide isolation channels

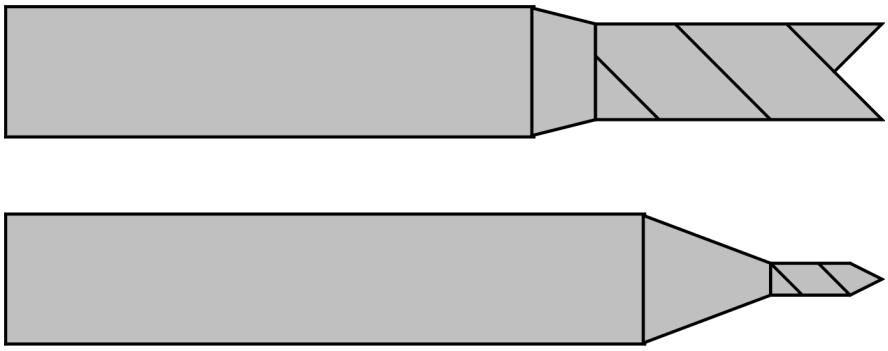
fig. 16: Double chamfered cutter

Wide isolation channels can be made with a 36 mm long double chamfered cutter. Various diameters are available.

The milling depth must be set such that when the copper is removed, only minimal burring results. The 3 mm double chamfered cutter is particularly well suited for milling very wide isolation channels (VDE regulations).

7.8 Front plate engraving

fig. 17: Universal cutter



For engraving, set the speed of movement as appropriate for the engraving depth and the material. Use an LPKF universal milling cutter or LPKF double chamfered cutter.

Danger! Use extractor when engraving, too!

The LPKF *ProtoMat* can be used for milling through 3 mm thick aluminium front panels.

7.9 Milling layout films

fig. 18: HF-Cutter

› Secure the film base (sheet of perspex or glass) on the machine table with masking tape.

› Lay the film material on the base with the coated (matte) side facing upwards.

› Now smooth the film material firmly and level on the film support until the air has been completely expelled.

› Now stick down the film on all four sides with transparent adhesive tape (which must not stretch) to form an air seal. There must not be any air bubbles between the film and the base.

The milling depth can now be set at the film edge. It can be checked by milling a frame around the film area (manual movement).

› The speed of movement should be reduced to about 15 mm/sec.

Note: The HF-cutter 0,25 mm is used for the milling of layout films.

› Switch on extractor, but only to half power, by extracting "secondary air" on the suction nozzle or, if there is one, reducing the power on the electronic extractor control.

The film milling program can now be started.

Film material comes in DIN A3 and A4 formats (special sizes available upon request).

Note: The film coating is easily scratched and is water soluble, so do not let it come into contact with water. The film can be recopied with a coloring device upon request. For further notes see chapter „Practical tips“ on page 38.

7.9.1 Correction agents

Gravure films can be corrected with Duroscal correction liquid red, which is easy to use. Paint in the problem areas with it, leave to dry for about 5 minutes and then further process the gravure film in the normal way.

The corrected areas can only have their coating removed with a quick acting coating remover.

Caution! Follow the safety instructions on the correction agent container!

7.9.2 Coloring milled films

For milled negative films, there is Duroscal color black, with which positives can be made. The fully milled gravure film is colored with Duroscal color by pouring the liquid onto a SAFIR pad and spreading it evenly over the whole film. Excess color must be wiped off with cellulose wadding. The stained film must be held against the light to check it and to find poorly covered areas so that they can be re-colored. Then immediately remove the coating. The color must not dry.

Caution! Follow the instructions on the color container! Important: the liquid must not get onto the back of the film as it cannot then be removed from it. The color is also difficult to remove from other surfaces (fabrics, skin) (wear apron and rubber gloves)!

7.9.3 Coating removal

Caution! Follow the safety instructions on the quick-acting coating remover container!

When removing coatings, only treat one film per container to prevent any damage of the second film by contact between the back of it and a surface wet with color.

There are two options when it comes to coating removal:

Quick coating removal

Pour the quick-acting coating remover onto the film and immediately wipe the dissolved protective coating with cellulose applying slight pressure. Then dry the film with cellulose wadding, blotting paper or a cloth.

Removal with water

For this method, the film must be placed in a bowl of hand-hot water (to which a small amount of washing-up liquid has been added). The protective layer dissolves after about 30 minutes. Any coating remains must be removed with a fine hand brush. This method is cheaper and more environmentally friendly. The film can be left in the water bath as long as you want.

7.10 Milling of solder mask foils

Settings

Tool:	Unimill 100 micro cutter
Tool diameter:	0,15 mm
Totational speed:	40.000 (20.000) min-1
Speed:	10 (5) mm/s

Values in brackets apply to circuit board plotters with DC-motors!

