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SAFRAN FemtoStepper 100fs Resolution Phase Stepper User Manual

**Femto Stepper
100fs Resolution Phase Stepper**

User Manual

Contents

Introduction

The FemtoStepper provides a highly stable 10MHz, available on four outputs, that is adjustable In phase and frequency with an extremely high resolution. In addition to the 10MHz outputs, the microstepper provides a one

pulse per second (1PPS) available on four outputs generated form the 10MHz output.

The FemtoStepper provides a 10MHz signal that is derived from a high performance, ultra low phase noise crystal oscillator which is phase locked to an external 10MHz reference input. It allows to adjust the outputs in phase and frequency without disturbing the reference signal source and precautions are taken in order to minimize the added noise.

The design is based on a double heterodyne architecture where a first structure is used for positive phase / frequency adjustment and the second structure for negative adjustment.

The device is controlled remotely through an RS-232 serial link, which provides a prompt with a defined list of commands. All commands are parsed for correct syntax and operational range prior to execution. Commands that contain errors are rejected.
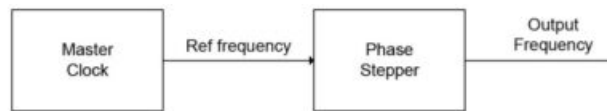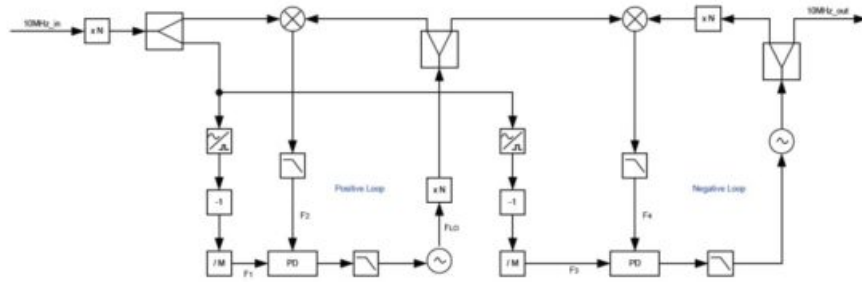

Figure 1: Application diagram

Figure 2: Block diagram

1.1. Frequency Adjustment

The frequency offset is applied to the output 10MHz OCXO through the double heterodyne structure in order to increase the resolution.

$$F_{out} = F_{in} + \frac{\Delta f}{G}$$

Where:

G: Heterodyne Gain of 106.

Δf is managed by the microprocessor.

$$F'_{out} = \frac{F'_{in}}{1 - \dfrac{N}{10^{17}}}$$

Where:

N: Frequency offset by 10-17 steps.

The frequency offset is always the absolute value from the 10MHz input.

The output range is limited nearly ±10-9. (±9.9999999 x 10-10)

1.2. Phase Adjustment

The output phase is adjustable with 0.1 picosecond resolution over a maximum range of ±50ns in order to cover an entire period of the 10MHz output signal. The phase adjustment is performed under microprocessor control.

1.3. Microprocessor Control and PPS (Pulse per Second) Facility

The microprocessor is controlling the functions. It is clocked by the 10 MHz_out. A division by 1e+7 is made, providing the PPS_out. The PPS_out can be aligned to a reference PPS_ref within +/- 200 ns when the command AL1 is issued.
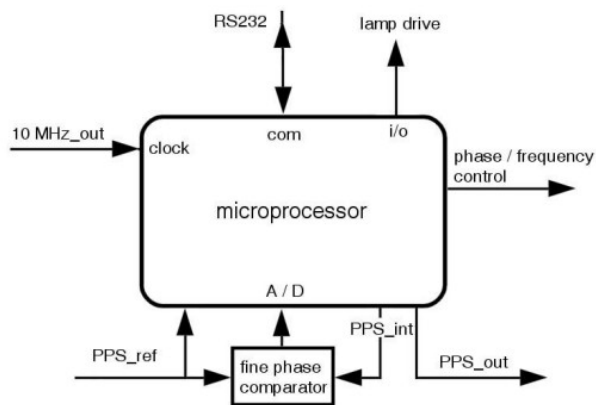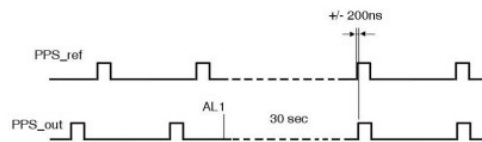
Figure 3: The microprocessor and its surrounding

