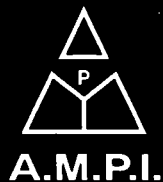
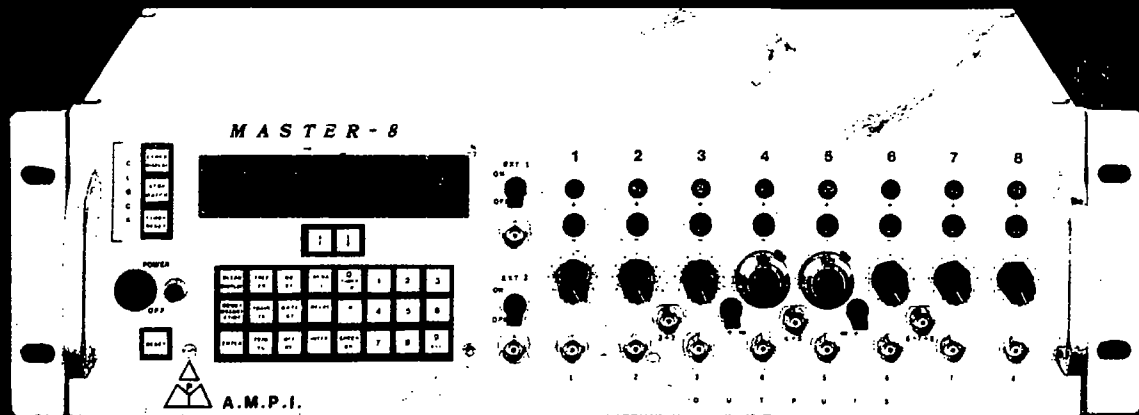


Master-8

EIGHT CHANNEL
PROGRAMMABLE PULSE GENERATOR

Operation Manual



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Thank you for buying **Master-8** — the most flexible pulse generator. **Master-8** is an 8 channel pulse generator, based on advanced microprocessor technology. Therefore **Master-8** has many handy options. Please read this manual carefully and become familiar with all the possibilities. You will find **Master-8** friendly to use and the programming simple and easy to learn. **Master-8** is an attractive unit and you will enjoy working with its eight paradigms.

On the following pages you will find:

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Introduction

Preprogrammed settings

Master-8 is an 8 channel pulse generator. With **Master-8** you can easily switch your set-up between completely different experiments (paradigms). **Master-8** stores eight user's preprogrammed paradigms. Each paradigm can use all the eight channels. You can switch your set-up to the selected setting by a single command. This option is very useful in the following cases:

- a) When you want to switch the experiment to another one. The changeover is very fast (50 msec).
- b) When several users are using the same set-up. Each user recalls his settings from the memory of **Master-8**.

All parameters of all the 8 paradigms are stored in the memory even after the power is switched off by a lithium battery with a guaranteed life of 7 years. There is no need to reinsert the parameters after switching on the unit.

Operation

Each channel operates independently in one of the following modes:

1. **FREE-RUN** — The channel delivers pulses continuously.
2. **TRIGGER** — Following a trigger, the channel delivers a single pulse.
3. **TRAIN** — Following a trigger, the channel delivers a train of pulses.
4. **DC** — DC output, time independent, turns on and off manually.
5. **GATE** (channels 1 and 2 only) — The channel delivers pulses continuously while it is externally gated.

Each channel can be internally connected with different channels and receive trigger pulses from them. *There is no need to connect wires between channels.*

The **Master-8-cp** model can be programmed by a computer via a standard RS-232 interface. The communication is bidirectional.

Channels 1 & 2 can receive external triggers. This offers a possibility of synchronizing those (and other) channels with external devices.

In addition to its standard 8 channels **Master-8** features a clock that counts the time that has passed from pressing the CLOCK-RESET key (e.g. the experiment time). It features a timer that can change the mode of a channel at a certain hour (e.g. turn it on or off).

The amplitude of the output pulses can be adjusted from -10V to +10V, and maximum current of 20 mA.

Description

THE POWER SWITCH is located on the lower left side of the front panel. Beside it is a red light indicating 'POWER ON'.

Front panel keys

The front panel keys are divided into 5 groups. Each group has a different shade, please follow:

- 1) The digits: 0 — 9.
- 2) The operation mode keys: FREE (Free Run), TRAIN, TRIG, DC, GATE, OFF.
- 3) The parameter keys: DURA (Duration), DELAY, INTER (Interval Time), M (No. of pulses per train), '↑', '↓'
- 4) The clock keys: CLOCK-DISPLAY, STOP-WATCH, CLOCK-RESET, TIMER.
- 5) The command keys: CLEAR-DISPLAY, CONNECT/DISCONNECT, CHECK, ENTER, RESET.

Some of the keys have a dual function.

Pressing a key is followed by a response on the display. The code of the key is written on the key. (For example: the code of FREE is 'FR').

Channel Board

On the right hand side of the key section is the external (EXT) input section divided into two parts--EXT 1 for channel 1 and EXT 2 for channel 2. Each has a BNC socket and an ON/OFF switch for enabling and disabling the input.

To their right is the eight channel control section. On the panel from the top down are: the channel number, a LED indicating that the channel is active, a switch to select the polarity of the output pulses, a knob to adjust the output amplitude, and a BNC socket to connect the output to external devices.

Outputs '2+3', '4+5' and '6+7+8' are the summations of the outputs 2+3, 4+5 and 6+7+8 respectively. These sockets can be used for multilevel pulses (e.g. +/- pulses). The two switches add the summations 2+3 and/or 6+7+8 to the '4+5' output, thus the '4+5' output can deliver up to 7 levels pulses + GND.

Rear panel

On the rear panel there is a switch to connect/disconnect the ground to/from chassis. Sometimes this switch is used to reduce the noise level of the system.

In the **Master-8-cp** model (computer programmable) there is a RS-232 interface for communication with a computer.

Operation

General

The operation of **Master-8** is simple and can be learned in a short time. Previous parameters remain in the memory even after the power has been switched off, unless the parameters are changed.

Every instruction is carried out only after pressing the ENTER key. As long as the ENTER key has not been pressed, the instruction can be changed or deleted by giving new instructions (e.g. the CLEAR-DISPLAY instruction).

If a non-operable instruction is inserted, an error message appears on the display. The unit does not accept this instruction and is ready to receive a new one.

The parameters

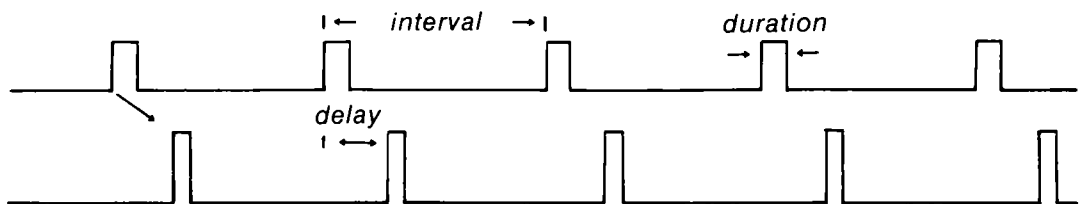
Each channel has its parameters (DELAY, DURA, INTER, M) which define the output pulse (See picture below).

The DURA (duration) parameter defines the time elapse from the onset of the output pulse to its end.

The DELAY parameter defines the time elapse from the beginning of the input trigger to the beginning of the output pulse.

The INTER (interval) parameter defines the time elapse between the beginning of a pulse and the beginning of the following pulse. (cycle time = $1/\text{rate}$).

The M parameter is the number of pulses per train in the TRAIN mode.