› Adjust the milling depth on the unused edge of the solder mask foil.

› To adjust the milling depth, cut a square of 2 x 2 mm with the engine switched on using the processing keys of *BoardMaster*.

› Switch on the exhaust unit.

› Start the milling with the data prepared by *CircuitCAM*.

› After the milling process, check if all pads have been cut out. If not, start the milling process again.

7.11 Drilling with the micrometer screw

The micrometer screw is used for the exact depth adjustment regardless of the material surface. It enables the processing of packed boards as well as mechanical parts. The lower oin of the micrometer screw serves as a stop and prevents the further lowering of the machine head.

7.12 Cleaning the PCB

Before components are mounted, the finished PCB must be thoroughly cleaned. This can be carried out manually or in PCB brushing machines.

If cleaning by hand, the PCB is placed on a flat support. The board is brushed in the direction of the conductor paths with wet board cleaner (e.g. LPKF board cleaner PAD). The purpose of the brushing is on the one hand to remove the layer of oxidation and on the other to remove swarf in the isolation channels. After brushing, the PCB must be free of any metal particles. From now on, the board should only be held by its edges and with gloves. The board should now be rinsed under running water and then dried with an air drier.

Caution! Never use compressed air as the oil particles it contains can cause problems later on.

After drying, both sides of the board are coated with solderable lacquer.

7.13 Practical tips

- Set the milling depth such that **engraving is too deep** rather than too shallow. Insufficient depth when engraving promotes milling tool wear.
- There can be a number of causes of **uneven milling width (depth)**.
    - It is important that the **machine bed is clean**.
    - **Residues of adhesive tape** or such like can adversely affect milling depth quite considerably.
    - Also, **milling swarf** between the machine bed, drilling support and PCB can reduce precision.
- Greatly **distorted materials** bend such that the sag shows underneath; in this case, secure the edges well with adhesive tape.
- Another important point for precise milling depth is the **removal** of milling and drilling chips.
- **Hooks** can occur **between the milling channels** if the incorrect milling direction sequence was specified followed, in particular with circles. If a circle is to be milled with a tool which rotates clockwise, **fine hooks** can arise between the copper areas if the milling tracks should overlap. The reason for this is that the cutting speed on the outer edges is reduced.
  The solution lies in selecting the right milling direction. When isolating conductor paths with LPKF isolate, the solder side should be mirrored before isolating as the isolation algorithm itself works in a clockwise direction. The standard postprocessing is already designed for this. *CircuitCAM* allows the user to select the direction of the milling tool and therefor mirroring prior to isolation is not necessary.
- **Milling burrs** can be caused by blunt tools or incorrect speeds of movement. If possible with the structure to be milled, deeper settings can be the answer. Otherwise, change the tool.
- **Burrs when contour milling** or **cut edges which are not clean** occur either due to a blunt tool or incorrect advance speed.
- With some materials, the **color of the milled channel** gives some indication of the state of the tool. With epoxy materials, dark isolation paths indicate a sharp tool, while lighter ones indicate a blunter tool.
- **Drilling burrs** occur either because the tool is blunt or the head lowering speed is excessive. In the first case, change the tool. In the second case, the tool height over the material must be reduced.
- **Drill deflection** occurs in particular with thin tools which are no longer absolutely sharp. However, this also depends on the surface structure of the material. If, for example the glass fiber structure of FR4 materials penetrates the copper, drill deflection cannot be avoided even with a sharp tool. For materials with additional, removable copper film (FR4 material with 18 µm or 9 µm Cu coating), drill deflection is very slight. With an additional processing step all drillings can first be marked. This also avoids the deviation of the drill.

- **Vitrification of the drilled hole** occurs where the drill stays in the hole too long once the hole has been made. These holes then cause problems at feedthrough stage. Reduce drilling times as appropriate.
- **Drills break** where the drilling base has already been used a number of times. The drilling base should be changed for every new PCB. It is not really possible to prevent breakage if a drill comes into contact with the edge of an existing hole in the base. Broken tools must be removed from the PCB and the drilling base. Drills can also break if the tool is too high above the material. By moving the adjustment valves of the pneumatic stroke the lowering speed can be adjusted. This prevents the breaking of drills and increases the edge life of all tools.
- In film milling, **milled channels are uneven** if there is still air under the film. If the **film** is secured with **elastic adhesive tape**, waves may form in the film after a while. It is particularly important here that the milling base should be level (LPKF film engraving base).
- **Burrs** are produced when milling films either because the tool is blunt or milling was too deep.
- **Misalignment of the solder and component sides** occurs where the HOME position is not accurately programmed.

