INSTRUCTION MANUAL

PowerFlex MTS-3, MTS-3LP   Software Version 2.00
PowerFlex MTS-3SLP, MTS-3SDI   Software Version 2.12
Dual Stepper Motors Telescope Drives,   identical with SINUS II
STATUS: Full Production

For the SLP or SDI Versions, there is a supplement chapter at the end of this document, which replaces preceding information and describes their improved and new features.

1. Introduction

Thank you for your decision to purchase one of our telescope drives. An investment, you surely will not regret, because the PowerFlex MTS-3 is a universally usable telescope drive, which was specially developed for ambitious amateur astronomers. Even professional astronomers use the MTS-3 yet for a long time because of its versatility and functionality.

Through the new software-version 2.00, the MTS-3 gets for the old price even more performance and facilities. With the MTS-3 you can virtually track each mount with stepper motors, starting from a small traveller mount to heavy stationary mounts.

Through the in wide limits programmable parameters and the selectable standard settings, a quick adapting to the mounts of well known manufacturers and especially self-construction mounts is possible without problems. Besides this, the MTS-3 also offers a number of facilities, like PC-Interface, Display, DE-Backlash compensation, PEC (periodic worm-gear error compensation), that devices at comparable costs from other manufacturers do not have.

Despite of all facilities the MTS-3 is a device, which you can handle intuitively and with ease, by the beginning amateur astronomer as well as by the experienced user.

Fundamentally: You can use all the facilities of the MTS-3, but you need not. Die MTS-3 is delivered for instant operation, so that you can start using it at once. Therefore, read the chapter "First Operations".

If you want to make use of the extended functions of the MTS-3, you can read all details precisely in the according chapters.

With the new Version 2.00, some things have changed, however not fundamentally. Please read more about that in chapter 4.

The instruction manual should answer the major part of all questions, however not all details are described in each relevant chapter in repetition, in order not to increase the size of this instruction manual. Nevertheless, this instruction manual has become very long. Nevertheless, you should not get confused by this, because for normal use, you really need only a few things to keep in mind.

For unanswered questions, our Hotline (Tel. 0049 9261 53853) is available. You can also get more information from our website and you can contact us by e-mail.

Now we wish you much success with your new MTS-3 and we would be pleased about a positive feedback and recommendation to your friends of stars.

2. Table of Contents

3. First Operation

You get the following parts delivered with the MTS-3:
- MTS-3 telescope drive (electronics/ hand switch box)
- Connection cable, fitting for Vixen or AstroPhysics mounts, consisting of power supply cable 2-pins (banana plugs) and two stepper motor connectors 5-pins (DIN plugs) with a common 15-pin DSUB connector for the MTS-3 telescope drive.
At the 14-pin connector at the bottom side of the box you can also connect (if purchased):
- Liquid Crystal Display (LCD) with flat cable
- Cable for CCD-Autoguider
- RS-232-cable for connection a Personal Computer (PC)
For the concurrent connection of several devices, you need a distribution cable.
In addition, you need a power supply, usually an accumulator (e.g. car battery) or a mains power supply with low voltage DC output (adjust about 12 Volts).
After you have all assembled, you connect the power by connecting the both banana plugs (red=PLUS, black=MINUS) with the according poles of the power supply. For disconnecting, all you should accordingly choose the reverse order.
Some characters should be readable on the Display (if available). Then switch the ON/OFF-switch (right) to the up position (ON). Now you should notice a motor by its pulsating running noise. This is the RA motor. Mark this cable and use it in future for the RA motor. If the motor cables are switched, turn off the MTS-3 and plug in the right cables.
It is important, that you don't get out the motor plugs, while the motor is running; else, it may cause disturbances or damages.
Then check the rotation directions of the RA motor by switching the FAST/SLOW-switch (left) on the upper position (FAST) and press the right key. Now your mount should slew with fast speed to west. If it slews the wrong way, you must switch the Dipswitch #9 to the other position. After you have switched your MTS-3 OFF and ON again the RA motor rotates the right way.
If you use a vixen mount, you can now use the MTS-3 for tracking. However, the correct tracking speed for any other mount has to be programmed. How to do this, please read the chapter Programming / Mount Selection.
For the moment, we should also mention the Dipswitches #1-8. They determine how many steps the MTS-3 makes for compensating the backlash in the DE axis with high speed. Switch these DipSwitches to the lower position, if you don't want to use this function, else read the chapter Tracking / Backlash Compensation DE.
If anything is not working as expected, please read the according chapters carefully to find the reason for this.

4. New Features of Version 2.00

Central part of Version 2.00 is the support of the RS-232-Interface, which is of course included in all older MTS-3, but was not used up to now.

Now you can read out all data, display them on your PC-monitor, realize a remote control, control the stepper motors directly and slew to certain positions automatically, save the adjustments on the PC and re-configure the MTS-3 with pre-saved adjustments within just a few seconds.

The frequency range was enlarged from 1 Hz to 5000 Hz; at the same time the phase jitter was substantially reduced. Eight different acceleration values are now selectable.

In addition, a fine and course adjustment of the frequency values is possible.

An exact tracking frequency is adjustable by the Dipswitches without the help of the LC-Display.

The backlash compensation for DE now also operates in FAST mode.

The PEC can be enabled and disabled, is not lost any more after programming and considers only periodic errors.

For the PEC, you need to input now the Motor*Gearing*Ratio instead of the worm-wheels teeth number.

Seven pre-defined and one self-defined mount0 is now selectable.

On the LC-Display now more data are displayed, including step positions, stopwatch and programming helps.

An undervoltage warning warns you in time from a power fail caused by empty batteries.

Last but not least, we hope that also this instruction manual has become better.

In the Version 2.00, the following features are not any more included:

Step mode selection: adjusted is now half step for all modes.

Combinations Solar/Lunar/Record-Mode are not any more supported.

Saving of adjustments or the PEC table cannot any more be avoided by the FAST position or the left key.

Mount selection with Dipswitch #10 does not exist any more.

Else, the programming procedure with combination of keys has not changed substantially, besides new and removed key combinations.

5. HANDLING PRINCIPLES
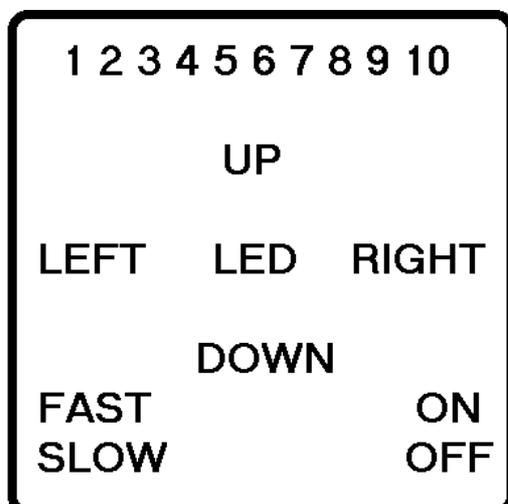
Keys and Switches

ON/OFF-switch:	Turn ON/OFF tracking. Activate programming modes, change/save data, if combination of keys is pressed when switching ON.
FAST/SLOW-switch:	In SLOW position, tracking is active, in FAST position the motor runs with fast speed if a key is pressed.
LEFT-key:	The RA-motor runs with reduced frequency according to the adjusted correction factor RA, or in FAST-position with fast speed backward.
RIGHT-key:	The RA-motor runs with increased frequency according to the adjusted correction factor RA, or in FAST-position with fast speed forward.
UP-key:	The DE motor runs slowly forward or in FAST position with fast speed forward.
DOWN-key:	The DE motor runs slowly backward or in FAST position with fast speed backward.

Dipswitches #1-10

The Dipswitches are used to input data for programming. If not specified differently for a specific programming, a number value is adjusted by the Dipswitches in binary format (as binary number, only zeroes and ones, like used in computers internally).

Each Dipswitch-# is assigned a binary digit. In upper position (ON), the binary digit is one, in lower position it is zero. The conversion to a decimal number is done by adding the values of each binary digit.

Dip-#	1	2	3	4	5	6	7	8	9	10
ON-value	1	2	4	8	16	32	64	128	256	512
OFF-value	0	0	0	0	0	0	0	0	0	0
Example:	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	ON
901	1		4					128	256	512

For the necessary binary adjustment of a decimal number, you must proceed with the reverse order: Split the decimal number according to the values of the Dipswitches.

In addition, the momentary adjusted value is displayed in decimal numbers on the Display.

For tracking, the Dipswitches have the following functions:

(More about it in the corresponding chapters)

Dipswitch 1-8:	Backlash compensation DE
Dipswitch 9:	Rotation direction RA
Dipswitch 10:	Rotation direction DE

How to use The MTS-3

For normal tracking, the keys have the function of manual speed control for RA and DE, as described above.

Besides this, they are also used to program the MTS-3. For each programming of a specific adjustment, there exists a corresponding programming mode with a defined combination of keys. For more frequently needed adjustments it consists of 1 or 2 keys, for rarely needed adjustments it consists of 3 or 4 keys.

To activate one of these programming modes, proceed like this:

1. Die MTS-3 is connected to the power supply and the ON/OFF-switch is in OFF-position.

2. You press this key combination and don't release it. Press the keys as accurate and vertically, so that you don't choose another programming mode by mistake. Now the programming mode is not activated yet, and if you have a LC-Display connected, the current adjustments are displayed.

3. Switch the ON/OFF-switch to ON-position.

4. Now, release the key combination. Now the programming mode is activated and you can make the adjustments. For each programming modes there are some particularities to consider, which are described precisely in the according chapter.

5. The programming mode can be terminated and changed adjustments are permanently saved, when you switch the ON/OFF-switch to OFF-position.

Generally the power supply may be disconnected only, if the ON/OFF-switch is in OFF position, else the MTS-3 has no chance to save the adjustments.

If this should happen nevertheless, the PEC becomes invalid and you should check the current adjustments on correctness.

LED Status Signal

The MTS-3 includes a 3-colour LED (green/yellow/red) for indicating the momentary operation mode of the PEC (->see PEC).

It is also useable to find the MTS-3 in the dark and to signal internal errors (->see undervoltage warning, memory error).

For the programming of the correction factor, the LED helps by red/green colour changes to distinguish the 17 possible values.

Memory Test

If the LED is blinking quickly after connecting the power supply, there exists a ROM memory error. The MTS-3 stops the program execution and doesn't proceed with any further functions. Distinguish this condition from an undervoltage warning!

Under some circumstances the MTS-3 can be used further (for the moment), if the error is located at a ROM memory address, which is uncritical not relevant for tracking. Press the DOWN-key to proceed.

Stop using the MTS-3, if it behaves in an uncontrollable manner.

Please contact us in the case of a memory error.

Undervoltage Warning

 (Only valid for any MTS-3 since 14.Jul.97)

If the LED starts blinking during operation, the supply voltage has decreased below a critical value of 10 ±0.5 volts. The MTS-3 proceeds operating without interruption for the moment:

The stepper motors can operate above a voltage of about 7.5 volts and the microcontroller works correctly above a voltage of about 5.5 Volt.