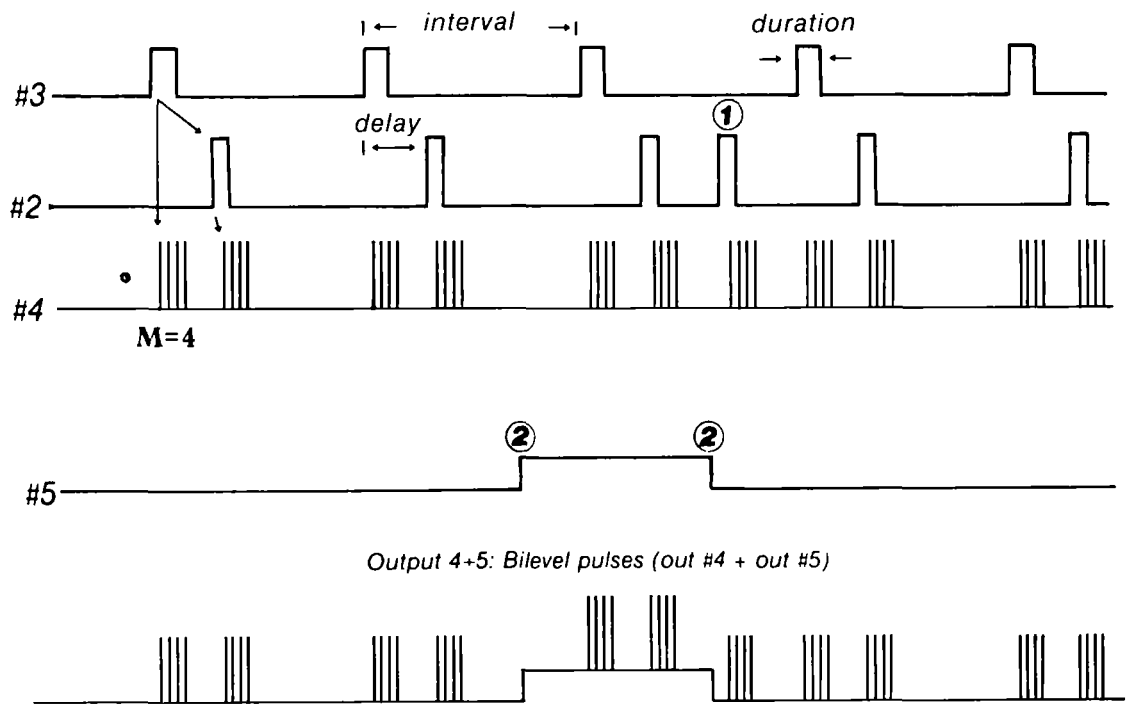


Before operating a channel in a certain mode, the relevant parameters to that mode have to be programmed:

- | | |
|--------------------------------|-----------------------------|
| In the FREE-RUN and GATE modes | — DURATION and INTERVAL. |
| In the TRIG mode | — DURATION and DELAY. |
| In the TRAIN mode | — DURATION, INTERVAL and M. |

Applications

The following illustration gives you an idea of how **Master-8** works. Don't follow the programming yet, you will do it in the next chapter.



CHANNEL	MODE	PARAMETERS IN USE	TRIGGERED BY
#3	FREE-RUN	duration, interval	none
#2	TRIG	duration, delay	#3
#4	TRAIN	duration, interval, M	#2 & #3
#5	DC	none	none

Notes for the figure:

- ① Triggered externally or manually (by one keystroke).
- ② Turned on and off manually (by one keystroke).

b) A special feature of **Master-8** is the 3 multilevel outputs: OUTPUTS '2+3', '4+5', and '6+7+8' which deliver the summations of the outputs 2+3, 4+5 and 6+7+8 respectively. These outputs can be used for multilevel pulses (e.g. +/- pulses). There are two switches to add the summations 2+3 and/or 6+7+8 to the '4+5' output, thus the '4+5' output can deliver up to 7 level pulses + GND.

3) Let's set channel #2 to the triggered mode.

Press: 'TRIG, 2, ENTER' (see page 10). and...nothing happens. Channel #2 is now on the TRIGGERED mode, but is waiting to accept a trigger. You can trigger it in 3 ways:

A) MANUAL TRIGGERING — **Press:** '2'. ('2' is the channel number.) Note that each press on '2' delivers the triggered pulse. Press '2' several times.

B) EXTERNAL TRIGGERING — Whenever there is an input pulse in the 'EXT 2' input it triggers channel #2 (see page 13).

C) INTERNAL TRIGGERING — You can internally connect each channel to any number of the other channels (see page 13).

(4) Let's connect channel #1 internally to channel #2 —

Press: 'CONNECT,1, 2, ENTER' and it is connected. (see page 13).

Each output of channel #1 triggers channel #2. You don't have to connect wires between channels. You also don't have to worry about the amplitude or polarity of the trigger source. Even the instruction itself is very straight forward (the same way you would say it: 'CONNECT from #1 to #2, ENTER'). Please note that you can add manual pulses by pressing '2'.

(5) Now set the duration of channel #2 to be 15 msec. —

Press: 'DURA, 2, 15, ENTER, 3, ENTER' (see page 11).

(6) Set the delay of channel # 2 to be 100 msec. —

Press: 'DELAY, 2, 100, ENTER, 3, ENTER' (Please check the new delay).

(7) Let's set channel #3 to the train mode. What is the instruction?

Right! Do you see how simple it is?

Press: 'TRAIN, 3, ENTER'.

Channel #3 is now in the TRAIN mode and is waiting for a trigger.

(8) Trigger it manually several times by pressing '3' (see page 13).

(9) PULSES PER TRAIN

Set the number of pulses per train in channel #3 to be 5.

Press: 'M, 3, 5, ENTER, 0, ENTER' (see page 11).

Now trigger Channel #3 manually again by pressing '3'.

(10) Now connect channel #1 to trigger #3. What is the instruction?

Press: 'CONNECT, 1, 3, ENTER' (see page 13).

Channel #1 is now triggering both channels #2 & #3. Please note the '→' sign on the panel above the '1.3' digits. This arrow indicates the direction of the connection.

And now for the most powerful feature of Master-8. Let's say that you programmed all the 8 channels to run in a specific pattern, which is your present experiment. Now you want to switch to a new pattern (paradigm) that also uses all the 8 channels. With **Master-8** you can do this very easily. But first you have to program the other paradigm.

(11) **Press:** 'ALL'

The name of the present paradigm (now '1') is displayed. In order to switch to paradigm #5, **Press:** '5, ENTER' (see page 14).

Since this is a new paradigm all the channels are off, all the internal connections are disconnected and all the time parameters have their default values.

(12) Set all the 8 channels to the FREE-RUN mode **by pressing:** 'FREE, 1, ENTER', 'FREE, 2, ENTER', etc. Each of the 8 channels is now running continuously at its own rate, independent of the other channels (Nice, isn't it?).

(13) Now you can switch back to the previous paradigm by recalling it.

Press: 'ALL, 1, ENTER' and you get the previous paradigm.

Press: 'ALL, 5, ENTER' and you get the other one. All the channels are now working in synchronization since you initiated them together.

(14) What about turning the power off? Let's try it. Turn the power off.

Master-8 stores all the 8 paradigms even when the power is turned off. There is a lithium battery for memory retention. This lithium battery should be replaced only after 7 years.

(15) Now turn the power on. **Master-8** immediately continues working in the last paradigm just as before you turned the power off.

(16) Switch to paradigm #1. **Press:** 'ALL, 1, ENTER'. Note that this paradigm is also stored in the memory after turning the power off.