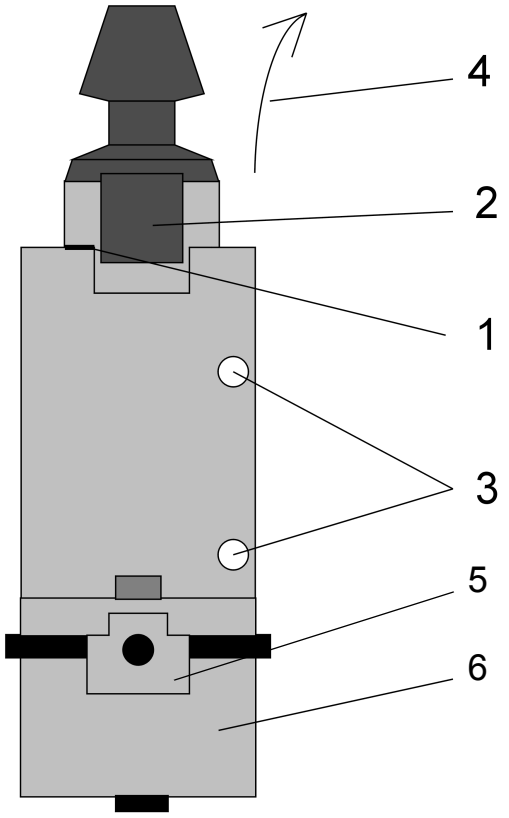
8.0 Appendix

8.1 Maintenance

- Keep spindles clean.
- In rooms with a high air humidity, wipe down with a lightly oiled cloth from time to time.
- Keep transport spindles oiled and clean.

Caution! Do not oil bearings!

fig. 19:



Strip and clean working depth limiters at regular intervals. To do this, first switch the device off, then proceed as follows:

› Mark the insertion depth of the spindle (1).

› Remove connector from the spindle (2).

› Release Allen screw with which the high-speedcycle spindle is clamped to the holding block (3).

› Spindle can now be pulled out towards the top (4). If necessary, turn it slightly to the left or to the right.

› Remove the holding block.

› The working depth limiter (6) can now be removed toward the side for cleaning .

› Clean both parts of the working depth limiter using the brush provided.

Caution! Only lightly lubricate the thread of the working depth limiter with graphite or Teflon!

› After cleaning the working depth limiter is refitted following the procedure in reverse. The spindle is inserted into the holding block. **Observe the insertion mark!**

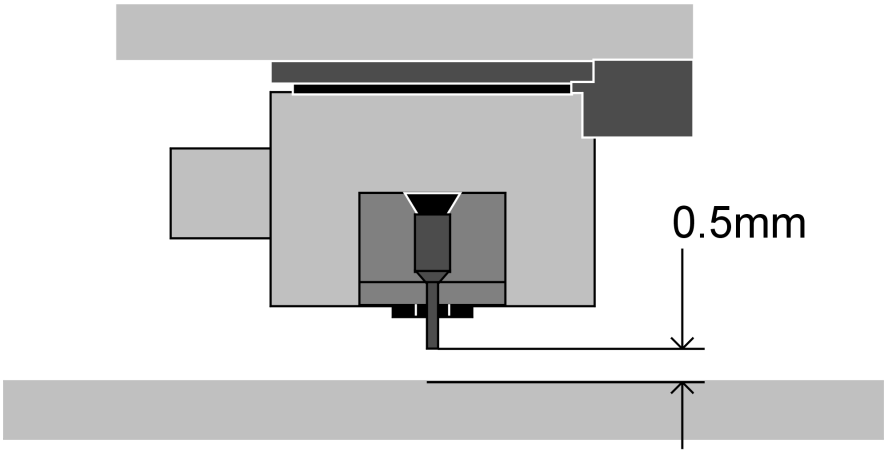
› Check the correct insertion depth of the spindle before setting it into operation. The distance between the drill tip and the machine plate must be 0.5 mm when the head is in its lower position.

Caution! The machine plate can be damaged during drilling when this distance is too small. At an insufficient distance the device can no longer drill through the workpiece.

› At last tighten the screws again (3) and put the connector again on the spindle.