Now we advice to check your power supply urgently, and if you use a lead accumulator, you should recharge it as soon as possible to avoid a deep discharge, which would damage the lead accumulator.

Don't rely on the undervoltage warning as a check for your lead accumulator alone.

We advise you to check it frequently with a voltmeter and to recharge it in time.

Temporary Baud Rates, Display-Redirection

If you don't know the adjusted baud rate and can't read it from the LC-Display, so there exists the chance to select it from two temporary baud rates and to activate the display redirection, independent from the adjustments. This selection is only valid as long as the MTS-3 is supplied with power.

The following is selected, if the following keys are pressed when power is connected (baud rate and display redirection may be combined):

LEFT:	RIGHT:	UP:
9600 Baud	57600 Baud	Display redirection ON

Handling

Thanks of the compact size (100*50*25mm), the low weight and the favourable arrangement of switches and keys, you can handle the MTS-3 even in the dark with ease. If it is very cold, you can put it in your jacket pocket while tracking. Hang the MTS-3 with the cord at a convenient place at your mount, so that it can't fall down. This avoids it getting dirty and a possible damage of the sensible oscillating quartz by the shock of the impact, after which the MTS-3 might not function any more. Additionally it is advisable – if you don't use it – to cover the connector at the bottom of the box with a strip of tape. Please handle your MTS-3 with the necessary care in order for a long using duration. Also, avoid influence of humidity (apart from normal dew) and excessive heat. To protect the contact pins from premature wear and tear it is advisable to keep the cable at the MTS-3 if possible.

Abbreviations, Definition of Terms

RA	Right Ascension, Right Ascension axis, hour axis
DE	Declination, declination axis
PEC	Periodical Error Correction, correction of the periodic error of the worm gear of the RA axis
Backlash	Dead travel in gearings
Frequency	Impulses per second, here: half steps per second or simply speed of the stepper motor
LOW-active	Connecting of a pin with ground means function is active
LED	Light Emitting Diode
Step sequence	Minimal number or series of the different states of current through the windings of a stepper motor for a certain step mode (half step: 8, full step: 4). Must be repeated in cycle for a rotation movement.
Coil/winding	Windings of isolated cooper wire for electric magnets. Here: to generate a rotating magnetic field in the stepper motor
Phase	Winding connections of the coil or coil itself or in other sense: phase within the step sequence
Step number	Number of full steps for a 360°-rotation of the stepper motor's shaft
Step angle	360° divided by step number
Tracking frequency	= Total gear ratio / 86164s Example: worm-wheel=144, gearing=120, motor=96 (half step) 144 * 120 * 96 / 86164s = 19.25259 Hz

6. Tracking

To start tracking mode, simply switch the ON/OFF-switch to ON (up) position. While you do this you may not press a key concurrently, else you would activate a programming mode.

Fine Corrections, SLOW Mode
If you observe with your telescope at high magnification or make exposures at long focal length, even with a heavy and precise mount and exact polar alignment you can't avoid to have to do small corrections of the tracking speed.

For this purpose, switch the FAST/SLOW-switch to SLOW (down) und press the LEFT- or RIGHT-key for a correction of RA and the UP- or DOWN-key the same way for DE.
Especially for astrophotography you should keep in mind the correction direction of each key before you start the exposure time, so that you don't press later the wrong key by mistake. Also, adjust the backlash compensation for DE correctly.

FAST Mode
Switch the FAST/SLOW-switch on FAST (up). As long as you don't press a key, the MTS-3 tracks with normal speed. If you press a key, your telescope slews with higher speed to the corresponding direction.

Rotation Directions of the Stepper Motors
Independent from all other adjustments the rotation directions are only determined by the Dipswitches: RA (Dip-#9), DE (Dip-#10), else you control the MTS-3 per RS-232 with the special speed commands.
They must be set properly before you start tracking. During tracking it is not possibly to change the rotation directions. You would have to switch OFF the MTS-3 in between for a short moment.

Lunar Tracking
Press the DOWN-key while you switch ON the MTS-3. When you take the DOWN key, tracking proceeds with lunar speed, which is calculated from the adjusted normal speed.

Solar Tracking
Press the UP-key while you switch ON the MTS-3. When you release the UP-key, tracking proceeds with lunar speed, which is calculated from the adjusted normal speed.

Backlash Compensation DE
If you want to track precisely, you sometimes will also have to make corrections in DE. If this takes place alternately in the one and after that in the other direction, so, the dead travel of the gearing and worm wheel in DE of most mounts will attract attention awkwardly. Often it will take several seconds up to a half minute until the dead travel is run through after a direction change, and you notice a correction. To avoid this, your MTS-3 can run trough this dead travel for a short time with high speed.
To adjust the dead travel the Dipswitches #1-8 are used. It can be adjusted to a maximum of 1020 half steps in 4-step increments.

The size of the dead travel has to be found out for each mount experimentally.

First set only #8 to ON (#1-7 OFF). Press alternately the UP- and the DOWN-key. If the object moves in the eyepiece, the dead travel is already adjusted too large. Set the Dipswitch to OFF and the next lower to ON.

Repeat this procedure, until you don't recognize a movement any more.

To refine the adjustment increasingly, set additionally the next lower Dipswitch to ON and repeat with this scheme, until the remaining dead travel is reduced to an acceptable size.

Don't try to eliminate the dead travel too precisely, because a small remaining dead travel does not harm, however with overcompensation you will obtain negative results.

It also may be, that depending of the position of the mount and the DE worm, the dead travel may vary a little. Before you make an astrophotography make sure, that no overcompensation exists.

PEC (Periodical ERROR Compensation) RA

With many mounts, the worm-wheel drive of the RA axis produces a more or less large periodical error, resulting from mechanical inaccuracies of the worm. The period corresponds exactly to the time for a complete rotation of the worm, while the motor runs with correct tracking speed.

Indeed there are also other error sources, but their elimination is partially difficult, impossible or not efficient, and thus not part of the MTS-3 functions.

If you own a mount with a really imprecise RA worm, we may suppose, that at least this error can be reduced substantially through the PEC function

The PEC is a quite complex and calculation intensive function (at least for the microcontroller) and needs some of your attention, if it shall work correctly. False handling or conditions will cause errors.

So, only use the PEC, if:

-You are familiar with the PEC function.

-The RA worm has an evident periodical error.

-The tracking frequency is correct.

-The motor*gearing-ratio is correctly programmed.

If all these conditions are fulfilled, you can record the PEC table. Proceed as follows:

1. Align your telescope to a star, and centre it in the cross wires eyepiece. Use for this the normal tracking mode.

2. The SLOW/FAST-switch must be at SLOW-position.

3. Switch the ON/OFF-switch to OFF-position.

4. Press the LEFT-key und switch concurrently the ON/OFF-switch to ON-position. Then release the LEFT-key.

5. Now you have 10 seconds, before the PEC record mode will start. Meanwhile you should have the star again on the cross wires. Now try to track the RA axis as well as possible, as long as the LED is alternately yellow or dark.

A restart of the recording can be done by quickly switching to FAST and back to SLOW as long as the procedure is finished and the LED lights red. For now on the PEC is active, and corrects the tracking frequency independently in short periodical intervals without your help.

If the PEC is active, you can handle the MTS-3 as usual.
The PEC becomes invalid, if one of the following conditions occurs:
-You start the PEC-record mode, and break it before it is finished.
-The power supply has failed, while the MTS-3 was ON.
-The RA worm was driven manually or not locked with the gearing shaft.
-The motor*gearing-ratio was changed.
-The position of the RA motor does not correspond to the step impulses from the MTS-3. This case occurs e.g. at overload, blocking, motor not/false connected, stand still at a too high FAST frequency. If this should be the case, deactivate the PEC, if it is not already deactivated, or record a new PEC table.

The momentary status of the PEC is indicated by the LED:

Green	PEC-table is not recorded or invalid	Invalid
Yellow	PEC-table is valid but disabled	Disabled
Red	PEC-table is valid and enabled	Enabled
Alternately yellow/dark	PEC-recording is in progress now. Light change signals that a table position xx of 32 total was just saved.	PECxx

You can deactivate or activate the PEC (if valid), if you start the PEC record mode and terminate it within 10 seconds. The PEC table itself is not changed in this case.

Stop Watch
If you have a LC-Display connected, you can measure the exposure time of an astrophotography. To stop the stopwatch, you must switch to FAST. Switching to SLOW resets the second counter to zero and starts the stopwatch again.

7. Programming

Mount Selection
For some frequent mounts you can initialise all mount specific adjustments at once from a table.
Compare the RA frequency and motor*gearing-ratio with the data of your mount.
Hold the key combination UP-DOWN-RIGHT pressed and switch to ON. Now release the keys. Select the Dipswitches (#1,2,3) according to your mount, and switch to OFF. Now the adjustments are programmed.

Non-Mentioned Mounts
If your mount is not included in the table, you can still use the other modes of programming, as direct frequency adjustment, learning mode and motor*gearing-ratio.

Mount	Dip-ON	RA-M*G	RA-SLOW	RA-FAST	DE-SLOW	DE-FAST
Vixen1	---	96*120	19.252588	308.0414	19.252588	308.0414
Vixen2	1--	96*300	48.131470	385.0518	48.131470	385.0518
AstroPhysics	-2-	96*150	32.087647	513.4023	32.087647	513.4023
Losmandy	12-	96*150	60.164338	481.3147	60.164338	481.3147
Astrotec1	--3	400*100	46.423100	742.7696	46.423100	742.7696
Astrotec2	1-3	400*100	92.846200	1485.539	92.846200	1485.539
Takahashi	-23	96*375	100.27389	802.1911	100.27389	802.1911
User-defined	123					

User-Defined Adjustments

You can save lastingly all current mount specific adjustments. They can't be changed by mistake, not even through a RESET of all adjustments.

To do that, press the key combination UP-DOWN-LEFT when switching ON.

To recall these adjustments, set Dipswitches #1,2,3 to ON and proceed the same like in Mount selection.

Standard Adjustments (RESET)

Die MTS-3 is already delivered with the following adjustments:

Mount:	Vixen1
Correction factor:	1.5
Acceleration:	0
PEC:	Invalid (disabled)
Baud rate:	9600
Display redirection:	OFF

If you should have deadjusted your MTS-3 in such a way, that something doesn't function any more as expected, you can recall these standard adjustments through the key combination UP-DOWN-LEFT-RIGHT when switching ON.

Motor*Gearing-Ratio (RA-M*G)

For the correct function of the PEC, the MTS-3 has to know, how many half steps are necessary for a complete rotation of the RA worm.

This corresponds to the half steps of the stepper motor per rotation of the motor shaft multiplied with the gearing ratio. If you want to use the PEC, you have to program these 2 numbers with the help of the Dipswitches (-> see chapter Dip-switches), if you have not selected a standard mount.