Dear User,

The last chapter was a brief demonstration of how to use **Master-8**. Now you have some idea of how **Master-8** works, but it is not enough. There are many instructions that you are not yet familiar with e.g. DC, GATE, CHECK, TIMER. Even the features that are demonstrated above are only partially demonstrated. Please read the rest of this manual carefully so that you will not miss any important feature. Pages 10-16 deal with the operation of **Master-8**. Pages 17-23 are about the communication of **Master-8-cp** with a computer.

(17) Before continuing clear all the memory of **Master-8** —
Press: 'OFF, ALL, ALL, ALL, ENTER'. (see page 14).

Modes of Operation

Each of the 8 channels can operate in one of the following modes:

FREE RUN: The channel delivers pulses continuously according to the programmed duration and interval times. The channel is independent of the other channels.

TRAIN: Following a trigger, the channel delivers a train of pulses according to the programmed duration and interval times. The number of pulses per train is set by 'M'.

TRIG: Following a trigger, the channel delivers a single pulse according to the programmed delay and duration times.

DC: The channel delivers a DC pulse (time independent). The channel turns on and off manually.

GATED: (available only on channels 1 and 2, the external gate is input through EXT 1 or EXT 2). The channel delivers pulses continuously while it is externally gated. When the external input stops, the channel stops working. A new input reactivates the channel.

Before operating a channel in one of the modes, the relevant parameters to that mode have to be programmed.

When on one of the modes TRAIN or TRIG the channel can be triggered by:

- 1) Manually.
- 2) The internal connections.
- 3) EXT 1 (for channel 1 only) EXT 2 (for channel 2 only).

Setting the modes of operation

In order to set the mode of operation of a channel, first press the chosen mode key then the channel number.

Example 1: In order to set channel #2 to the FREE-RUN mode —

Press: 'FREE, 2, ENTER'.

Channel #2 now delivers pulses continuously, according to the duration and interval preprogrammed times (or the default times).

Example 2: In order to set channel #3 to the TRAIN mode —

Press: 'TRAIN; 3, ENTER'.

Channel #3 is now on the TRAIN mode. There are several ways to trigger it. Trigger it now manually by pressing '3' (the channel number).

Example 3: In order to turn off channel #2 —

Press: 'OFF, 2, ENTER'.

Example 4: In order to turn off all the channels —

Press: 'OFF, ALL, ENTER'.

Setting Parameters

In order to set the time parameters (DURA, DELAY or INTER), first press the chosen parameter key then the time desired.

Example: In order to set the duration of channel 6 to be 52 msec (52×10^{-3} sec, the time is always given in seconds).

Press: 'DURA,6'. (The previous duration is displayed. If the duration time has never been inserted, the sign 'FFFF FF' is displayed).

Now press: '52,ENTER, 3, ENTER'. ('3' for msec)

Before pressing the ENTER key, you can change the instruction. The time is accepted only after the last ENTER.

52 msec can be inserted also as 0.052×10^0 sec, or 5.2×10^{-2} sec, or 5200×10^{-5} sec, etc.

For your convenience it is recommended to use only exponents of 6 (μ sec), 3 (msec) or 0 (sec). Thus for 52 msec use either 52 msec or 0.052 sec.

Using the '↑' and '↓' keys:

You can increase or decrease each time parameter using the '↑' and '↓' keys.
Example: **Press:** 'DURA, 6'. Now, prolonged presses on the '↑' and '↓' keys change the duration of channel 6. **Please note that the change takes place only after releasing the key.**

Setting the 'M' parameter:

Example: To set $M=80$ pulses per train on channel 8, —

Press: 'M,8'. The previous M8 is displayed.

Now press: '80, ENTER, 0, ENTER'.

Only integer numbers are accepted for M. The exponent should equal 1 only for $M > 9999$.

Counting the pulses

Whenever channel 8 is in the TRAIN mode, the display shows how many pulses still remain on the existing TRAIN.

Press: 'TRAIN, 8, ENTER'.

Now trigger channel 8 manually by pressing: '8'.

Table 1

Parameters and error indication

	Min	Max	Error indication for illegal values. (x is the channel number)	
1. M	1	59,990	Mx	Err
2. DURATION	40µsec	3999 sec	Dx	Err
3. DELAY	100µsec	3999 sec	Lx	Err
	DELAY > DURATION / 10,000		Lx	Err
4. INTERVAL	60µsec	3999 sec	Ix	Err
a) Normal usage:	INTERVAL > DURATION + 9µsec		Rx	Err (Rate err)
b) Train mode:	INTERVAL > DURATION + 59µsec		Tx	Err (Train err)
c) If the channel internally activates other channels:	INTERVAL > 500µsec		Cx	Err (Connect err)

Example: The message 'R7 Err' indicates 'Rate error' on channel #7. The reason is that the channel is now running on FREE-RUN, GATE or TRAIN mode, and the interval is shorter than the duration or at least
INTERVAL < DURATION + 9 µsec.

In order to get rid of the R7 Err message you should move out of this situation in one of the following ways:

- a) increase the interval time of channel #7.
- or b) decrease the duration time of channel #7.
- or c) change the mode of channel #7 to TRIG, DC or OFF.

Please note that there is no delay in the TRAIN mode. The channel delivers the train of pulses immediately after receiving the trigger input. In order to get a delay time, you should use an intermediate channel in the TRIG mode.

Triggering

Manual triggering

In the modes: TRAIN, TRIG, or DC the channel can be triggered manually.

Example 1: When channel 3 is on the TRAIN mode, every press on the '3' key, evokes a train of pulses according to the parameters of channel 3.

Example 2: When channel 4 is on the DC mode, every even press '4' turns the channel on, and every odd press turns it off.

When a channel is not in one of the above modes, or if it has already received a trigger but has not yet completed its response, pressing the channel number does not affect the channel (It just clears the display).

Setting the internal connections:

In the modes TRAIN or TRIG the channel can be triggered by other channels internally. Each channel has an internal input and an internal output. By inserting the right instructions, you can connect an internal input to an internal output.

Example 1: In order to connect the output of channel 2 to the input of channel 3 —
Press: 'CONNECT, 2, 3, ENTER'.

The arrow above the display shows the direction of the connection. For example, $\overline{2}3$ means that the output of channel 2 is connected to the input of channel 3. Every internal output can be connected to any number of internal inputs. Every internal input can be connected to any number of internal outputs. The level or polarity of the output does not affect the internal connections.

Disconnecting is performed by pressing the 'CONNECT' key twice.

Example 2: In order to disconnect an existing connection between 2 and 3 —
Press: 'CONNECT, CONNECT, 2, 3, ENTER'.

It is possible to disconnect all inputs or outputs of any single channel.

Example 3: To disconnect all outputs from channel 5 —
Press: 'CONNECT, CONNECT, 5, ALL, ENTER'.

Example 4: To disconnect all inputs to channel 5 —
Press: 'CONNECT, CONNECT, ALL, 5, ENTER'.

Example 5: To disconnect all inputs and all outputs of all channels —
Press: 'CONNECT, CONNECT, ALL, ALL, ENTER'.

The external inputs

In the modes: TRAIN, TRIG or GATE channels 1 and 2 can be triggered (gated) externally. EXT 1 activates only channel 1. EXT 2 activates only channel 2. (channels 1 and 2 can activate the other channels internally).

The external input has to be in the range of 5-10 V.

Please note that a computer can trigger each channel directly 'manually' via the RS-232 interface of **Master-8-cp** (see page 17).