Check the distance when mounting the high-speedcycle spindle

fig. 20:



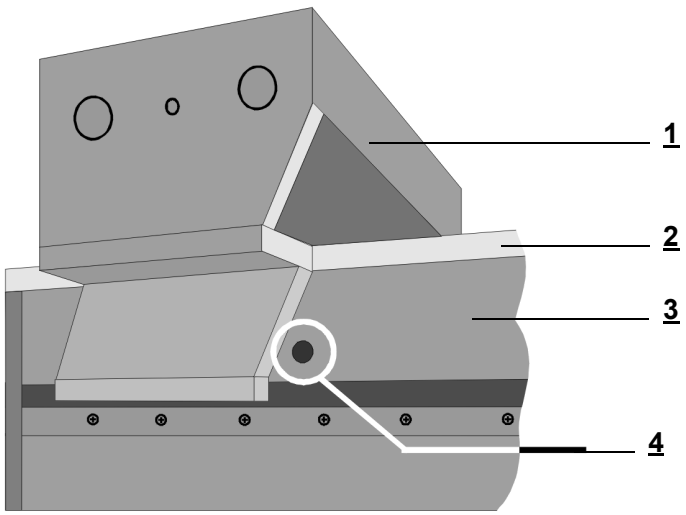
8.2 Lubricating the carriage guide wipers

You must make sure that the carriage guide wipers on the LPKF *ProtoMat* M60 are always well lubricated.

8.2.1 Carriage guide wipers of the X-axis

The wipers (4 in total) are located on both sides of the carriage both in front of and behind the guide cheeks. A hole has been drilled on the left and right of the guide rail cover to allow access these wipers.

fig. 21:



1- Tool carriage
2- Machine base plate
3- Cover for guide rails
4- Supply port

8.2.2 Oiling the rear wipers

› Move the carriage to the tool change position.

The supply ports are now behind the guide wall.

Use the syringe to inject oil through the port and into the hole on both sides of the wiper (0,5 ml).

8.2.3 Oiling the front wipers

› Move the carriage 112 mm to the rear (+X) of the tool change position.

The supply ports is now located in front of the guide wall and the wipers can be oiled using the syringe.

Caution! Wipe any excess oil from the casing as it might corrode the paintwork. Never move the carriage manually. Doing so could cause the output stages of the stepping motors to be damaged by induced voltage.

8.3 Serial port SERIAL 1

The serial data channel SERIAL 1 is an RS 232-C standard interface with photo diode decoupling and is used for communication between the control unit and a PC. The DCD signal input on the control means that the control unit can be STOPPED quickly when the signal level changes from low to high. In this way, it is possible to stop the machine directly from the PC by activating the DTR signal. The SERIAL 1 transmission speed is programmed with DIL switches 1 and 2.

Switch 1	Switch 2	Baud rate
OFF	OFF	4800 baud
ON	OFF	9600 baud
OFF	ON	19200 baud
ON	ON	-

SERIAL 1 settings:

Pin	Signal	Meaning
2	TXD	Transmit data
3	RXD	Receive data
4	RTS	Request to send
5	CTS	Clear to send

7	GND-I	Ground (isolated)
8	DCD	Data carrier detect
20	DTR	Data terminal ready

All signals are electrically galvanically decoupled; all contacts not mentioned are not used.

8.4 Serial port SERIAL 2

The serial data channel SERIAL 2 is an RS 232-C standard interface and can be used for communication between the control unit and another system. The transmission speed of SERIAL 2 is programmed with DIL switches 3 and 4.

Switch 3	Switch 4	Baud-rate
OFF	OFF	4600 baud
ON	OFF	9600 baud
OFF	ON	19200 baud
ON	ON	-

SERIAL 2 settings:

PIN	Signal	Meaning
3	TXD	Transmit data
2	RXD	Receive data
7	RTS	Request to send
8	CTS	Clear to send
5	GND	Ground

All contacts not mentioned are not used.

8.5 Motor connection

The stepping motors are connected per axis via a 15-pole SUB-D plug. If the limit switch is actuated, any further axis movement in the direction of the limit switch is immediately blocked. The position of the sockets is described in the section see „Displays and connections“ on page 15. Another 5-pole cable is used to supply the high-speedcycle spindle with power.

Caution! Never confuse the stepper motor and the mill/drill head cables!

8.6 Mill head connection

The mill/drill head is connected to the control unit with a 15-pole socket. The socket position is described in the section see „Displays and connections“ on page 15. Another five-pole cable supplies the high-speed cycle spindles.

Caution! Never confuse the stepper motor and the mill/drill head cables!

8.7 EPROMs

The software for the control unit is in 2 EPROMs. If the EPROMs need to be replaced (updates), the LPKF *ProtoMat* M60 has to be partially dismantled, so follow the procedure described in the section „Fuses, commuting the device voltage“ on page 45 and change the EPROMs, ensuring that the EPROMs are correctly aligned and positioned.

Use only an IC extractor to remove the EPROMs as otherwise the contacts of the mounting might be damaged. When inserting new EPROMs support the PCB from the bottom in order to avoid bending of the board. Take care that the orientation of the EPROMs is correct.