Proceed as follows:

1. Get these 2 numbers (mount handbook).

2. These numbers may not be identical (why is explained below). If they are identical however, take the half of the one and the double of the other, important is only that both numbers multiplied result the same. Convert both (decimal) numbers to binary numbers.

3. Adjust the one binary number at the Dipswitches #1-10.

4. Press the key combination UP-LEFT-RIGHT when switching ON.

5. Adjust the other binary number at the Dipswitches #1-10.

6. Switch the MTS-3 to OFF. After this the programming is finished.

If you have a LC-Display connected, you can observe the programming; respectively you can verify the current adjustments. Also displayed is further the worm gear-ratio, which would be derived from the current tracking frequency and the motor*gearing-ratio. If this value deviates from the actual one, either the motor*gearing-ratio is some wrong or the tracking frequency (or both).

If now the motor*gearing-ratio is correctly programmed, you have the possibility to program the exact tracking frequency by further inputting the ratio of the worm gear (number of teeth of the worm wheel, if one-gear worm).

This is especially useful, if you have no LC-Display and want to program quickly an exact tracking frequency.

Proceed as follows:

1. Convert this (decimal) number to a binary number.
3. Adjust this binary number at the Dipswitches #1-10.
4. Press the key combination UP-LEFT-RIGHT while switching ON.
   Don't change the Dipswitches now any more!
5. Switch the MTS-3 to OFF. After this the programming is finished.

Direct Frequency Adjustment

With this, you can program the SLOW frequency as well as the FAST frequency for both axes variably and verify them directly too.

If a Display is connected, also the current frequency value is displayed. You have the choice to adjust the frequencies in fine or course steps.

With one key the frequency is decreased, with the opposite key it is increased. If you hold one key pressed for a longer period, the frequency is increased/decreased increasingly quickly.

	Relative change/key hit	SLOW/FAST-switch when switching ON
Fine:	1/100000	SLOW
Coarse:	1/1000	FAST

Key pressed when switching OFF:	Does not save values, keep old values
No key pressed when switching OFF:	Save values, overwrite old values

If you have then activated one of the both programming modes, it depends from the SLOW/FAST-switch, if the SLOW- or the FAST-frequency can be changed by pressing a key. You can switch SLOW and FAST as you like and change both frequencies. First, adjust the coarse frequencies and then the fine frequencies.

Don't worry that the LC-Display shows a higher precision than you can adjust. 1/100000-Accuracy is more than necessary. The frequency range is for SLOW from 1 Hz to 1000 Hz, for FAST from 15 Hz to 5000 Hz.

Don't be surprised, if your stepper motor stands still at a certain frequency or has no power any more respectively. So, adjust the FAST-frequency only as high that it runs reliably.

Also, consider the influence of the acceleration adjustment.

RA-Frequencies

Hold the key combination LEFT-RIGHT pressed when switching ON. Now you can change the RA frequencies, increase them with UP and decrease them with DOWN.
The DE motor remains switched OFF and does not react on UP and DOWN.
The RA motor behaves like when tracking and reacts completely normal on LEFT and RIGHT. In order to check the FAST frequency you can press the LEFT or the RIGHT key.
If you have then programmed the frequencies to the desired values, you can switch OFF the MTS-3. Then both frequencies are saved, if you don't press a key.

DE-Frequencies

Hold the key combination UP-DOWN pressed when switching ON. Now you can change the DE frequencies, increase them with RIGHT and decrease them with LEFT.
The RA motor runs with normal tracking speed, however it does not react on LEFT and RIGHT.
The DE motor behaves like when tracking and reacts completely normal on UP and DOWN. In order to check the FAST frequency you can press the UP or the DOWN key.
If you have then programmed the frequencies to the desired values, you can switch OFF the MTS-3. Then both frequencies are saved, if you don't press a key.

Learning Mode RA

With this, you have the possibility to adjust the RA frequency more and more precisely while tracking. Especially for this mode the correction factor is set to 2.0 (maximum value), independent from its adjustment. The DE motor behaves like when tracking. The PEC is not considered.
It may be advisable to have the RA tracking frequency at least coarsely adjusted before with the direct frequency adjustment. However, you can't improve an already exactly adjusted frequency through the learning mode. However, it may make sense to use the learning mode for tracking the moon or comets for example.

To use the learning mode optimally, proceed as follows:
1. Look for a star (as high as possible and near the equator) and try to centre it in the cross wires eyepiece.
2. Then activate the learning mode by pressing the key combination UP-RIGHT when switching ON.
3. Let the tracking run for some seconds and try to get the star into the centre of the cross wires with help of the keys.
4. When the star is exactly on the centre of the cross wires, switch to FAST and to SLOW for a short moment. Herewith the learning process is started. You can repeat this as often as necessary.
5. Let now SLOW adjusted and try to hold the star in the centre of the cross wires. If this is not possible, the frequency at the beginning was too low. Start in this case the learning mode for another time and press the RIGHT key to increase the frequency and proceed with point 4.

6. The longer you are tracking, the more exactly the tracking frequency is getting. Recommendable would be the duration of one worm rotation (to exclude a periodical error) or a multiple of it. When the tracking speed seems to be good enough, you can save the learnt tracking frequency by switching OFF, when the star is in the centre of the cross wires.

Correction Factor RA

The correction factor RA defines, how much the tracking frequency increases in SLOW mode when pressing the RIGHT-key, respectively decreases when pressing the LEFT-key (2.0 minus correction factor RA). There are 16 different adjustments form 1.0625 to 2.0000 possible. You can change the pre-adjusted value of 1.5000 by holding the RIGHT-key pressed when switching ON. When pressing the up KEY the value increases, when pressing the DOWN key it decreases. The possible values can be distinguished from each other through the colour change of the LED.

At the same time, you can check the adjustment with the LEFT- and the RIGHT-key, or you can read it directly if a LC-Display is connected.

The correction factor RA is saved when switching OFF.

Acceleration

To get the stepper motors in FAST mode or for automatic GOTO without loss of steps or even stand still to a high speed, the MTS-3 uses a ramp control. In doing so, the motors are accelerated and decelerated gradually.

You can program the value of the acceleration in 8 selectable steps. Therefore, adjust the binary values 0 (small) to 7 (large) at the Dipswitches #1-3 (the others are ignored).

This value is programmed by pressing the key combination DOWN-RIGHT when you switch ON, then release the keys and switch OFF.

In any case, you should check if the stepper motors can manage the acceleration.

8. Display (LC-Display)

As accessories, you also can connect a digital display to the MTS-3. It is an alphanumeric liquid crystal display (LCD) with two lines, each 16 characters.

It is foreseen to program the MTS-3 easier, faster and safer and to show you all current adjustments.

Fundamentally, the MTS-3 is also programmable without a LC-Display.

Beyond that, the LC-Display shows the following in tracking mode:

-Size of adjusted backlash compensation DE

-Step position RA

-Step position DE

-State of the PEC in record mode

-Seconds of the stopwatch

The LC-Display is contained in a separate (MTS-3 like) box and is connected through a flat cable at the pinhead connector of the MTS-3. The LC-Display must be connected to the MTS-3 before connecting the power supply.

9. Function, Schematic Diagram
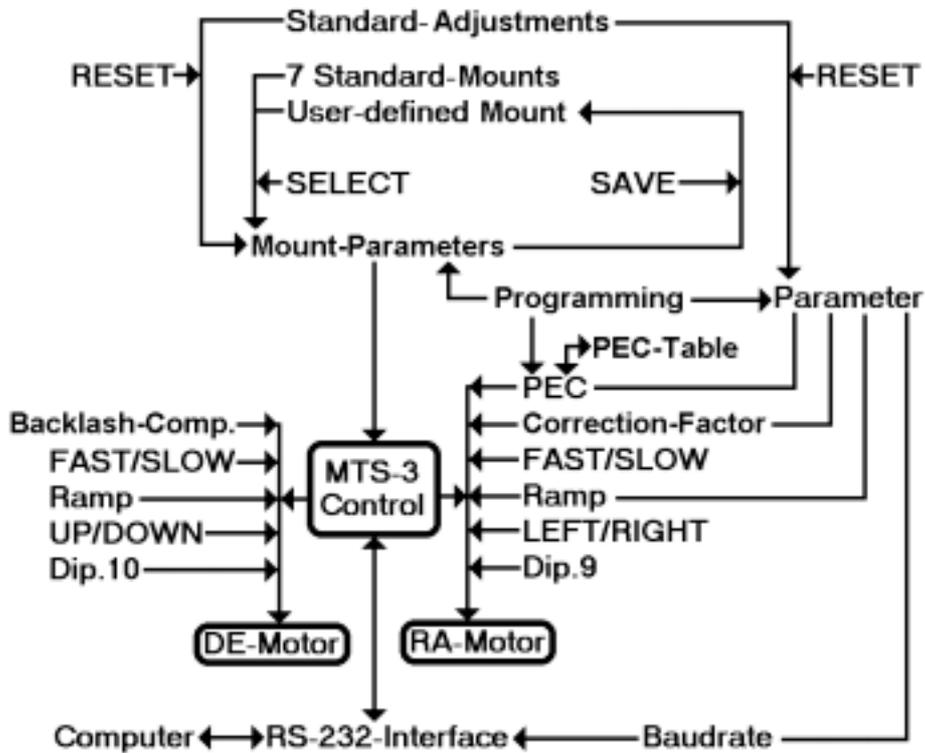
10. RS-232-Interface

With Version 2.00, the MTS-3 supports for the first time the serial connection to a personal computers (PC) through the RS-232-interface.
Herewith many interesting facilities present, which were not possible with versions before.
By the way, also all older MTS-3 can use the RS-232 with a Version 2.00 upgrade.

Application Facilities

1. For the simplest way, you can emulate the LC-Display with your PC on the monitor. The therefore necessary small QBasic-terminal program is included as listing in the manual. You are all shown that would be shown on the LC-Display too. Thus you can program the MTS-3 as easily as with the separate LC-Display.
2. You can control the MTS-3 completely through your PC, set and reset all keys, switches and Dipswitches with commands. With this, you can remote control the MTS-3.

3. All key and switch positions, system time and step positions for RA and DE can be read out as desired and be shown, computed or saved on the PC.

4. You can read out the parameter memory of the MTS-3 as well in single portions as completely and rewrite it to the MTS-3. With this you have the ability to save the adjustments of the MTS-3 and reconfigure the MTS-3 completely in a few seconds, e.g. for different mounts. With the parameter memory, you have also access to the PEC data for special evaluations.

5. The included commands for fast GOTO (5000Hz) set FAST and SLOW-speed, allow you to realize a telescope drive on your PC to your ideas. There are hardly set limits for the facilities.

Beginning from small function extensions up to a comfortable automatic object GOTO or a complete full automatic observation program, much is possible.

6. You can use the abilities #1 to# 5 or all together at the same time.

7. You also may alienate the MTS-3 for other non-astronomical purposes.

Baud Rates and Display-Redirection

For the communication with the PC, there is a selection of different baud rates available. The baud rate of the PC and the MTS-3 must be identical. Use high baud rates if you have to transmit quickly a lot of data a low baud rates if you want to have a maximum of reliability and/or the serial cable is very long.