Eight Stored Paradigms

A paradigm specifies the modes and parameters of all the channels and their internal connections. **Master-8** stores eight different programmed paradigms. The changeover from one paradigm to another is very fast (50 msec).

Transferring to another paradigm

Example: To transfer to paradigm number 7 — **Press:** 'ALL' (the previous paradigm is displayed) '7, ENTER'.

You don't have to worry about saving the old paradigm. Each instruction is saved the moment you insert it.

NOTE: Transferring from one paradigm to another **does not** affect the clock, the stop-watch or the timer.

Copying paradigms

Copying paradigms is very useful when you want a new paradigm with just some changes from a present one. Instead of programming the whole new paradigm, you can copy the present one and just make the changes.

Example: In order to copy paradigm #2 to paradigm #6 —

Press: 'ALL, 2, 6, ENTER'. (Please note the arrow sign ('→') for the source-target direction). Paradigm #2 is not affected by this instruction.

Clearing the memory

In order to turn off all the channels — **Press:** 'OFF, ALL, ENTER'.

In order to disconnect all the internal connections (in the present paradigm) — **Press:** 'CONNECT, CONNECT, ALL, ALL, ENTER'.

In order to clear all the memory of the present paradigm —

Press: 'OFF, ALL, ALL, ENTER'. This will turn off all the channels, disconnect all the internal connections, and change all the parameters of all the channels to the initial values 'FFFF FF'.

NOTE: Clearing the present paradigm does not affect the other paradigms, the clock, the stop-watch and the timer.

In order to clear all the memory of all the 8 paradigms (and **Master-8** will then be without any user program)

Press: 'OFF, ALL, ALL, ALL, ENTER'.

Ways to Check

There are many details you can check. All the checking instructions begin with the word 'CHECK'.

1) To check the modes of all the channels —

Press: 'CHECK, ENTER'.

The display shows the modes of all the channels that are not turned off and the present paradigm number.

2) To check the mode and the parameters (DURATION, DELAY, INTERVAL and M) of a specific channel (e.g. channel 2) —

Press: 'CHECK, 2, ENTER'.

You can check (and change) each parameter individually, as described above (in 'setting parameters', Page no. 11).

3) Checking the internal connections:

Example 1: To check which inputs are internally connected to the output of channel 4 —

Press: 'CHECK, 4, CONNECT, ENTER'.

If channel 4 does not have any output connections this instruction just clears the display.

Example 2: To check which outputs are internally connected to the input of channel 7 —

Press: 'CHECK, CONNECT, 7, ENTER'.

Note the arrow above the display shows the direction of the connections.

Example 3: To check all the internal connections —

Press: 'CHECK, CONNECT, CONNECT, ENTER'. (or: 'CHECK, CONNECT, ENTER').

Clock Options

In addition to its standard 8 channels, **Master-8** features 2 internal clocks. The first is called 'clock' and counts the time in seconds up to 24 hours. The other called 'stop-watch' counts the time by tenths of seconds up to 1 hour.

The clock

The clock is used:

- 1) to measure the time that passed from an event (e.g. the beginning of the experiment).
- 2) for the 'TIMER' option (see below).

The clock time can always be displayed by pressing the 'CLOCK-DISPLAY' key. The clock can be reset by pressing the 'CLOCK-RESET' key. The resetting can be performed **only when the clock time is displayed**.

The clock never stops running. A second press on 'CLOCK-DISPLAY' (or any other key except the 'CLOCK-RESET' key) clears the clock display.

The stop-watch

The first press on the 'STOP-WATCH' key displays its present situation. Then every odd press activates it and every even press stops it.

The stop-watch can be reset by the 'CLOCK-RESET' key **only when the stop-watch time is displayed**.

NOTE: The main 'RESET' key resets both clocks, regardless of what was shown on the display.

The timer

The TIMER is linked to the clock and can change the mode of any single channel at a fixed time. For example, if you want to set the experiment to stop at a given time you can instruct one channel (or all of them) to do so.

Example 1: In order to turn off channel #2 at 3:45 (as counted by the **clock**).

Press: 'TIMER, ENTER'. Now the timer shows its last setting (if no instruction was inserted, it shows 'OFF').

Now Press: 'OFF, 2, ENTER, 3, ENTER, 45, ENTER'.

Check by pressing: 'TIMER, ENTER'.

To exit from the TIMER checking, press the CLEAR-DISPLAY key.

Example 2: If the TIMER is already set and you want to cancel the TIMER action, you can turn the TIMER off by pressing: 'TIMER, OFF, ENTER'.

Master-8-cp

Programming by a computer

Master-8-cp can be programmed through the front panel keys in the same way as **Master-8**. In addition **Master-8-cp** can be programmed via a computer or even by a terminal consisting of a monitor and a keyboard.

In order to communicate with a computer, you should connect the **Master-8-cp** to the computer via the standard RS-232 interface on the rear panel. The connections are described in Appendix A.

Master-8-cp can receive and transmit ASCII characters. The setting of the communication parameters i.e. baud-rate and the character-format is very simple (See Appendix B).

Communication

A. PROGRAMMING **Master-8-cp** BY A COMPUTER

Programming **Master-8-cp** via a computer is identical to programming it via the front panel keys. Each key has a corresponding code (see Appendix C). Sending the code by the computer has the same effect as pressing the specific key.

Example 1: The instruction: 'FREE, 3, ENTER' (meaning set channel #3 on the FREE-RUN mode) is performed by the computer writing 'F 3 E' to **Master-8-cp**. (See Appendix C).

Example 2: The instruction: 'DURA, 2, 1.4, ENTER, 3, ENTER' ("set the duration of channel #2 to be 1.4 msec") is performed by the computer writing — 'D 2 1.4 E 3 E' to **Master-8-cp**.

In fact, **Master-8-cp** does not distinguish whether a certain instruction was inserted via the keys or via the computer (except for the CHECK instruction, see below).

Please note that the computer can trigger each channel 'manually'.

Example 3: When channel #8 is on the TRIG or TRAIN mode, you can trigger it manually by pressing the '8' key. The computer can also trigger channel #8 manually by writing '8' to **Master-8-cp**.

B. COMMUNICATION FROM **Master-8-cp** TO THE COMPUTER.

The communication from the computer to **Master-8-cp** does not need any initial or final codes. **Master-8-cp** is always 'listening' to the computer. However, in the communication from **Master-8-cp** to the computer, the computer has to send codes indicating that it is ready to accept information. Otherwise its internal buffer will fill with insignificant information.

Whenever the computer is ready to receive information, its program has to send to **Master-8-cp** the initial code 'B 1 E' (meaning B=1, ENTER). To stop the flow of

information, the code 'B 0 E' (B=0) should be sent to **Master-8-cp**. While B=1, **Master-8-cp** transfers all the information that appears on the front panel display to the computer.

When **Master-8-cp** accepts a CHECK instruction, it recognizes whether it was sent by the front panel keys or by the computer. If it was sent by the keys **Master-8-cp** waits a while after displaying each parameter. If it was sent by the computer **Master-8-cp** does not wait at all, and sends the suitable information to the computer. In the case of the CHECK instruction, **Master-8-cp** sends information even when B=0.

You have to take special care when you send the CLOCK or STOP-WATCH information to the computer, because this information is running continuously and can easily fill internal buffers of the computer. Whenever you want to read such information from **Master-8-cp**, send the letters 'B 2 E' (B=2), read the information and immediately set back to B=0 or B=1.