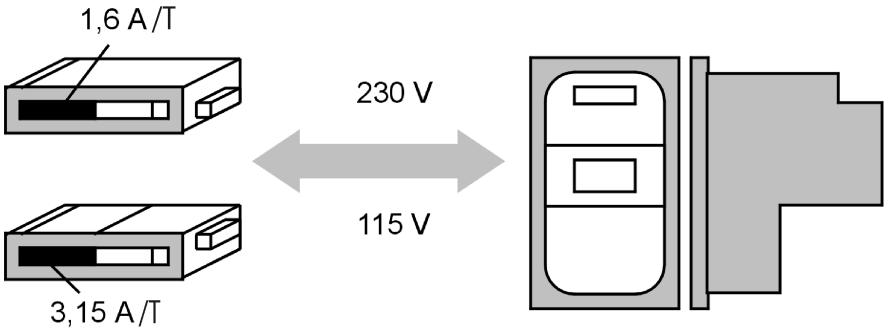
8.8 Fuses, commuting the device voltage

Danger! Before working on the fuses or opening the device, make sure that the power cord is removed!

In the LPKF *ProtoMat* M60, the primary and secondary voltages are fused. The main fuses (primary) are in the power connection of the control unit and are accessible from the outside.

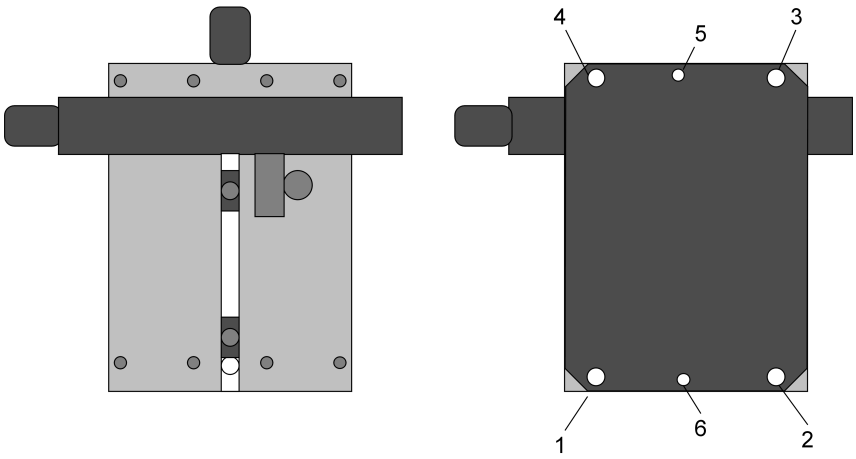
Caution! When switching to another line voltage make sure that both fuses are exchanged. Both fuses must be of the same value.

fig. 22: Voltage setting and fuses



The secondary fuses are inside the control unit. The control unit must first be removed from the mechanical part to replace the fuses. To do this, loosen screws 1, 2, 3 and 4 at the bottom of the device and then remove the cable connections between the mechanical part and the control unit.

fig. 23:Position of screws for removing the electronics from the mechanical part of an LPKF ProtoMat M60

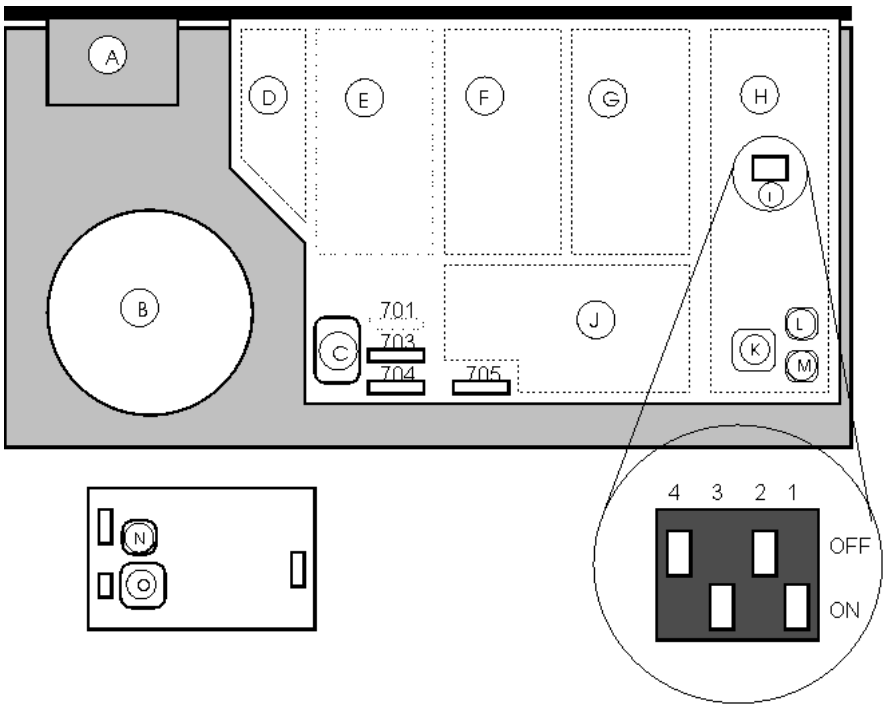


Caution! Be sure the power cable is removed!