Furthermore, you can adjust the Display redirection to the RS-232, so that it is active at once without any additional command. This might make sense for example, if you want to connect a special LC-Display to the RS-232.

To program the baud rates and the Display redirection hold the key combination LEFT-RIGHT-DOWN pressed while switching ON. The Dipswitches #1-3 determine the baud rate; Dipswitch #4 determines the Display redirection and all others are ignored.

Baud rate	9600	19200	28800	38400	0(OFF)	2400	4800	57600
Dip ON	---	1--	-2-	12-	--3	1-3	-23	123

Dip 4 OFF:	Display-redirection OFF
Dip 4 ON:	Display-redirection ON

The other parameters are: 8 data bits, 1 stop bit, no parity and no handshaking.

When you have adjusted the Dipswitches accordingly, switch the MTS-3 OFF for saving. The new adjustments are used by the MTS-3 not before power is connected the next time. Up to then the old adjustments are used.

Communication Protocol, Data / Command Formats

For an error-free communication between the MTS-3 and PC, a special protocol is defined, which allows to send data and commands to the MTS-3 and to receive data from the MTS-3.

As commands, one-byte binary codes are defined for a specific function. After reception of this binary code, the MTS-3 executes the according command.

Some commands need for their execution additional data. These data must be loaded into the 4-byte containing data buffer of the MTS-3 before sending a command. Fundamentally, these data consist command depending always of a 4-byte binary integer number (long) or a 4-byte binary floating-point number (IEEE single precision float).

In order that the MTS-3 can distinguish data from commands, there are two special commands, which encode each a half byte (nibble) in their command code, which they load then into the data buffer.

To load the data buffer with 4 bytes of data, always 8 bytes have to be transmitted to the MTS-3.

The transmission starts always with the highest value half byte and finishes with the lowest value half byte. How this looks like in detail, you can look up in the commands descriptions and the QBASIC-routines.

Some commands return data to the PC, that are command depending always one byte or 4 complete bytes (long). These data are transmitted in their binary format. In the case of 4 bytes, the highest value byte is coming first and the lowest value byte is coming last.

Command Groups

The command set is divided up in several groups of commands:

-Control commands:	Display, keys ON/OFF, reset
-Read commands:	Position, data buffer, time, keys, (Dip)-switches, ready
-Motor commands:	GOTO, speed, start, stop, OFF
-Memory commands:	Parameter memory read/write

For every command group there are some particularities to consider:

-Some commands need data. These data must be loaded into the data buffer before execution.

-Some commands transmit data. A following command may only be transmitted after reception of all data. Besides this, the Display redirection must be OFF.

-Some commands need a longer time to execute. During this execution, no other command may be transmitted with longer execution time. Use the ready command!

-Some commands are not possible in all operating modes.

-The memory commands need for security reasons an unlocking through a key-code.

The command particularities are noted in the individual descriptions.

Command List / Command Description

Abbreviation	Meaning
RD1	Returns 1 byte
RDL4	Returns 4 Bytes as long
WRL4	Needs 4 bytes as long
WRF4	Needs 4 bytes as float
BUSY	Longer execution time
TR	Only in tracking mode
OFF	Only when ON/OFF-switch is OFF
X,x	Undefined
-	No limitation

Command name	Hex-Code	Function	Particularities
loadhighnibble	8XH	Load upper half byte X into data buffer	-
loadlownibble	9XH	Load lower half byte X into data buffer, sets pointer to next byte	-
displayon	A0H	Display-redirection ON	-
displayoff	A1H	Display-redirection OFF	-
ready	A2H	Returns 0, if last command has finished, else returns last command code	RD1
Reset buffer	A3H	Sets pointer to first byte of data buffer. Allows unlocking of readEEprom/writeEEprom, if a certain key-code is in the data buffer	(WRL4)
upon	A4H	Set UP-key	-
upoff	A5H	Release UP-key	-
downon	A6H	Set DOWN-key	-
downoff	A7H	Release DOWN-key	-
lefton	A8H	Set LEFT-key	-
leftoff	A9H	Release LEFT-key	-
righton	AAH	Set RIGHT-key	-
rightoff	ABH	Release RIGHT-key	-
modeon	ACH	Reserved, do not use!	-
modeoff	ADH	Reserved, do not use!	-
onon	AEH	Switch ON	-
onoff	AFH	Switch OFF	-
faston	B0H	Switch FAST	-
fastoff	B1H	Switch SLOW	-
notracking	B2H	In tracking mode the motors are OFF at the beginning	OFF
readswitch	B3H	Returns all switches/keys in 1 byte encoded: X,X,ON,FAST,UP,DOWN,LEFT,RIGHT set bit=key/switch pressed/ON	RD1
readswitchtime	B4H	Returns 1st byte like readswitch + 3 bytes system time in 1/100 seconds since power on	RDL4
readtime	B5H	Returns1st Byte=0 + 3 bytes system time in 1/100 seconds since power on	RDL4
readbuffer	B6H	Returns current data buffer	RDL4
readRA	B7H	Returns RA-position	RDL4
readDE	B8H	Returns DE-position	RDL4
readdip	B9H	Returns current Dip-switch setting [0,1023]	RDL4
writedip	BAH	Replaces Dip-switch setting with data buffer [0,1023], until readdip is transmitted again	WRL4
writeaccel	BBH	Set acceleration to data buffer [0,7], may not be set while motors are running FAST	WRL4
writeRApos	BCH	Starts GOTO RA with target position in data buffer or set a new target position	WRL4, BUSY,TR

writeDEpos	BDH	Starts GOTO DE with target position in data buffer or set a new target position	WRL4, BUSY,TR
writeRAlimit	BEH	Set FAST-frequency RA with data buffer [15.0,5000.0]	WRF4, BUSY,TR
writeDElimit	BFH	Set FAST-frequency DE with data buffer [15.0,5000.0]	WRF4, BUSY,TR
writeRAslow	C0H	Set SLOW-frequency RA with data buffer [±1.0, ±1000.0]	WRF4, BUSY,TR
writeDEslow	C1H	Set SLOW-frequency DE with data buffer [±1.0, ±1000.0]	WRF4, BUSY,TR
pecon	C2H	Activate PEC	BUSY,TR
pecoff	C3H	Disable PEC	BUSY,TR
pecrec	C4H	Record PEC	BUSY,TR
RAtrack	C5H	Start tracking SLOW RA-motor	BUSY,TR
RAstop	C6H	Stop tracking RA-motor an	BUSY,TR
RApowerdown	C7H	Switch RA-motor (current) OFF	BUSY,TR
DEtrack	C8H	Start tracking SLOW DE-motor	BUSY,TR
DEstop	C9H	Stop tracking DE-motor an	BUSY,TR
DEpowerdown	CAH	Switch DE-motor (current) OFF	BUSY,TR
readEEprom	CBH	Returns parameter memory data at address of data buffer: [adr, x] as [adr, data]. Keycode must be set before, else readEEprom is not executed	BUSY, OFF, WRL4, RDL4
writeEEprom	CCH	Writes parameter memory data at address data buffer: [adr, data]. Keycode must be set before else writeEEprom is not executed.	BUSY, OFF, WRL4

Display-Redirection

With the command displayon, you can activate the Display redirection, if it wasn't already programmed as fixed adjustment. All data, which the MTS-3 transmits after that must be interpreted and displayed on the monitor through a program, which understands the command set of the LC-Display. Don't read out other data, when the Display redirection is activated. The command displayoff disables the Display-redirection again.

Key Simulation

The commands, which set or release the keys and switches, have the same effect as if you control the MTS-3 manually. When a key/switch is set through a command, it only can be released through the opposite command again. The same is true for the commands writedip and readdip. Commands for keys/switches are allowed in all operation modes.
Keys and switches are LOW active. A set key/switch drives simultaneously the corresponding pin at the connector to a LOW-level.

Reading out Data

The command, which read data are allowed in all operating modes (except readEEprom). readRA and readDE return the current position of the stepper motors as half steps. When you switch ON the MTS-3, the RA position contains always the last RA-Position reduced on the interval ±motor*gearing (because of PEC): RA-position modulo motor*gearing. The DE-position is always zero on power ON.

During the execution of commands with longer execution time (BUSY-commands) you should use ready-commands, until the last one returns a zero. The data buffer always contains the last read or written data. Else, the data buffer remains unchanged. With the command readbuffer, the last sent (4-byte) data can be verified, or the last received (4-byte) data can be read out another time.

GOTO, Motor Commands

The commands writeRApos and writeDEpos make the MTS-3 slewing automatically exactly to a chosen target position in half steps and stopping there, including automatic acceleration and deceleration.

By cyclic reading of readRA and readDE, the PC can determine, when the target position is reached. While the motor is running towards a target position you may give at any time a new target position or you can change the maximum speed with writeRAlimit and writeDElimit or you can already adjust a new SLOW-frequency.

The automatic GOTO finishes respectively breaks:
-When the target position is reached
-Through RAtrack, RAstop (DEtrack, DEstop)
-By pressing a key LEFT, RIGHT (UP, DOWN)

The commands RApowerdown, DEpowerdown, writeaccel or switching OFF should only be done when the motors stand still or in SLOW mode, because steps might be lost through an immediate stop.

The tracking of one axis is finished:
-through the commands RAstop (DEstop)
-Through the commands RApowerdown (DEpowerdown), which additionally switch OFF the motor current and set the MTS-3 in a power-SAVE standby-mode.

The tracking of one axis respectively the SLOW mode is started:
-Through the commands RAtrack (DEtrack)
-By pressing a key LEFT, RIGHT (UP, DOWN)
By the way the motor current is switched OFF after a stand still (=frequency 0.0) of 2.56 seconds. When the frequency changes e.g. by pressing/releasing a key it is switched ON again automatically.
The functions of both axes work fully independently from each other, analogous to the manual operation, which can be done at any time in parallel to the motor commands.

Backlash Compensation DE

The backlash compensation DE is also considered when using GOTO. With this, a target position is automatically corrected with the adjusted value of the backlash when changing the direction. You should consider this for the target position and for the position read out. Else, disable the backlash compensation with writedip(0).

Reading out and writing Parameter Data

The commands readEEprom and writeEEprom read data from the parameter memory respectively write data back to the parameter memory. These commands can only be executed:

-In OFF state (OFF-position)

-If they were enabled with the following key-code:

Load the hexadecimal value 12345678H into the data buffer and execute a subsequent resetbuffer-command (A3H). If the resetbuffer-command is executed with other data, readEEprom and writeEEprom are disabled again.

The parameter memory (EEprom) is organized word wise (16 Bit) and occupies 128 bytes in total. A read- and write-access is only possible word wise and at even addresses. readEEprom expects the address in the data buffer and returns address and data. writeEEprom expects the address and data in the data buffer and returns nothing:

	readEEprom data buffer	readEEprom return value	writeEEprom Data buffer
1.Byte	High(address)	High(address)	High(address)
2.Byte	Low(address)	Low(address)	Low(address)
3.Byte	Undefined	High(data)	High(data)
4.Byte	Undefined	Low(data)	Low(data)

Because of the special format, addresses and data can be treated together as a long-value. With this, reading, modifying and writing back of single parameters is simplified. A return value of readEEprom can serve directly as input data for writeEEprom.