The instruction 'H X E' (checks all the internal connections, like 'CHECK, CONNECT, ENTER') invokes **Master-8-cp** to send a table of all the internal connections to the computer as follows:

➔	1	2	3	4	5	6	7	8	
1			+	+		+	+		
2					*				
3							+		
4							*		
5			+						
6									
7		+				+			
8									

'*' — Symbolizes that there is an operational connection between the two channels. i.e. there is a connection between them, and it fulfills the following conditions:
 a) The target channel is in one of the modes TRIG or TRAIN (the modes in which the channel expects a trigger input).
 b) The source channel is not in the OFF mode. (Thus it may send a trigger).
 In the table there is an operational connection from channel #2 to channel #5.

'+' — symbolizes that there is a connection that is not operative between the two channels. In the above table all the internal outputs of channel #1 are not operative.

The instruction 'H A E' ('CHECK, ALL, ENTER') transfers to the computer (or monitor) all the information about the present paradigm. (the table of the connections, the modes and parameters of all the channels).

See Appendix D for some examples of communication with a computer.

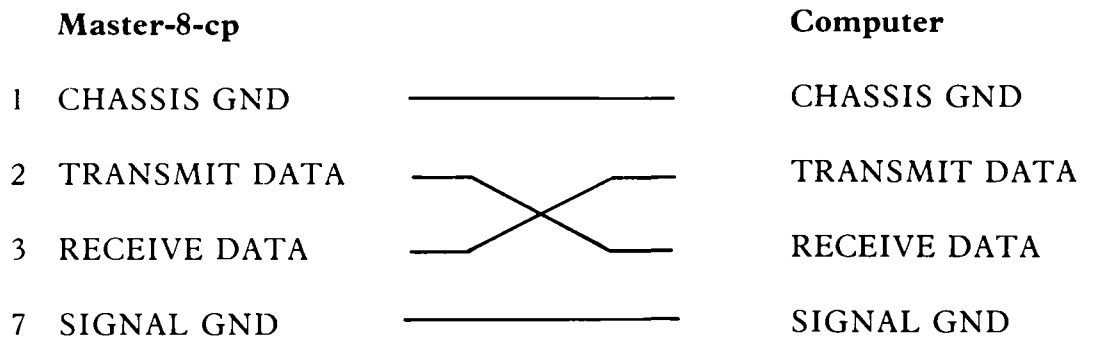
Communication between Master-8-cp and a terminal

The communication between **Master-8-cp** and a terminal (monitor and keyboard) is identical to the communication with a computer, but it is recommended to insert the initial code 'B 1 E' at the beginning of the communication (without the final code 'B 0 E').

In this case **Master-8-cp** sends all the information that appears on its display to the monitor. The instruction 'H X E' ('CHECK, CONNECTIONS, ENTER') causes **Master-8-cp** to send the connections-table to the monitor as described above. The instruction 'H A E' sends all the parameters of the present paradigm, including the table of connections.

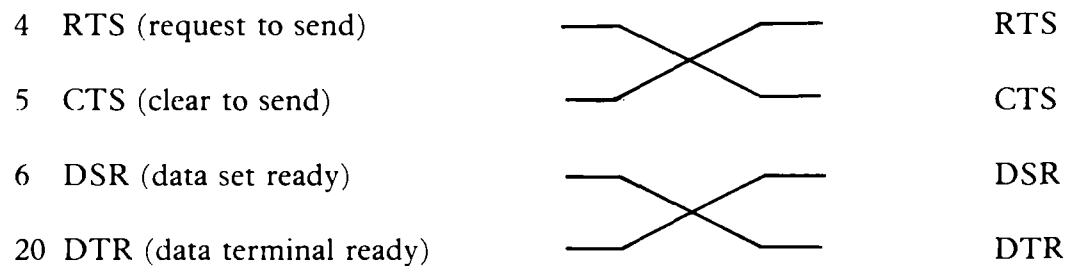
Appendix A

For minimum system interconnection, pins no. 1, 2, 3, 7 should be connected as follows:

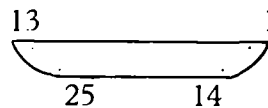


A jumper should be connected between pins no. 4 and 5 (CTS,RTS) on the connector in the **Master-8-cp** side.

For a regular connection, pins no. 1, 2, 3, 7 should be connected as described above, without the jumper between pins 4 and 5. In addition pins no. 4, 5, 6, 20 should be connected as follows:



The RS-232 connector:



Appendix B

Setting the baud-rate and character format

- 1) A double press on the ALL key shows the present baud rate. Each additional press on the ALL key selects the next baud-rate in the cycle:
75,110,150,200,300,600,1200,2400,4800,9600,19200.
- 2) Pressing the ENTER key latches the selected baud-rate.
- 3) BITS PER CHARACTER: Each press on the ALL key selects either 7 or 8 bits per character (ASCII).
- 4) Pressing the ENTER key latches the number of bits per character.
- 5) PARITY BIT: Each press on the ALL key selects the next parity mode in the cycle: 0 — no parity. 1 — odd parity. 2 — even parity.
- 6) Pressing the ENTER key latches the selected parity.
- 7) STOP BITS: Each press on the ALL key selects either 1 or 2 stop bits.
- 8) Pressing the ENTER key latches the selected number of stop bits.
- 9) Press: CLEAR-DISPLAY.

Check that you selected the right setting **by pressing:** —
CHECK, ALL, ENTER.

Appendix C

The codes of the keys

DURATION	— D	A,9	— ALL, 9
INTERVAL	— I	B	— BEGIN
DELAY	— L	C	— DC
<u>M</u>	— M	D	— DURATION
FREE-RUN	— F	E	— ENTER
TRAIN	— N	F	— FREE - RUN
TRIG	— G	G	— TRIG
DC	— C	H	— CHECK
GATE	— T	I	— INTERVAL
<u>OFF</u>	— O	L	— DELAY
0, TIMER	— 0,W	M	— M
1-8	— 1-8	N	— TRAIN
9,All	— 9,A	O	— OFF
<u>'</u>	— '	Q	— CLOCK DISPLAY
CLOCK DISPLAY	— Q	R	— CLOCK RESET
STOP-WATCH	— S	S	— STOP-WATCH
<u>CLOCK RESET</u>	— R	T	— GATE
CHECK	— H	W,0	— TIMER, 0
CLEAR DISPLAY	— Y	X	— CONNECT
CNCT/DSCNCT	— X	Y	— CLEAR DISPLAY
*DISCONNECT	— Z	Z	— DISCONNECT
<u>ENTER</u>	— E	1-8	— 1-8
BEGIN	— B	'	— '

Appendix D

Notes for programming the Master-8-cp by a computer

When programming **Master-8-cp** through your own program, you have to program the RS-232 communication parameters first.