› Remove the cover with the x limit switches.

The control unit thus released is constructed as Fig. 24 on page 47.

fig. 24: View of the PCB of the LPKF ProtoMat M60 PCB



A- Power filter
B- Transformer
C- Transformer connection
D- Power pack for mill/drill head
E- Power pack, Z axis (not used)
F- Power pack, Y axis
G- Power pack, X axis
H- Processor section
I- DIL switches for baud rate setting (with default setting)
J- Power packs
K- Processor
L- EPROM L
M- EPROM H
N- EPROM of the high-speedcycle spindle (PCB under cover)
O- Processor of the high-speedcycle spindles (PCB under cover)
701-705 = Various fuses (see below)

The secondary current circuits are protected with fine-wire fuses as follows:

Fuse	Type	Power circuit
F701	3,15 A	Power high level
F703	3,15 A	+24 V at I/O-Interface
F704	2,00 A	+5V and VREF
F705	0,50 A	RS 232 C / SER1

The units are mounted in the opposite sequence to that described above for dismantling.

Caution! Never confuse the stepper motor and the mill/drill head cables!

Before switching on, always check that the head and motor cables are in the correct place.

The fuses in the primary current circuit are in the power switch, which also contains the mains filter and the power selector (e.g. 230 V/115 V). The fuses should be medium semi-time lag:

- 230V fused with 1.6A/T
- 115V fused with 3.15A/T

8.9 The LPKF ProtoMat M60 Commands

8.9.1 Command structure

The SMCU (**S**ignal **P**rocessor **C**ontrol **U**nit) control unit of the machine interprets the HP-GL commands described below and converts them into set reactions.

The resolution of the machine is 0.0079375mm. This is a different resolution than that of standard HP-GL-plotters. Therefore the output is scaled down when original commands are used.

The syntax:

Symbol	Meaning
{...}	The contents can be repeated any number of times
()	The command parameters are between these brackets.
[]	The content of these brackets is optional and does not have to be included.

The SMCU expects a separator between the command parameters which is not any of the figures or upper case letterscapitals. A new command can follow a parameter without a separator. The last character in a command file which is sent must be a semicolon or a line feed symbol (0A hex.).

Unknown commands are ignored by the control unit, but their parameters can lead to unwanted plot absolute or plot relative commands.

8.9.2 HP-GL standard commands

AA (x,y,a{,?}){;}
Arc Absolute
Draws an arc around the absolute coordinate (x,y) starting from the current position with the arc angle a=[degree]. With a negative arc angle a, it is drawn clockwise, but otherwise counterclockwise.

AR(x,y,a{,?}){;}
Arc Relative
Draws an arc around the relative coordinate (x,y) starting from the current position with the arc angle a=[degree]. With a negative arc angle a, it is drawn clockwise, but otherwise counterclockwise.

CI (r{,?}){;}
Circle
Draws a complete circle around the current position with radius r. Resolution ß is ignored as the maximum resolution is always used when drawing.

EA (x,y){;}
Edge rectangle absolute
Draws a rectangle defined by two corner points lying diagonally to each other. The first corner point is determined by the current position and the second by the absolute coordinate (x,y).

ER (x,y){;}
Edge rectangle relative
Draws a rectangle defined by two corner points lying diagonally to each other. The first corner point is determined by the current position and the second by the relative coordinate (x,y).

IN {;}
Initialize
Changes the control unit to the same status as after switching on. This restores all default settings.

IW (x0,y0,x1,y1){;}
Input window
Restricts the working area on the XY axis to a window with the given corner coordinates.

OH {;}
Output hard clip limits
The control unit automatically determines its maximum travel range within the limit switches and send the coordinates determined in this way as an ASCII string in the form ("W
Xmin,Ymin,Zmin,Xmax,Ymax,Zmax<cr>") to the PC.

OS {;}
Output status
The control unit sends its status line as ASCII hex ("S xxxx <cr>") to the PC.

PA (x1,y1{,...xn,yn}){;}
Plot absolute
Draws a line from the current position to the absolute coordinates listed one after the other. The commands PU and PD can be given between the pairs of coordinates as parameters. If additional pairs of coordinates are sent, the command word PA is not necessary. All pairs of coordinates without a command word are taken to relate to the last PA or PR commands sent and are carried out accordingly.