Parameter Memory (EEPROM)

Size: 128 bytes   Organization: 64 * 16 Bits

Byte-Order: big endian (highest value byte at lower address, lowest value byte at upper address)

Also used by 68xxx (Macintosh, Amiga, Atari)

Notes: 80x86 uses little endian (reverse order!)

Notice: MTS-3 uses internally special format with other position of sign and exponent.

Float format single precision (32bit):

MTS-3:	Exponent:8 , Sign:1 , Mantissa: 23 + hidden bit
	EEEEEEEE SMMMMMMM MMMMMMMM MMMMMMMM
IEEE:	Sign:1 , Exponent:8 , Mantissa: 23 + hidden bit
	SEEEEEEE EMMMMMMM MMMMMMMM MMMMMMMM

Address	Type	Parameter	RESET-content
0	Long	Motor*gearing	11520L
4	Float	DE-SLOW	19.252588
8	Float	DE-FAST	308.0414
12	Float	RA-SLOW	19.252588
16	Float	RA-FAST	308.0414
20	Long	User-motor*gearing	-
24	Float	User-DE-SLOW	-
28	Float	User-DE-FAST	-
32	Float	User-RA-SLOW	-
36	Float	User-RA-FAST	-
40	Float	Correction factor	1.5000000
44	Long	RA-position modulo Motor*gearing	0L
48	Long	Reserved	0L
52	Bit field	pecactive 0:1 pecvalid 1:1 acceleration 2:3 mountselect 5:3 baudrate 8:3 display 11:1	0 0 0 0 0 0
54	Short	Stop watch	0
56	Int[32]	PECTABLE	0[32]
120	Long	PECBASE	0L
124	Long	PECDIFF	0L

11. QBasic Example Routines

DECLARE FUNCTION receivelong& ()
DECLARE SUB sendlong (daten&)
DECLARE SUB sendfloat (freq!)
DECLARE SUB delay (sec!)

```
Example1:       'Example for reading Dip-switches, keys, time and position
Baudrate& = 9600
GOSUB initport         'open COM2
CLS
DO
  LOCATE 1, 1
  PRINT #1, CHR$(&HB4);   :  x& = receivelong&        'readswitchtime
  tasten& = x& \ &H1000000
  IF tasten& AND 1 THEN PRINT "RIGHT" ELSE PRINT "     "
  IF tasten& AND 2 THEN PRINT "LEFT" ELSE PRINT "    "
  IF tasten& AND 4 THEN PRINT "DOWN" ELSE PRINT "    "
  IF tasten& AND 8 THEN PRINT "UP" ELSE PRINT "  "
  IF tasten& AND 16 THEN PRINT "FAST" ELSE PRINT "SLOW"
  IF tasten& AND 32 THEN PRINT "ON " ELSE PRINT "OFF"
  PRINT "Time: "; x& AND &HFFFFFF
  PRINT #1, CHR$(&HB9);   :   PRINT "Dip: "; receivelong&  'readdip
  PRINT #1, CHR$(&HB7);   :   PRINT "RA: "; receivelong&   'readRA
  PRINT #1, CHR$(&HB8);   :   PRINT "DE: "; receivelong&    'readDE
LOOP WHILE INKEY$ = ""
END
Example2:    'GOTO: Motors go 1500 steps forward and backward in endless loop
Baudrate& = 9600
GOSUB initport          'open COM2
sendlong (3)
PRINT #1, CHR$(&HBB);   'writeaccel
GOSUB waitready
sendfloat (500)
PRINT #1, CHR$(&HBE);   'writeRAlimit
GOSUB waitready
sendfloat (500)
PRINT #1, CHR$(&HBF);   'writeDElimit
DO
  GOSUB waitready
  sendlong (1500)
  PRINT #1, CHR$(&HBD);   'writeDEpos
  delay (2)
  GOSUB waitready
  sendlong (1500)
  PRINT #1, CHR$(&HBC);   'writeRApos
  delay (2)
  GOSUB waitready
  sendlong (0)
  PRINT #1, CHR$(&HBD);   'writeDEpos
  delay (2)
  GOSUB waitready
  sendlong (0)
  PRINT #1, CHR$(&HBC);   'writeRApos
  delay (2)
LOOP WHILE INKEY$ = ""
END
```

Example3:

```
'Program for the emulation of a dot matrix display as it is
'used for the PowerFlex MTS-3 / SINUS-II telescope drive
Baudrate& = 9600
GOSUB initport         'open COM2
Display:
 CLS
 maxspalte% = 16 : maxzeile% = 2    'Display size
 zeile% = 0 : spalte% = 0                'Cursor on 0,0 (left up)
 rs% = 1            'printable character on
 PRINT #1, CHR$(&HA0);         'switch Display-redirection ON
 DO
  IF INKEY$ <>"" THEN PRINT #1, CHR$(&HA1); :CLOSE: END
    IF LOC(1) > 0 THEN        'print byte if received
    c$ = INPUT$(1, 1)
    c% = ASC(c$)
    IF c% = 255 THEN        '255 always precedes a control command
     rs% = 0                    'next byte is control command
    ELSE
     GOSUB LCD           'print character or execute control command
    END IF
  END IF
 LOOP
END


LCD:
 IF rs% = 0 THEN              'control commands
  IF c% >= 128 THEN
   IF c% >= 192 THEN zeile% = 1 ELSE zeile% = 0
    spalte% = c% AND &H3F     'dd set
  ELSEIF c% >= 64 THEN         'cg set unused
  ELSEIF c% >= 32 THEN         'function set unused
  ELSEIF c% >= 16 THEN         'shift unused
  ELSEIF c% >= 8 THEN         'displaycontrol unused
  ELSEIF c% >= 4 THEN         'entrymodeset unused
  ELSEIF c% >= 2 THEN
    zeile% = 0: spalte% = 0         'home
  ELSEIF c% >= 1 THEN
    CLS : zeile% = 0: spalte% = 0    'clear
  END IF
  rs% = 1     'printable character ON
  RETURN
 END IF
 'printable charchters
 LOCATE zeile% + 1, spalte% + 1
 IF spalte% < maxspalte% AND zeile% < maxzeile% THEN PRINT c$
 spalte% = spalte% + 1
 IF spalte% >= &H50 THEN spalte% = 0
RETURN
```

Example4:

```
'Example for read out and write back parameters
Baudrate& = 9600
GOSUB initport          'open COM2

sendlong(&H12345678)            'key-code
PRINT #1, CHR$(&HA3);              'resetbuffer as EEpromenable

DIM eeprom&(64)                 'array for parameters

FOR i& = 0 TO 63                '64 words
  sendlong(i& * 2 * 65536)     'send address
  PRINT #1, CHR$(&HCB);             'readEEprom
  eeprom&(i&) = receivelong&        'receive address and data and save them
  PRINT i&, eeprom&(i&) AND 65535    'display address and data
NEXT
STOP                    'stop here, press F5 to write back data

FOR i& = 0 TO 63                '64 words
  sendlong(eeprom&(i&))        'send address and data from array
  PRINT #1, CHR$(&HCC);            'writeEEprom
  GOSUB waitready
NEXT
END

waitready:
  DO
    PRINT #1, CHR$(&HA2);         'ready?
  LOOP UNTIL ASC(INPUT$(1, 1)) = 0
RETURN

initport:
OPEN "COM2:2400,N,8,1,CD0,CS0,DS0,OP0,RS,TB2048,RB20480" FOR RANDOM AS 1
  IF Baudrate& <> 2400 THEN
                    'only for IBM compatible PC's
    OUT &H2F8 + 3, 128             'baud rate input ON
    OUT &H2F8 + 0, 115200 \ Baudrate&     'baud rate low byte
    OUT &H2F8 + 1, 0              'baud rate high byte
    OUT &H2F8 + 3, 3       '8 Bit + 1 stop bit and baud rate input OFF
  END IF
RETURN
```

```
SUB delay (sec)
exittime = TIMER + sec
WHILE TIMER < exittime
WEND
END SUB


FUNCTION receivelong&
  daten$ = "1234"
  FOR i% = 4 TO 1 STEP -1
    MID$(daten$, i%, 1) = INPUT$(1, 1)
  NEXT
  receivelong& = CVL(daten$)
END FUNCTION


SUB sendfloat (freq!)
  daten$ = MKS$(freq!)
  FOR i% = 4 TO 1 STEP -1
    byte% = ASC(MID$(daten$, i%, 1))
    nibblehigh% = (byte% \ 16) + &H80
    nibblelow% = (byte% AND 15) + &H90
    PRINT #1, CHR$(nibblehigh%); CHR$(nibblelow%);
  NEXT
END SUB


SUB sendlong (daten&)
  daten$ = MKL$(daten&)
  FOR i% = 4 TO 1 STEP -1
    byte% = ASC(MID$(daten$, i%, 1))
    nibblehigh% = (byte% \ 16) + &H80
    nibblelow% = (byte% AND 15) + &H90
    PRINT #1, CHR$(nibblehigh%); CHR$(nibblelow%);
  NEXT
END SUB
```

12. Stepper Motors

This chapter shall only explain the characteristic features of the subject „stepper motors". It addresses primarily those who construct a mount for themselves. It is not difficult to construct together with the MTS-3 and a stepper motor a functioning telescope drive. However there are some things to consider   finding the optimal stepper motor, fitting for the MTS-3 and the mount. This is especially important, if you have higher requirements for the telescope drive like a heavy mount and a high GOTO speed. You can get further information from other technical literature or from brochures and datasheets of the manufacturers. If you wish we could send you a list of stepper motors manufacturers and sources of supply.

Stepper Motor Function
The stepper motor distinguishes from other motors that it follows the step impulses of the driving electronics with an exactly defined rotation movement („one step") without an additional expense of control. Thus, it is well suited for low and high rotation speeds with exact frequency.

There exist many variants of stepper motors. They distinguish primarily in:
- 2-phases or 5-phases
- Step numbers/rotation (usual 24,48,100,200,400)
- Phase resistance and inductance
- Bipolar and unipolar
- Number of connections / windings
- Current intake, power and temperature stability
- Design / shape, magnet material
- Shaft, ball bearing, gliding bearing
- Size and weight
- Torque and resonance behaviour
- Holding torque and micro step suitability
- Rotor inertia and acceleration power
- Maximum reachable speed
- Costs and availability

However, the **basic function principle** for all stepper motor is the same:
Two (with 2-phase) fixed coils (stator) produce a rotating magnetic field (control by the electronics), in which the rotor, consisting of a permanent magnet, rotates guided by the rotating magnetic field. The high step numbers are obtained through a special geometric design of stator and rotor and a special magnetization of the rotor with many pole pairs.