For example the instruction (BASIC, IBM compatibles):

```
OPEN "COM1,9600,N,8,1,CS,DS,LF,PE" AS #1
```

tells the PC to communicate at baud rate 9600, no parity, 8 bits per character, 1 stop bit and suppress the control lines. From now on the computer refers to **Master-8-cp** as #1. Now, to operate channel 3 on the FREE-RUN mode, you can use the instruction:

```
PRINT #1,"F 3 E";  
which is the equivalent to 'FREE, 3, ENTER'.
```

To set the duration of channel 3 to 250 msec. use the instruction:

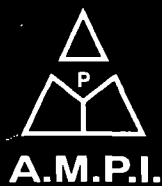
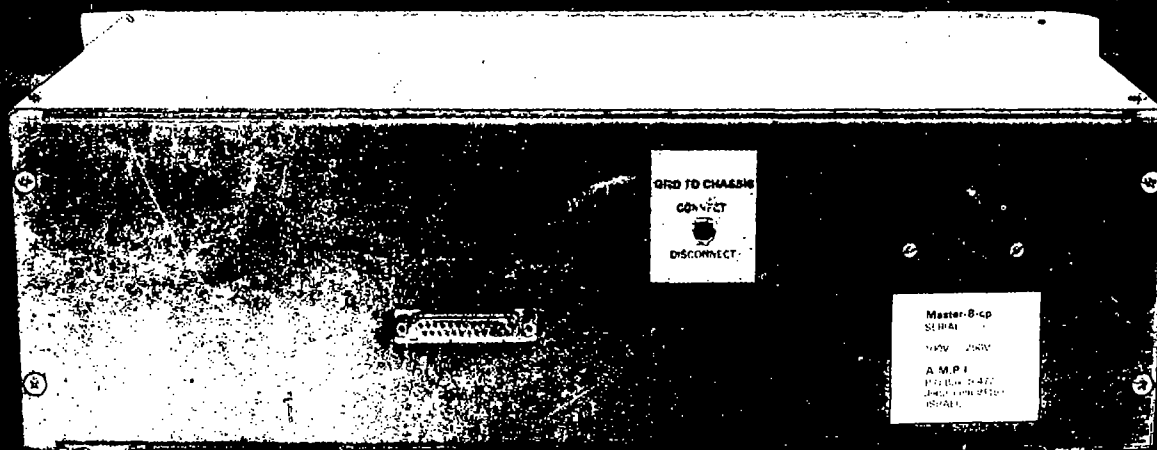
```
PRINT #1, "D 3 250 E 3 E";  
which is the equivalent to 'DURATION, 3, 250, ENTER, 3, ENTER'
```

One can also use variables. The following is an example of programming the delay of channel 1 to be 100 msec., delay 2 to be 200 msec., delay 3 to 300 msec. etc.

```
FOR I=1 TO 8  
J=100*I  
PRINT #1,"L";I;J;"E 3 E";  
NEXT I
```

The instruction `PRINT #1,"L";I;J;"E 3 E";` has the meaning: Set the delay of channel I, into J msec.

When you switch between paradigms please note that the changeover takes a while. Thus after the instruction to switch to a new paradigm, you should make a break of 100 msec in your program before giving a new instruction.



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VCS

Master-8-vp

THE VOLTAGE PROGRAMMABLE
PULSE GENERATOR



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In this manual we assume that you have already read the manual of Master-8. Thus, it describes only the features of Master-8-vp that Master-8 does not have.

If you are an experienced user of Master-8 you probably know that Master-8 is a very flexible unit. Master-8-vp adds this flexibility in the fields that require increment/decrement voltage steps.

Using the FIXED STEPS or the VARIED STEPS modes, in combination with the different modes of operation: FREE-RUN, TRIG, TRAIN, GATE and DC, and setting the 8 channels to synchronize the voltage steps with many other instruments, make Master-8-vp a very effective and powerful tool in your lab.

On the following pages you will find:

- Page 2 - Introduction
- 3 - Setting Parameters
- 6 - Output Offset
- 6 - Output '4+5'
- 6 - Parameters
- 7 - Demonstration
- 9 - Appendix A: Higher Voltage Resolution
- 10 - Appendix B: Voltage Calibration
- 11 - Appendix C: Capacitive Currents
- 12 - Appendix D: Communication With a PC

INTRODUCTION

General

Master-8-vp has the same features as Master-8-cp. You can easily switch between 8 preprogrammed paradigms (in order to switch between different experiments) using a single command. You can set all parameters using the front panel keys or via the RS-232 interface. You can also run the channels in the following modes: FREE-RUN, TRIG, TRAIN, DC and GATE and have the same parameters and time and voltage ranges as described in the manual of Master-8.

The only additional feature of Master-8-vp over Master-8-cp is the output voltage control of channels 4 and 5.

VOLTAGE CONTROL

While in all the other channels you adjust the voltage output level using the front panel knobs, the voltage amplitudes of channels 4 and 5 are programmed via the front panel keys or via a PC.

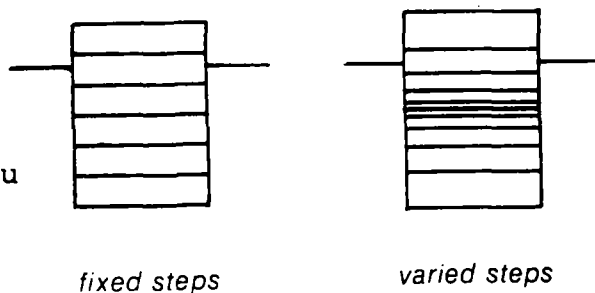
INCREMENT AND DECREMENT STEPS

Master-8-vp has an additional powerful feature - Channel 5 can be set to increment or decrement output voltage steps. You set these steps in one of three modes:

1) No steps - You set $\Delta V=0$ and you don't have any steps (all the output pulses of channel 5 have the same amplitude).

2) Fixed steps - You set the ΔV and the number of steps per cycle. The number of steps is unlimited. The only limit is the saturation of the voltage range.

3) Varied Steps - You set each individual step and the number of steps per cycle. You can mix depolarizing and hyperpolarizing steps. The number of steps is limited to 30 steps per cycle.



Setting Voltage Parameters

You can set the voltage amplitude of channels 4 and 5.

Example 1: In order to set the amplitude of channel 4 to - 2.3 V -
Press: 'V , 4, 2.3, ENTER, -, ENTER' .

Example 2: In order to set the amplitude of channel 5 to 1 V -
Press: 'V , 5, 1, ENTER, ENTER' .

The voltage range is from -12.7V to +12.7V with steps of 0.1 V.
(If you use Master-8-vp as the EXTERNAL COMMAND driving a Patch Clamp unit, the Patch Clamp divides the amplitude by a factor of 10 to 1000).

If you want smaller steps than 0.1 V, and you don't mind having a smaller voltage range, you can modify the steps and range as described in Appendix A.

Setting ΔV

In channel 5 you can set the increment or decrement of the voltage amplitude. You can use one of three modes: NO STEPS, FIXED STEPS or VARIED ST

1) NO STEPS mode - Set $\Delta V = 0$ by pressing: ' ΔV , 0, ENTER, ENTER'.
Now there is no increment/decrement in channel 5.

2) FIXED STEPS mode - Set the ΔV to the desired value and set the number of steps per cycle. The number of steps is unlimited. The only limit is the saturation of the voltage range.

Example 1: In order to set decrement of -0.3 V -
Press: ' ΔV , 0.3, ENTER, -, ENTER'.

Example 2: In order to set increment of 1.2 V -
Press: ' ΔV , 1.2, ENTER, ENTER'

Please note that ΔV always rides on the voltage amplitude of channel 5.

The number of steps per cycle is set by M of channel 5. Channel 5 can be set to all the modes :FREE-RUN, TRIG, TRAIN, DC and OFF.

Example 3: If $V5=2$, $M5=4$ and $\Delta V=0.5$ then:

the 1st pulse = 2.5V
the 2nd pulse = 3V
the 3rd pulse = 3.5V
the 4th pulse = 4V

Channel 5 delivers its pulses using the time parameters (DURATION, INTERVAL and DELAY) the same way as the other channels do. The only difference is the increment/decrement steps.