PD {;}
Pen down
Lowers the tool.

PR (x1,y1{,...xn,yn}){;}
Plot relative
Draws a line from the current position to the relative coordinates listed one after the other. The commands PU and PD can be given between the pairs of coordinates as parameters. If additional pairs of coordinates are sent, the command word PA is not necessary. All pairs of coordinates without a command word are taken to relate to the last PA or PR commands sent and are carried out accordingly.

PU {;}
Pen up
Lifts the tool.

VS (v{,n}){;}
Velocity select
Defines the track speed in the XY level v=[µm/s] with the tool lowered and allocates this speed to the tool with number n.

8.9.3 Special commands

All special commands begin with the symbol "!" and their syntax is otherwise like that for HP-GL standard commands.

!AS (a){;}
Acceleration Set
Defines a new acceleration constant a=mm/s^2. The valid value range is 10...50000.

!CC {;}
Close channel
Ends a data transmission introduced with !OC.

!CM (n){;}
Change mode
Switches between the drill (n=0) and mill (n=1) working modes.

!CT (n){;}
Command counter
Switches between echo mode (n=1) and non-echo mode (n=0). In echo mode, the machine acknowledges every correctly completed command with the message "C<cr>".

!EM (n){;}
External motor
Switches the mill/drill motor on (n=1) or off (n=0).

!ES (n){;}
Enable stop
Release (n=1) and block (n=0) the external stop function. After switching on, the external stop function is blocked.

!FP {;}
Full power
Switches the motors of the XYZ axis to full power.

!HP {;}
Half power
Switches the motors of the XYZ axis to half power.

!OC {;}
Open channel
Opens a direct data transmission from serial data channel SER1 to serial data channel SER2. All characters received on data channel SER1 are sent to data channel SER2 until the character string !CC is received.

!ON (a){;}
Output nominal position
The control unit sends the nominal position (target position) of the motor axis addressed with parameter a. The following addresses are attributed to the motor axes:

- 0 = X,Y,Z axis
- 1 = X axis
- 2 = Y axis
- 3 = Z axis

!RD (a){;}
Read port
Effects the reading of the input port with the address a=<0..15>. The data is output via the serial interface from the which the command came, as an ASCII figure.

!RS (r){;}
Resolution set
Gives the control unit the step size (r=µm/step) of the machine. The valid value range is 1...32000.

!TA (x,y,z){;}
Plot three-D absolute
Carries out a physical movement from the current position to the absolute coordinate (x,y,z).

!TD (t1,t2,t3,t4){;}
Time for drilling
Sets new drill times t=[ms].

!TM (t1,t2,t3,t4){;}
Time for milling
Sets new mill times t=[ms].

!TR (x,y,z){;}
Plot three-D relative
Carries out a physical movement from the current position to the relative coordinate (x,y,z).

!TS (t){;}
Time to stabilize
Sets a stabilization time t=[ms] between the individual commands.

!TW (t){;}
Time to wait
The following command is only carried out after a wait t=[ms].

!VU (v){;}
Velocity if pen up
Defines the track speed v=[µm/s] of the movement in XY plane when the tool is raised.

!VZ (v){;}
Velocity Z axis
Defines the speed v=[µm/s] of the movement in the Z axis.

!WR (a,d{,m}){;}
Write port
Effects an output of the data word d on the port address a=<0..15>, whereby a bit mask can be given.

!ZA (z){;}
Plot Z axis absolute
Moves the Z axis from the current position to the absolute coordinate (z).

!ZR (z){;}
Plot Z axis relative
Moves the Z axis from the current position to the relative coordinate (z).

8.9.4 Special command for the high-speedcycle spindle

Before communicating with the high-speedcycle spindle, send the command for opening the SERIAL2 (!OC;), then the serial interface SERIAL2" must be closed again (!CC;)

!RM (r){;}
Revolutions Motor, r=0...60.
Sets the speed (r)*1000 of the high-speedcycle spindle.

8.9.5 Direct commands

Direct commands are special commands which, once they have been interpreted, are carried out via the command buffer.

!CB{;}
Clear buffer
Deletes all commands from the command buffer.

!GO{;}
Go on
Removes the stop command and continues the command implementation.

!RC{;}
Repeat command
Repeats the last command carried out.

!ST{;}
Stop
Interrupts command processing when the current command is completed.

The command set implemented is a subset of the HP-GL. If the equipment is to be driven by any CAD system, with HP-GL commands, it must be ensured that the step size is substantially lower than with normal pen plotters.

The step size is 7.9375 µm/step (0.0003125 inch/step).

8.10 Inventory of available tools

Tools shaded gray cannot be used for the LPKF *ProtoMat* M60.