Operation Mode
Stepper motors can be controlled in different operation modes. The differences consist in the curve form of the current in the individual windings, the by it achievable step resolution and the therefore necessary control electronics.
-Full step:
Both windings are changed in current polarity for a step sequence in mutual succession. Both windings get for that the same absolute current. The step number corresponds to the nominal value.
-Wave drive:
Variety of full step, where only one winding gets current at the same time. (Step number = nominal value)

-Half step:
Alternately both windings and then only one winding get current. This allows the double nominal step number. It is favourable respectively full step concerning step resolution, resonances, speed and current consumption.
This mode is use by the MTS-3.

-microstep:
The current curve in both windings is approximated to a sine- respectively a cosine curve with more or less steps. This allows even finer step resolutions and less resonances, but needs a more complex drive electronics and for optimal operation microstep suited stepper motors.

Wiring Modes

There are 4 possible modes of wiring a stepper motor:
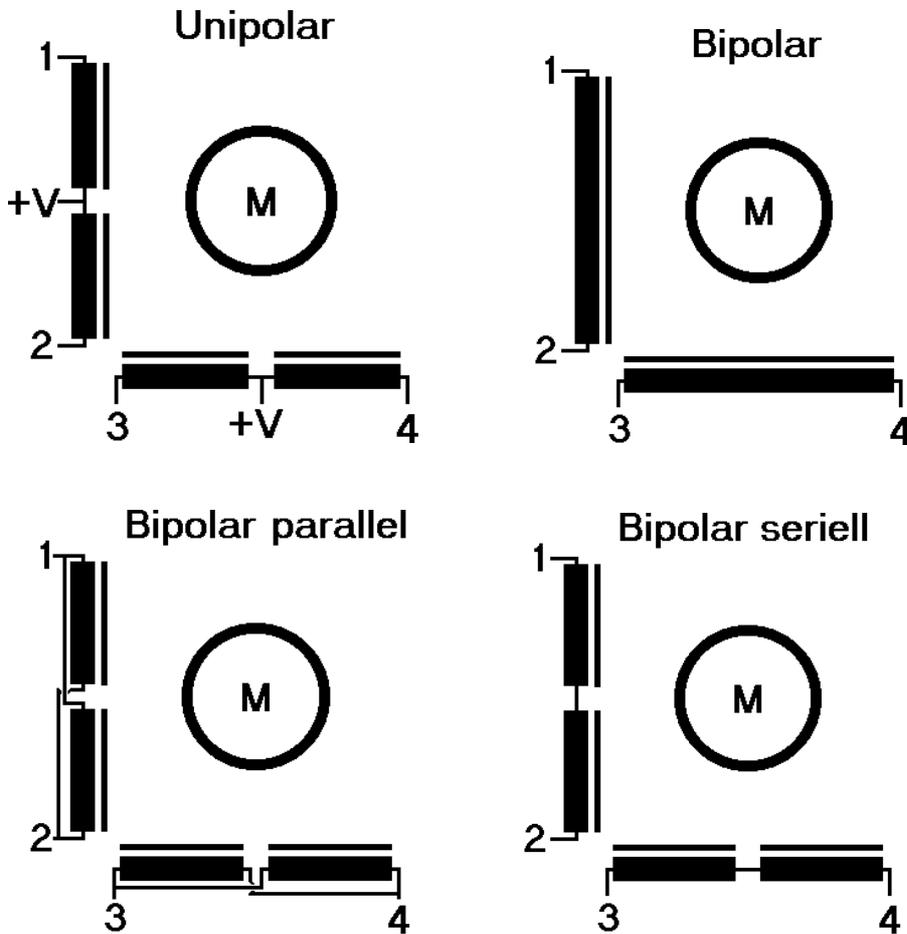
Which mode of wiring is possible depends from the number of wires of the stepper motor and from the driver type of the electronics. The MTS-3 uses bipolar-driver, so all types of 2-phases stepper motors can be connected. The Unipolar stepper motors with 5 or 6 connection wires can also operate bipolar, if the middle wire is not connected.

Selection of suitable Types

As most important basic parameter, the necessary torque for driving the worm should be found out. Second, you must decide, how high the tracking frequency shall be. For small traveller mounts e.g., which are used only for low focal length observations or astrophotography, a low frequency is sufficient, perhaps about 10Hz or lower. For the other extreme case (heavy stationary mount) one might strive for a non-oscillating tracking a frequency about 50Hz or higher. Nevertheless, generally you should test, how a certain mount reacts on the vibrations of the stepper motor at a specific frequency. The next decision is the selection of the FAST frequency for fast GOTO. You should be aware that physical laws set them limits. The moving of a heavy mount needs a certain amount of power, and the power output of the MTS-3 is limited.

Fundamentally it must be noted, that high torque and high speed are contrary requirements. Now, if you need a high FAST-frequency, you have to consider all facts against each other and find a compromise solution.

There are e.g. stepper motors, which have at low frequency and low current consumption a very high torque, but lose torque already at some 100 Hz significantly.

Here the differences are clear between a cheap stepper motor, which might stand still already at 500Hz and a high value fast running disc magnet stepper motor, which can operate at several kHz.

As the torque of stepper motors decreases toward higher operating frequencies more or less depending on it's type, you should study and compare the torque diagrams, measured by the manufacturers.

Current Consumption

The most important basic parameter is the current consumption of the stepper motor, which should not exceed 600mA/Phase when operating only one stepper motor or 400mA/Phase when operating two stepper motors continuously. In any case, the total current consumption must remain below the threshold of the overload protection.

The winding resistance and the supply voltage determine the current consumption.

If the current consumption of a stepper motor is higher than allowed, it should be reduced accordingly either by wiring the windings in series (with bipolar types with 8 wires) and/or with an additional (ohm) resistor in series to each winding

Take care that the resistors are suited for the developing power dissipation and that they may need cooling. Generally, ohm resistors and a higher supply voltage improve the torque at higher frequencies, but have the disadvantage of lower total power efficiency and a higher total current consumption also while tracking at lower frequencies.

Torque

The Torque to turn the worm can found out quite easily. Attach therefore a control knob at the horizontally aligned worm axis and wrap a cord a few times around it firmly, so that it can't slip off. To the other end of the cord, you hang a floating bucket. Fill this bucket slowly with water, until the worm begins turning. Now weigh the mass of the bucket including the water.

Now calculate: Torque = mass[kg] * 9.81 N/kg * knob radius[m]

With this procedure you should also consider harder conditions, which may occur in operation, e.g. when having an uneven loaded mount or a viscous lubrication of the bearing when it is cold. The torque DS, which the stepper motor has to raise is then:

DS = torque * gearing ratio / gearing efficiency
Example: DS = 0.5 Nm * 1/50 / 0.7 = 0.014 Nm = 1.4 Ncm

Gearing

Between worm and motor (in most cases) an additional bearing must be connected, so that the necessary torque can be achieved and you get an acceptable value for the tracking frequency. The gearing might consist of a single toothed wheel stage and/or a complete housed gearing with mounted bearings. As designs forehead wheel gearings, planetary gearings or worm gearings (not so good because of the low efficiency) are suited. For the calculation the load capability and efficiency (about 90% per toothed wheel stage) has to be considered besides.
Many manufacturers offer for additionally to their stepper motors suited gearings, already assembled or not assembled in several variants and with standard gearing ratios:
This may be e.g.: 1:9 1:12 1:24 1:48 1:90 or 1:12.5 1:25 1:50 1:100.

13. Electric Connections

Only connect the foreseen cables and devices. Especially don't touch the pins to avoid electrostatic discharges, which may harm the electronics. Especially synthetic carpets inside, synthetic clothes and shoes with rubber soles can cause high electrostatic charging. Avoid all this, when you manipulate at the pin connectors.
Outside, you normally don't have to expect electrostatic charging.

The MTS-3 has besides the connector for 2 stepper motors and power supply additional connection capability of other devices or accessories:

CCD-Autoguider-Connector

All available CCD-Autoguider-tracking systems from the companies SBIG (ST-x), Meade (Pictor), OES and others can be connected together with the MTS-3 without any modification. For the named company products ready-to-use cables can be delivered. Special cables can also be delivered on request.

External Hand-Control Box

For a concurrent parallel operation it is possible to connect another hand control box externally. For this purpose all connections of keys and switches are available at the pin connector.

RS-232 Serial Interface

For serial communication, the MTS-3 has the connection pins Txd, Rxd and Gnd. The connection to the PC is done with an adapter cable and a standard 9-pin DSUB-cable and if needed a 9->25 adapter plug. Therefore, Txd and Rxd from PC and MTS-3 are connected crosswise together.

LC-Display

The LC-Display is connected with a flat cable to the MTS-3, at which 3 data lines are contacted for serial transmission, also Vcc and Gnd.

14-Pin-Connector

To all pins (except Rxd) no external voltages may be connected. The signal inputs RIGHT,LEFT,DOWN,FAST,UP,ON only may be switched together with Gnd (use open collector, open drain, optocoupler, relays or diodes!)

```
┌──────────┐
│ 1    2   │   1: LCD data/rs    8: FAST
│ 3    4   │   2: LCD clock       9: UP
│ 5    6   │   3: RIGHT          10: Txd
│ 7    8   │   4: Gnd(0V)        11: Rxd
│ 9   10   │   5: LEFT           12: LCD enable
│11   12   │   6: Vcc(+5V)       13: ON
│13   14   │   7: DOWN           14: LED
└──────────┘
```

15-Pin Power Supply/Motors Connector
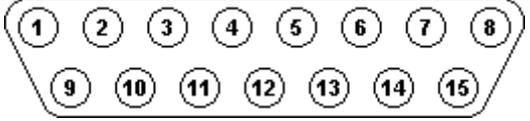
(1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12) (13) (14) (15)	1: RA Phase1 5: DE Phase4
	2: RA Phase2 6: DE Phase3
	3: RA Phase3 7: DE Phase2
	4: RA Phase4 8: DE Phase1

9,10 :   **+ Supply Voltage**
11,12,13: + Supply Voltage (MTS-3)
11,12,13: not connected (MTS-3LP, MTS-3SLP,MTS-3SDI)
14,15:   Ground

2-Pin Power Supply Plugs
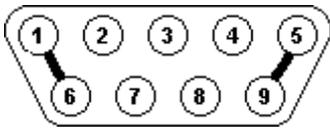
Wire with red line = red banana plug = Vdd (PLUS)
Black wire = black banana plug = Gnd (MINUS)

5-Pin Motor-Cable (Vixen compatible, Top View on Pins)
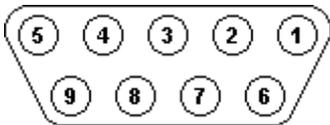
1: Phase4
2: not connected
3: Phase1
4: Phase2
5: Phase3

9-Pin Motor-Cable (Escap compatible, serial operation)

2: Phase4
3: not connected
4: Phase1
7: Phase2
8: Phase3

1,6: connected together
5,9: connected together

9-Pin Motor-Connector Escap (serial or parallel operation)

1: yellow
2: red
3: not connected
4: brown
5: orange
6: red-white
7: yellow-white
8: orange-white
9: brown-white

14. Electric Data MTS-3LP

For owners of an older MTS-3 (not MTS-3LP), therefore the information of the older manual remains valid !!!