In the above example it is interesting to understand what channel 5 does in each of the different modes of operation:

- TRAIN : Following each trigger channel 5 delivers the above 4 pulses.
TRIG : Following each trigger channel 5 delivers the next pulse in the above cycle. If there is a trigger after the last pulse, the cycle starts again.
FREE-RUN: Channel 5 generates pulses continuously. The amplitude of the pulses varies in the above cycle. After the last pulse the cycle starts again.
DC : The channel is time independent. The first time that you press '5' (manual trigger) the channel delivers a DC output with the first amplitude (2.5V in the example). The next '5' terminates the DC output. The next '5' delivers the 3V DC output and the next one terminates it, etc.

Channel 5 (as every other channel) can be triggered:

- 1) Internally, by another channel through the internal connections.
- 2) Manually, by pressing '5' (- the channel number).

When you want to trigger channel 5 by the computer you can do it in one of the following ways:

- 1) The computer triggers channel 1 (or 2) via the 'EXT 1' ('EXT 2') input. Internally connect channel 1 to trigger channel 5. Channel 1 can also be used to trigger the oscilloscope, recorder, etc.
- 2) 'Manually' by the computer: The computer sends the letter '5' (- the channel number) via the RS-232 interface.

For most applications you may use channel 5 in the TRIG or TRAIN modes and the trigger comes from the computer, from another channel or manually. In the demonstration of page 7 please find examples of such applications.

2) Varied Steps - You set each individual step and the number of steps per cycle. You can mix depolarizing steps with hyperpolarizing steps. The number of steps is limited to 30 steps per cycle.

Example 1: In order to set 4 pulses per cycle: the first step -8.5V, the second -5V, the third -2V and the fourth +2V:

- 1) Set M of channel 5 to 4 by pressing: ' M, 5, 4, ENTER, ENTER'.
- 2) Set V5=0 by pressing: ' V, 5, 0, ENTER, ENTER'.
- 3) Set the VARIED STEPS by pressing: ' ΔV, ENTER'
Now press: '8.5, ENTER, -, ENTER' (first pulse -8.5V)
and continue: '5 , ENTER, -, ENTER, (second pulse -5V)
'2 , ENTER, -, ENTER, (third pulse -2V)
'2 , ENTER, ENTER' (fourth pulse +2V)

Please note that by this instruction you set the different step levels, but you still haven't switched to the VARIED STEPS. Thus you still get the FIXED STEPS.

- 4) Switch to the VARIED STEPS by pressing: ' ΔV, OFF, ENTER'.

If you want to switch back to the FIXED STEPS, set the desired increment/decrement step again.

NOTE:

When ΔV = OFF - Master-8-vp uses the VARIED STEPS.

When ΔV = Value - Master-8-vp uses the FIXED STEPS.

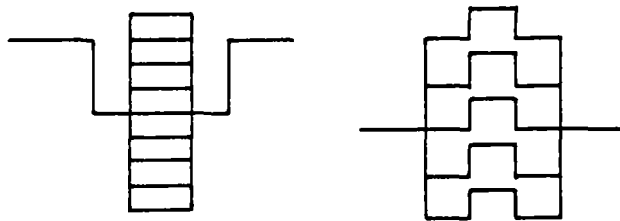
When ΔV = 0 - Master-8-vp doesn't have any steps (but delivers pulses with constant amplitude = V5).

Output Offset

You can adjust the voltage offset using the knobs of channels #4 and #5.

Output '4+5'

Output '4+5' is the summation of channels 4 and 5. Thus from this output you can get pulses like the following examples:



In each example the ΔV can be fixed or varied by presetting each individual ΔV .

Parameters

In Channels 4 and 5 the parameters are as follows:

Voltage range: from -12.7 volt to +12.7 Volt.

Interval time of Channel #5: 500 usec. to 3,999 sec. (more than an hour).

In all the other channels all parameters are as described in the OPERATION MANUAL of Master-8.

Demonstration

In order to follow the demonstration in this chapter use an oscilloscope. In this demonstration we use channel 1 as the trigger source to channels 4 and to the scope.

Connect channel 1 to the external trigger input of the scope. Set channel 1 to run with the following parameters:
FREE-RUN mode, $D_1=0.1$ msec., $I_1=500$ msec.
Check that channel 1 now triggers the scope.

Set the scope to run with the parameters: TIME: 1 msec/div, GAIN : 1V/div. Connect the '4+5' output to the scope.

Make sure that the offset knobs of both channels 4 and 5 are adjusted to 0.

Now set the modes, time parameters and amplitudes of channels 4 and 5:

1) Channel 4: TRIG mode, $D_4 = 0.5$ msec., $L_4 = 2$ msec., $V_4 = 1$ Volt.
Connect channel 1 to trigger channel 4.

Now on the scope you see the pulses of channel 4.

2) Channel 5: TRIG mode, $D_5 = 4$ msec., $L_5 = 15$ msec., $V_5 = -2V$
and $\Delta V = 0$ (no increment/decrement)
Connect channel 1 to trigger channel 5.

On the scope you now get the outputs coming from both channels 4 and 5.

So far we set the timing and voltage parameters. You don't get increment/decrement steps as $\Delta V=0$.

Now lets say that we want increment steps in channel 5, using 6 fixed steps of 0.5 V each:

3) Set $M_5 = 6$, $\Delta V = 0.5V$. Watch the results on the scope. Please note that the increment steps ride on the $V_5 (= -2V)$ pulse.

4) Change to $V_5 = 0$. Watch the scope.

5) In order to switch to the VARIED STEPS, Press: ' ΔV ,OFF, ENTER'
You don't see any steps as all the steps now have their default value = 0.

6) Now lets say that we want the following VARIED STEPS:
-4V, -2V, -1V, -0.5V, +2V, +4V .

In order to set these steps press: ' ΔV , ENTER'

Now Master-8-vp is ready to get the different steps.

Press: '4,ENTER,-,ENTER, 2,ENTER,-,ENTER, 1,ENTER,-,ENTER, 0.5,ENTER,-,ENTER, 2,ENTER,ENTER, 4,ENTER,ENTER' .

Now press: 'CLEAR DISPLAY' In order to exit out of the sequence.

Watch the scope and see that you get the varied ΔV .

7) Switch back to FIXED STEPS by setting $\Delta V = 0.5V$, Watch the scope.

8) In order to switch back to the VARIED STEPS, Press: ' ΔV , OFF, ENTER'.
Watch the scope.

9) Set $V_5=1V$, The VARIED STEPS ride on the 1V pulses.

10) If you don't want any steps set $\Delta V = 0$.

* Please note that it is very convenient to switch between NO STEPS
($\Delta V=0$), FIXED STEPS (ΔV =any value), and VARIED STEPS (ΔV =OFF).

12) So far channel 1 is running continuously. Lets trigger channel 1 manually
Set channel 1 to the TRIG mode.

Now each time that you trigger channel 1 (manually, by pressing '1', or
through the PC via the 'EXT 1' input) you get the next trace in the above
cycle.

13) Set channel 1 to the TRAIN mode. Set $M_1=6$ (M_1 should be equal M_5). Now
each time that you trigger channel 1 you get the whole cycle.

Please note that in this example M_1 counts the number of pulses per train
of channel 1 which is the number of pulses per cycle. M_5 counts the number
of different amplitude levels in the cycle. Usually M_1 should be equal to
 M_5 . It may happen that the pulses of 'OUT 5' do not start from the first
pulse. In this case press: ' TRIG, 5, ENTER' to restart the pulses.

* Please note that different paradigms store different sets of steps.
Thus you can also change the steps by transferring between paradigms.

* When you copy one paradigm to another you also copy the entire sequence
of the steps.