Name	Diameter.	Length		Delivery
	in mm	36 mm	38 mm	L= in stock
Universal milling cutter	0.2 - 0.4	*		L
micro milling cutter	0.1 -0.2	*		L
HF-Cutter	0.25	*		L
Konturenfräser	1.0	*	*	L
	2.0	*	*	L
	3.0	*	*	L
Double chamfered cutters	0.8	*		L
	1.0	*	*	L
	2.0	*	*	L
	3.0	*		L
Drills	0.5		*	L
	0.55		*	
	0.6		*	L
	0.65		*	
	0.7	*	*	L
	0.75	*	*	
	0.8	*	*	L
	0.85	*	*	L
	0.9	*	*	L
	0.95	*	*	
	1.0	*	*	L
	1.05	*	*	L
	1.1	*	*	L
	1.15	*	*	
	1.2	*	*	L
	1.25	*	*	L
	1.3	*	*	L
	1.35	*	*	
	1.4	*	*	L
	1.45	*	*	
	1.5	*	*	L
	1.55	*	*	
	1.6	*	*	L
	1.65	*	*	
	1.7	*	*	L
	1.75	*	*	
	1.8	*	*	L
	1.85	*	*	
	1.9	*	*	L
	1.95	*	*	
	2.0	*	*	L
	2.05	*	*	
	2.1	*	*	L

	2.15	*	*	
	2.2	*	*	L
	2.25	*	*	
	2.3	*	*	L
	2.35	*	*	
	2.4	*	*	L
	2.45	*	*	L
	2.5	*	*	L
	2.55	*	*	
	2.6	*	*	L
	2.65	*	*	
	2.7	*	*	L
	2.75	*	*	
	2.8	*	*	L
	2.85	*	*	
	2.9	*	*	L
	2.95	*	*	
	3.0	*	*	L
	3.05	*	*	

8.11 Concluding remarks

As a rule the machine recommendations 93 / 44 of the European Community, dated June 14, 1993 applies to this manual. If an EC recommendation has not been taken into consideration in one of the chapters, these recommendations are hereby referred to and any claims concerning completeness and liability are excluded. Furthermore, we hereby point out to remaining risks unknown to the manufacturer which might occur due to inexpert handling of the machine. LPKF is not responsible for damage following the operation and handling of the LPKF *ProtoMat* M60. This also applies to the case of these damage having been referred to.

9.0 Declaration of conformity

1. Manufacturer of the machine designated LPKF *ProtoMat* M60 is company:

LPKF
Laser & Electronics AG
Osteriede 7
D-30827 Garbsen
Germany

2. The machine designated as LPKF *ProtoMat* M60 is a circuit board plotter, suitable for the production of circuit boards-prototypes and engraving films, as well as for the engraving of aluminum or plastics. The series number of the above-mentioned machine is 1P..... (see also bottom plate). Further details of the LPKF *ProtoMat* M60 can be seen in the enclosed manual.

3. The LPKF *ProtoMat* M60 corresponds to the provisions of the EC recommendation 93/44 dated June 14,1993 (see also Appendix I of the recommendation).

4. Existing DIN regulations have also been applied for the production of the LPKF *ProtoMat* M60.

5 Authorized signatory is

Mr. Bernd Hackmann
Technical Manager LPKF
Osteriede 7
D-30827 Garbsen/Germany

Bernd Hackmann

9.1 Konformitätserklärung

1. Hersteller der mit LPKF *ProtoMat M60* bezeichneten Maschine ist die Firma:

LPKF
Laser & Electronics AG
Osteriede 7

D-30827 Garbsen

2. Bei der mit LPKF *ProtoMat M60* bezeichneten Maschine handelt es sich um einen Fräsbohrplotter, der zum Erstellen von Leiterplattenprototypen und Gravurfilmen, sowie zum Gravieren von Aluminium oder Kunststoff geeignet ist. Die Seriennummer der vorstehenden Maschine ist 1P.....(siehe auch Bodenplatte). Weitere Angaben zur LPKF *ProtoMat M60* sind dem beiliegenden Handbuch zu entnehmen.

3. Die LPKF *ProtoMat M60* entspricht den Bestimmungen der EG-Maschinenrichtlinie 93 / 44 vom 14. Juni 93 (siehe auch Anhang I der Richtlinie).

4. Bei der Erstellung der LPKF *ProtoMat M60* fanden auch bestehende DIN- Vorschriften Anwendung.

5. Bevollmächtigter Unterzeichner dieser Erklärung ist

   Herr Bernd Hackmann
   Vorstand LPKF AG
   Osteriede 7

   D-30827 Garbsen

   Bernd Hackmann

10.0 Index

L

M

N

O

P

Q

S

T

V

W