Power Supply

Limits:	Minimum	Recommended	Maximum
Voltage:	10 Volts	12 - 18 Volts	28 Volts

Batteries

Suitable are: lead accumulator ("car battery"), NiCd-accumulator, NiMH-accumulator or (non)-rechargeable alkaline-manganic batteries. For a sufficiently long lasting power supply, you should absolutely consider the current consumption when choosing the accumulator's capacity.

Formula: t=C/I (t: time[h], C: capacity[Ah], I: current consumption[A])

However, the formula is only valid approximately, as the exact capacity (not the labelled!) depends from charge state, age, temperature und current taking. Therefore, also consider the manufacturer's information of accumulator and recharging device. Also check the voltage frequently, in order not to fall below of the minimum voltage of 10 volts, to avoid a deep discharge (if lead accumulator).

AC Power Supplies with DC Output

Suitable are power supplies with fixed or variable output voltage. Take absolutely care for a sufficient output current capability and a stabilized output voltage. In this respect the often-found plug power supplies are overloaded and therefore not suited. Very ingenious is also a current limiting. With variable voltage power supplies, you have to consider, that the voltage limits of the MTS-3 must not be exceeded by mistake.

Reverse Polarity Protection

The MTS-3 has an optimised MOSFET-reverse polarity protection circuitry, which has only a low current dependent voltage loss and minimizes the power dissipation in contrary to the often-used diodes.

The voltage loss is at 1 Ampere about 0.055 volts. If the MTS-3 is connected with wrong polarity by mistake, it simply doesn't switch ON. You don't need to expect any damages.

Current Consumption

Electronics without motors: about 15mA - 25mA dependent of operation mode
LC-Display: about 1mA - 2mA
Motors: allowed maximum 4 * 400mA (2 motors in continuous operation)
Or maximum 2 * 600mA (one motor continuous operation)
The current consumption depends from the phase resistance of the motors
Iph = Vdd / (Rph + Rtr)   with Iph: current/phase
Rph: phase resistance
Rtr: driver resistance (about 2 Ohm)
Vdd: supply voltage
Imax=2*Iph(RA)+2*Iph(DE)   Imax: maximum total supply current

For 2 stepper motors with 40 Ohm/phase each and 12 volts you would get:
Imax=2 * 12V/42 Ohm + 2 * 12V/42 Ohm = 1.14 Ampere
In tracking mode the DE motor might be OFF for the most time, so that this value reduces about to the half and with the half step mode it reduces to another 75%.
The average consumption is therefore: 1.14A * 0.5 * 0.75 + 0.025A = 0.45 A.
Consider this for the battery capacity.

Overload Protection and Motor Drivers

The MTS-3 uses integrated H-bridge-MOSFET-motor drivers of the type 2 * L6204 (SGS-Thomson) to drive 2 stepper motors in bipolar wiring.

Above a total current consumption of about 2 Amperes, the overload protection circuit switches all motor drives OFF and switches them ON again in intervals of about 1/10 second. This state can cause a very heavy uncontrolled vibration of the motors and should be terminated as soon as possible bay switching OFF.

The drivers also include a high temperature shutdown circuit, which reacts at a chip temperature of about 150°C. The switching OFF by the overload protection circuit is only to protect the MTS-3 from permanent damage and is no allowed operation mode. An overload can occur, when:

-The motors have a too low winding resistance.

-There exists a short circuit in the electronics, plugs, cables or in the motor.

The overload protection circuit reacts on overloads between all phases to each other and the +supply voltage, but not between the phases and ground (-supply voltage). A short circuit between ground and one phase will probably destroy the driver. So be accordingly careful.

Cables and Connectors

The cables and connectors to the motors and power supply are the most frequent reason for malfunctions. Therefore, you should consider the following:

The current supply cable should have good contact to the current source. Loose crocodile clips and oxidized contacts, which can cause unwished current supply failures, are not well suited. Even short voltage breakdowns cause the MTS-3 to make a restart, which does not cause harm, but breaks the tracking unnecessarily and the PEC information is lost. For necessary extension cables, you should use a sufficient wire thickness. It's not advisable to use the usual 12Volt-cable drums wit car plugs (also may often be loose!) and long and thin wires, especially when the current consumption is higher.

Use e.g. a safe plug connection with banana plugs and corresponding sockets. With screwed clamp connection you should consider, that they might get loose after frequent use and then may cause loose contacts. Maybe that (well) soldered connections are better suited.

For the motor plugs the same is true as explained above. A stepper motor only can operate, when all 4 phases are connected correctly. Else it does not move at all, makes uncontrolled movements or rotates without power accidentally sometimes to the one or the other direction. So, make sure that:

-All phases are connected with the correct scheme.

-The plug fits correctly, in the centre (not distorted!) and fixed in the connector. Especially the 5-pin DIN-plugs can be plugged into 8-pin DIN-connectors easily with one pin distorted! If needed, block the unused pins!

-The contacts are not oxidized and free of dirt.

-The contact clips at the connector are not over-stretched and give save contact. If needed bend them some together with a needle!

-The cable is not damaged. Especially outdoor it may break at extreme coldness or when stepping on it.

15. Software Details

Frequency Accuracy

The MTS-3 saves all frequency values internally as single precision floating point numbers, thus for this purpose extreme precisely. For controlling the motors, the frequency values are converted to time intervals between 2 successive steps.

The time raster of these time intervals is for the tracking frequency 4.24 nanoseconds, and for all other frequencies 1.085 microseconds. It should be noted that because of the interrupt driven step output, single steps may have delays up to about 30 microseconds maximum (called phase jitter), but they don't accumulate. At a FAST-frequency of 5000Hz there would be a maximum frequency raster of 0.5425 percent = 27.125Hz. You should not worry, that the displayed frequency is not exactly the actual frequency, because the MTS-3 selects the next possible value.

At a tracking frequency of e.g. 50Hz, the frequency raster would be only 0.2 ppm (parts per million), which is a disappearing small value. Actually, the frequency stability of the oscillating quartz is about 30 ppm. Thus, the tracking frequency accuracy is also 30ppm.

PEC Function Principle

The PEC recording functions in principle like this: The MTS-3 calculates the difference between the actual step position of the RA motor, (in which also all your manually corrections with LEFT and RIGHT result) and the calculated step position (with out any corrections).

The MTS-3 saves this difference in the PEC table exactly 32 times during one exact revolution of the worm.

After one exact revolution of the worm is completed, the PEC begins controlling the tracking frequency with use of the PEC table. The PEC does this by interpolative calculating the step difference for a future step position (t + 2 seconds) from the PEC table in intervals of some seconds.

The normal step position, which is calculated with constant tracking frequency, is then corrected with this difference.

From this corrected step position and the momentary step position, the MTS-3 can calculate a new tracking frequency (in intervals of 2 seconds). The tracking repeats thus quite exactly the corrections you made during the PEC record, in doing so these corrections get some natural smoothing and are more steadily, because of the only 32 values of the PEC-table. The PEC-correction is only coupled to the step position and thus independent from the frequency. This allows to have the PEC table saved permanently and to use the FAST mode or automatic GOTO without losing the PEC information.

When you record a PEC table, all corrections accumulated during one revolution of the worm should neutralize each other. Actually, this will rarely be true, because also other influences than the periodic worm error act. The PEC also considers this and corrects really only a periodic error by eliminating remaining difference trough normalizing the whole PEC table.

Therefore, the average PEC controlled tracking frequency during one revolution of the worm is exactly the same as the original programmed tracking frequency.

16. Error Causes and how to remove Errors

If anything does not function as expected, you can find here some hints. Please also read again the belonging chapter.

Motor is vibrating, wrong/accidental rotation direction
 Check the motor connector.
 Perhaps there is an overload or short circuit. Switch OFF immediately!
Motor stands still/sounds with high frequency
 Frequency was adjusted to high.
 Motor is not suitable or too weak.
 Supply voltage is too low.
Wrong tracking speed
 Check your mount data.
LC-Display does not show anything
 The LC-Display must be connected before connecting the supply voltage, because it is only once initialised at power up.
 Versions before 1.10 don't support the LC-Display yet.
 Perhaps the cable is not properly connected or defect.
LC-Display shows extreme values
 Probably the MTS-3 is wrongly programmed. Try to make a RESET.
MTS-3 does not react
 Perhaps the MTS-3 is in the wrong operation mode.
 Switch OFF the MTS-3 and switch ON again.
RS-232 serial Interface does not function
 Check the baud rate, COM-port and the command protocol.
LED blinks
 -> undervoltage warning -> memory error

17. Application Destinations, Guaranty

The MTS-3 and all connected accessory parts or devices may only be operated under attention of the conditions listed in this operation manual. For any other handling, using or unauthorized manipulations or repair attempts we don't take over any responsibility and liability.

For the MTS-3 and accessories there is a guaranty of two years on all electronic and mechanical parts.

Excluded are parts, which were recognizably stressed over the limits or wrongly treated.

The manufacturer promises that our devices have the described features, were tested intensively and therefore accomplish their destined function.

However, if you find defects or malfunctions, you should contact us as soon as possible to give us the chance to fix them.

There is no claim for a return or rework, if a located deficiency is irrelevant for the functioning of the device or a malfunction can be avoided by appropriate handling.

Nevertheless, please contact us, if you find such trifles, that we can remove them and improve the MTS-3 further for the future.

18. <u>Service</u>

Accessories and Prices
 (Inclusive 16% value added tax) **Status: April 1998**
Delivery costs are calculated according to the expense (minimum DM 11,60).
Dealers, who order frequently, get a discount of 10%.

This old pricelist is just included for reference and is not valid any more.
For up-to-date prices and new articles refer to the pricelist on our website.

PowerFlex MTS-3LP Controller Inclusive Supply/motor-cable and instruction manual	DM 580,00
Supply/motor-cable individual	DM 55,00
LC-Display	DM 240,00
RS-232-cable 1m 9-pin (with 5m extension cable)	DM 35,00
ST-4-cable 2m	DM 35,00
ST-7-cable 2m	DM 35,00
Pictor-cable (ST-x-cable + adapter cable)	DM 55,00
Flat cable distribution connector individual	DM 5,00
Flat cable distribution cable 0.5m 3-connectors	DM 35,00
Upgrade to Version 1.15	DM 50,00
Upgrade to Version 2.00 inclusive instruction manual	DM 120,00
Instruction manual individual Is credited if you order a MTS-3LP or a upgrade 2.00	DM 10,00
Complete servicing of older MTS-3 including exchange of all switches, keys and plastic box and function test	DM 120,00

Special designs are also possible on demand. For a concrete application, we can also offer suited stepper motors and gearings.