APPENDIX A - Higher Voltage Resolution

The voltage range of channels 4 and 5 is from -12.7 V to +12.7V. with resolution of 0.1V. This range and resolution are suitable to patch clamp units as the patch clamp divides this output by a factor of 10 to 1000. However, if you want a finer resolution, you can double it, by dividing the output of the channel by a factor of 2. This gives a resolution of 0.05 V but changes the whole range to -6.35 V to 6.35 V.

You should keep in mind that Master-8-vp does not know that you made this change. Thus, after switching, if you want an output of 1 V, you should set the channel to a 2 V output.

In order to divide the output, open the top cover, and find 2 small red DIP switches on the rear side of the circuit board. The one to your left relates to channel 4 and the one to your right relates to channel 5. If you didn't make any changes, both switches are in the OFF position, and the output is not divided. In order to divide the output of channel 4 by a factor of 2, set the left switch to ON. In order to divide the output of channel 5 by a factor of 2, set the right switch to ON. Now you may have to adjust the zero level and calibrate the output voltages as described in Appendix B.

APPENDIX B - Voltage Calibration

Before shipping the unit we already calibrated the output voltages. However, if you find that the output voltage of channels 4 and 5 are not accurate, you can calibrate them. First check that the offset knobs of those two channels on the front panel are set to 0 offset. Now remove the top cover of Master-8-vp. On the rear part of the circuit board, find 4 trim-potentiometers (trimpots). These trimpots are blue or gray. They protrude above the surface and have a rectangular shape. Each one has a small screw on its side.

Concerning these 4 trimpots: The one to your left side (A) is to adjust the zero level of pulses from channel 4. The second one from the left (B) is to adjust the zero level of pulses from channel 5. The third from the left (C) is to calibrate the voltage output of channel 4 and the one to your right (D) is to calibrate the voltage output of channel 5.

In order to make the adjustments and calibrations, we use channel 1 as the trigger source to channels 4 and 5 and to the scope:

Connect channel 1 to the external trigger input of the scope. Set channel 1 to run with the following parameters:
FREE-RUN mode, D1=0.1 msec., I1=500 msec.
Check that channel 1 triggers the scope.

Set the scope to run with the parameters: TIME: 1 msec/div, GAIN : 1V/div. Connect the '4+5' output to the scope.

Now set the modes, time parameters and amplitudes of channels 4 and 5:

1) Channel 4: D4 = 1 msec., L4 = 3 msec., V4 = 1 V, Mode 4 = TRIG.
Connect channel 1 to trigger channel 4.
Now on the scope you see the pulses of channel 4 with the above parameters.

2) Channel 5: D5 = 4 msec., L5 = 5 msec., V5 = 1 V, Mode 5 = TRIG.
Set $\Delta V = 0$ (no increment/decrement). Connect channel 1 to trigger channel

On the scope you now get the outputs coming from both channels 4 and 5.

3) ZERO ADJUSTMENT:

Now set V4=0, V5=0. Switch the gain of the scope to 0.1V/div. Check that both outputs are zero. If not, using a fine screwdriver, turn the screw on the left trimpot (A) for zero adjustment of channel 4, and that of trimpot (B) for zero adjustment of channel 5.

4) OUTPUT LEVEL CALIBRATION:

In order to calibrate the voltage output, first switch the gain of your scope to 2V/div, and set V4=12V, V5=12V.

Now adjust trimpot C to calibrate the output of channel 4, and trimpot D to calibrate the output of channel 5.

APPENDIX C - Capacitive Currents

If you are a patch-clamp user, you are probably familiar with the capacitive currents that may appear at the rise and fall of each pulse. These capacitive currents may be eliminated using the fast and slow capacitance in your patch-clamp unit. However, sometimes especially for large pulses, you cannot eliminate them completely.

Sometimes when using your patch clamp sampling program also to generate the command pulses, you may not see the capacitive currents even if they exist. This may happen because of the synchronization between the command pulses and the sampling. This occurs especially when the delay and duration of the command pulses are measured in units of samples and not in time units.

Thus, when the command pulses are generated from the sampling program it is possible that there are capacitive currents but you never sample them (because of the synchronization). If the same command pulses come from Master-8-vp and there is no synchronization with the sampling you may sample those capacitive currents.

APPENDIX D - Communication With a PC

When setting the parameters of Master-8-vp through your PC you should send ASCII codes of letters instead of pressing keys. The codes are the same as the codes of Master-8-cp. See the operation Manual of Master-8-cp Appendix C.

In addition Master-8-vp uses the following additional codes:

<u>key</u>		<u>code</u>	
'ΔV'	-	J	(for jumps)
'V'	-	V	
'-'	-	-	(the minus sign)

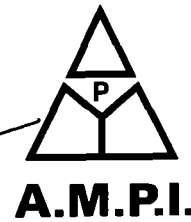
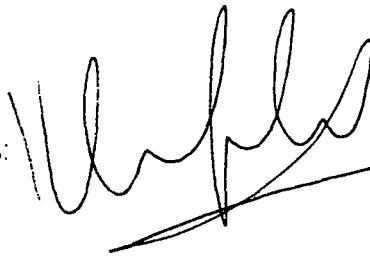
Example 1: The instruction (from panel keys): ' V, 5, 3, ENTER, -, ENTER' (meaning $V_5 = -3V$) is performed by the computer writing 'V 5 3 E - E'.

Example 2: The instruction : ' V, 4, 2.1, ENTER, ENTER' (meaning $V_4 = 2.1V$) is performed by the computer writing 'V 4 2.1 E E'.

Example 3: The instruction ' ΔV, 1, ENTER, -, ENTER' ($\Delta V = -1V$) is performed by the computer writing 'J 1 E - E'.

Example 4: The instruction ' ΔV, OFF, ENTER' ($\Delta V = \text{OFF}$, Switch to VARIED STEPS mode) is performed by the computer writing 'J 0 E'.

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March 16, 1997

Dear Doctor,

Thank you for buying Master-8 - the most flexible pulse generator. Enclosed please find two manuals. Read them carefully and become familiar with the flexibility of Master-8. The programming is friendly and easy to learn. I am sure that you will find Master-8 an attractive unit and you will enjoy working with its eight paradigms as many users do.

Please note that channels 4 and 5 are the voltage programmable channels. In the other channels you adjust the voltage amplitude using the channel knob. In channels 4 and 5 you set the voltage amplitude by the front panel keys or by a computer via the RS-232 interface. The front panel knobs of these 2 channels is used for the voltage offset.

You now have the Master-8-vp unit and you can program it in three ways:

- 1) Through the front panel keys.
- 2) By a computer, using the RS-232 interface.
- 3) By a terminal, using the RS-232 interface. You can program the Master-8 through the keyboard, and see its parameters on the monitor.

If you have an IBM or its compatibles, you can use the enclosed diskette. It contains two programs (written in QBASIC):

1) M8VP.BAS - With this interactive program you see on the screen all the parameters of the present paradigm, including the table of the internal connections. (Thus you can change the internal connections by moving the cursor within the table using the arrows of the keyboard.)

2) TERMINAL.BAS - This program switches your computer into a simple terminal. Now, in order to see on the screen the parameters of the present paradigm press 'H A E' (for: 'CHECK, ALL, ENTER').

Press: 'M8VP' (M8VP.BAT) to run the M8VP.BAS program, or 'TERMINAL' (TERMINAL.BAT) to run the TERMINAL.BAS program.

For connecting the Master-8-vp to your PC you have to use a wire as described in Appendix A in the manual of Master-8. For using the programs in the diskette choose (Appendix B): Baud-rate 9600, No parity, 8 bits per character.

If you have any questions or comments, please do not hesitate to contact me.

Very truly yours,



Dr. E. Armon
Sales Manager
A.M.P.I.