Advisory Service , Repairs
In conjunction with the MTS-3, we can make a competent advisory service.
The very most questions can be answered quickly, if you simply call us. We would please you to use this opportunity first.
As manufacturer, we are able to do necessary repairs or error fixes at low costs quickly and correctly. However, from experience we know that the most complaints were no real defect, but the reason was a wrong handling or wrong connection.
Therefore, we please you to send devices back to us only after a prior consultation by telephone and with a detailed error description.

Upgrade of older MTS-3 to Version 2.00
If you already own a MTS-3 and want to use the new features of the new software version, your MRS-3 can be upgraded. Therefore, send us your MTS-3 after calling us. Then we exchange the micro controller and test the MTS-3. You get your MTS-3 back immediately.

19. Security Information

Only connect the MTS-3 to a suitable DC power supply, which meets the allowed limits. A connection to a too high voltage or even to the AC mains voltage will destroy your MTS-3 with certainty and you may risk your health or even life!!!
So absolutely keep the MTS-3 including cables away from children and other unauthorized persons, because the banana plugs could also fit in the mains power sockets!!!

20. Function Short Overview

To select a function, hold the key combination pressed when switching ON.
To save data and terminate the function simply switch OFF.

Function	Key combination	To notice
Tracking	None	LED green: PEC OFF LED yellow: PEC OFF / available LED red: PEC ON
Solar "	UP	"
Lunar "	DOWN	"
PEC ON/OFF	LEFT	Switch OFF within 10 seconds
PEC recording	LEFT	LED alternately yellow/dark Start with FAST->SLOW
Correction factor	RIGHT	16 values: 1.0625 - 2.0000 UP: increase DOWN: decrease LED alternately red / green when value changes
Learning mode	UP+RIGHT	Start with FAST->SLOW
Acceleration	DOWN+RIGHT	8 values at Dip-switches # 1,2,3
RA-, DE-frequencies directly	Prior switching ON: SLOW: fine 1/100000 FAST: coarse 1/1000	After switching ON: SLOW: change SLOW frequency FAST: change FAST frequency
RA-frequencies	LEFT+RIGHT	UP: increase DOWN: decrease
DE-frequencies	UP+DOWN	RIGHT: increase LEFT: decrease
Baud rate	DOWN+LEFT+RIGHT	8 values at Dip-switches # 1,2,3 Display-redirection at # 4
Motor-gearing	UP+LEFT+RIGHT	Dip-switches # 1 - 10
Mount selection	UP+DOWN+RIGHT	Dip-switches # 1,2,3
Save parameters	UP+DOWN+LEFT	User-defined mount
RESET	UP+DOWN+LEFT+RIGHT	Standard adjustments for all mount dependent parameters, (except user-defined mount)
Undervoltage	LED is blinking	Check the power supply immediately!

21. Supplement to Manual Version 2.00 New Functions of MTS-3SLP and SDI

Switches and Keys

The new switches now have a longer lifetime. For later versions, an additional square key is already included. In the Version 2.12, it has no function yet. The internal keys are now readable independent from the external autoguider connector, so that the programming modes can only be activated through the internal keys and accidental programming is therefore avoided.

Terrestrial Observations, Correction Factor RA

The correction factor RA defines, how much the tracking frequency increases in SLOW mode when pressing the RIGHT-key, respectively decreases when pressing the LEFT key (2.0 minus correction factor RA). There are **17** different adjustments form **1.0000** to 2.0000 possible. You can change the pre-adjusted value of 1.5000 by holding the RIGHT-key pressed when switching ON. When pressing the up KEY the value increases, when pressing the DOWN key it decreases. The possible values can be distinguished from each other through the colour change of the LED.
At the same time, you can check the adjustment with the LEFT- and the RIGHT-key, or you can read it directly if a LC-Display is connected.
The correction factor RA is saved when switching OFF.
With the special value of 1.0000, the RA motor is controlled exactly like the DE motor. This means that it stands still if no key is pressed und runs on a key hit to the corresponding direction. This functionality makes sense for terrestrial observations or other non-astronomical applications.

Microstep Operation, Microstep Width, Acceleration

To get the stepper motors in FAST mode or for automatic GOTO without loss of steps or even stand still to a high speed, the MTS-3xx uses a ramp control. In doing so, the motors are accelerated and decelerated gradually.
For an as smooth as possible tracking you can program the step width of the stepper motors as needed. Acceleration and microstep width are valid for both stepper motors and can only be programmed together.
You can program the value of the acceleration in 8 selectable steps. Therefore, adjust the binary values 0 (small) to 7 (large) at the Dipswitches #1-3.
The microstep width (only MTS-3SDI) has to be adjusted at the Dipswitches #4-6. All other Dipswitches are ignored
Depending on the microstep width the maximum possible SLOW frequency is reduced in order not to overload the microcontroller.
The microstep frequency is internally limited at 2000Hz, independent for adjusted values. So don't chose a microstep width smaller than it is allowed for an adjusted frequency value in the table. For not especially microstep suited stepper motors, a smaller microstep width than 1/8 or 1/16 has may show no substantial improvements.

Microstep width	Dip-switch ON	max. SLOW-frequency (related to half steps)				
		DE	RA 1.25	RA 1.5	RA 1.75	RA 2.0
½	---	1000	1000	1000	1000	1000
¼	4--	1000	800	666.66	571.42	500

1/8	-5-	500	400	333.33	285.71	250
1/16	45-	250	200	166.66	142.85	125
1/32	--6	125	100	83.33	71.42	62.5
1/64	4-6 , -56, 456	62.5	50	41.66	35.71	31.25

.
These values are programmed by pressing the key combination DOWN-RIGHT when you switch ON, then release the keys and switch OFF.
In any case, you should check if the stepper motors can manage the acceleration.
Also consider the frequency limitation for the microstep width.

Important note: To allow microstep operation, the PWM pulse width must be programmed to an other value than 0%, else half step operation is used.

Direct Frequency Adjustment
This functions as described in the operation manual for Version 2.00 with one exception:
If you only want to change the frequencies, the Dipswitch #10 must be OFF during the entire adjustment mode.
Else, you would change the PWM adjustments of the phase current or the 100%-limit frequency (see next point).

Current-Saving Operation
The MTS-3Sxx allows through a software pulse width modulation (PWM) of the stepper motor's phase currents, a linear reduction of the current consumption in fine steps from 0% to 100% of the nominal value (according to Ohm's law I=U/R).
With this, it is now possible to extend the operation time of a battery substantially, to use higher supply voltages without overheating the stepper motor and to use lower resistance stepper motors too.
The MTS-3Sxx is now able to drive all mounts with stepper motors, if the maximum phase current of 500mA is sufficient.

By default, (RESET-values) the phase current is adjusted with the PWM pulse width to 01%.
With this value, the MTS-3Sxx functions like the older MTS-3, which means that the PWM is deactivated and half step mode is used (independent from microstep width adjustment).

For values larger than 0% the PWM is activated and the phase current is controlled automatically to the adjusted value (which is also necessary for using microstep operation).
Select the value as large that the stepper motor has enough power at the tracking frequency.
It may also make sense to watch the current consumption with an ampere meter or to use the optional LC-Display, which also shows all adjustments.

For an optimum operation of the stepper motor in FAST mode, there is another adjustment.
The phase current fits very well to the adjusted value at low frequencies (tracking frequency).
However, stepper motors have the attribute, that the phase current reduces itself increasingly, when the stepper motor is operated at higher and higher frequencies (depending on type). This is the reason, why each stepper motor stands still at a certain maximum frequency and load.
An additional reduction of the phase current at higher frequencies through the PWM is therefore not desirable.
Therefore, it is possible to adjust a 100%-limit frequency, at which the PWM pulse width is automatically increased up to 100%, respectively is totally disabled.

This increase is done linearly with the frequency, when the stepper motor is accelerated or decelerated.
This can be watched very well with an ampere meter, if the acceleration is adjusted to the lowest value 0.
The adjustment is good, if the current shows no larger peak while accelerating. It is sufficient to make only a coarse adjustment (about 100Hz exactly).
For the most standard stepper motors, which do not run with higher frequencies anyway, it is sufficient to take the recommended (RESET-) adjustments.

Please note that you have to make these adjustment separately for each of the two stepper motors and that these adjustment are reset after a RESET to the standard values.

Adjust the PWM pulse width as the following:

   a) Set the Dipswitch #10 to ON.
      If it would be OFF, the saved adjustment would not be changed.
   b) Set the Dip-switch #9 to OFF
   c) Activate RA-frequency (or DE-frequency) direct adjustment mode.
   d) Adjust at Dipswitches #1-6 the PWM pulse width, which results from the sum of the ON Dipswitches' values.
      For 100% you would have to set all Dipswitches #1-6 to ON.
   e) Check with the control keys, if the motor has sufficient power at tracking speed. If needed increase the PWM-pulse width
   f) Now switch OFF to save the adjustment.
      If you don't want to save the PWM pulse width, set Dipswitch #10 to OFF before.

Dip-#	1	2	3	4	5	6
ON-value	1.6%	3.2%	6.3%	12.7%	25.4%	50.8%
OFF-value	0%	0%	0%	0%	0%	0%
Example:	-	-	-	ON	ON	-
38.1%				12.7%	25.4%	

Adjust the 100% limit frequency as the following:

   a) Set the Dipswitch #10 to ON.
      If it would be OFF, the saved adjustments would not be changed.
   b) Set the Dipswitch #9 to ON.
   c) Activate RA-frequency (or DE-frequency) direct adjustment mode.
   d) Adjust at Dipswitches #1-8 the 100% limit frequency, which is 57600 divided by the sum of the ON Dipswitches' values.
      If all Dip-switches #1-8 were OFF, the sum would be assumed as 256, this means that the 100% limit frequency would be 57600 / 256 = 225 Hz.
      This is also the standard value (RESET-adjustment).
      The highest adjustable value of the 100% limit frequency is about 3600 Hz.
   e) Check with the control keys, that the stepper motor has enough power in FAST mode and if it takes too much current.
      If needed change the 100% limit frequency.
   f) Now switch OFF to save the adjustment.
      If you don't want to save, the 100% limit frequency set Dipswitch #10 to OFF before.

Dip#	1	2	3	4	5	6	7	8
ON value	1	2	4	8	16	32	64	128
OFF value	0	0	0	0	0	0	0	0
Beispiel:	-	-	-	-	-	ON	ON	-
57600 / 96 = 600Hz						32	64	

Note that you can program the PWM pulse width and the 100% limit frequency at one time, if you switch therefore Dipswitch #9.
Again, these values can only be saved, if Dipswitch #10 is ON, while you switch OFF.
You can also program the FAST and SLOW frequencies concurrently and test them.

For the most mounts, it is a good choice to program the PWM pulse width to about 50% and for the 100% limit frequency to take the RESET value of 225 Hz.

Software-Download (only MTS-3SDI)
The MTS-3SDI can be programmed with a new software version through the implemented RS-232 interface (you can also get the RS-232 cable from us) very easily.
When it is available, you can download it from our website. Simply connect the PC and the MTS-3SDI together and follow the instructions of the download program.