Figure 4: The PPS_out can be aligned to the PPS_ref

Installation

2.1. Safety
Warning: Use proper ESD precautions
Caution: Ensure that all cables are properly connected
Handling the product in reasonably foreseeable conditions do not cause any risk for human health,exposure to the SVHC (substances of very high concern) would require grinding the component up.

2.2. Environmental Responsibility

- The equipment contains materials, which can be either re-used or recycled.
- Do not deposit the equipment as unsorted municipal waste. Leave it at an authorized local WEEE collection

  point or return to Safran Trusted 4D to ensure proper disposal.
- To return the appliance:
    - Submit a support ticket at aftersales.clocks@nav-timing.safrangroup.com and request an RMA.
    - We will contact you for more information and/or with shipment process details.

2.3. Unpacking
Unpack and carefully inspect the unit. Check for physical damage. If physical damage is observed,then immediately contact Safran Trusted 4D.
Unit Supply:

- 1 FemtoStepper Rack 19"/2U
- 1 Cable SUB-D 9 pins male/female
- 1 Euro power cable
- 2 Brackets for rack mount (only with standard version)
- 1 Connector for Backup DL power supply

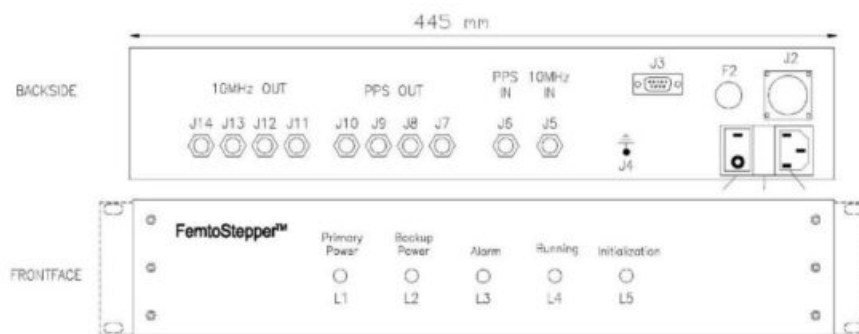### 2.4. Electrical & Indicator Interfaces

Figure 5: Interfaces

N°	In/Out	Designation	Type
J1	In	230VAC primary power	Schurter KM00.1105.11
J2	In	+24VDC backup power	Jaeger 5306004006
J3	In/Out	COM Interface	Sub-D-9P-FEM
J4	–	Ground connection	Screw M4
J5	In	10 MHz reference signal	SMA
J6	In	PPS reference signal	SMA
J7-J10	Out	4x PPS output	SMA
J11-J14	Out	4x 10MHz output	SMA
S1	–	On/Off switch	
F1	–	Primary power supply fuse – T 3,15A	
F2	–	Backup power supply fuse – T 1,6A	
L1	–	Primary power indicator	Green
L2	–	Backup power indicator	Green
L3	–	Alarm indicator	Red
L4	–	Running indicator	Green
L5	–	Initialization indicator	Yellow

Table 1: Interfaces

	Pin	Designation
J1	In	230VAC primary power
J2	In	+24VDC backup power
J3	In/Out	COM Interface
J4	–	Ground connection

Table 2: Backup Power Connector
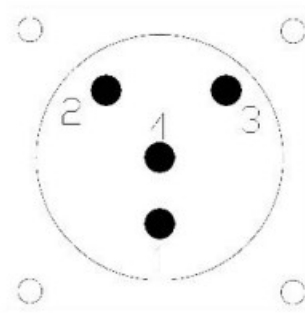
2.5. Connections

- Connect the 10MHz input reference to the FemtoStepper unit (J5).
- Connect, if PPS functionality is desired, the PPSref signal (J6).
- Connect the male SUB-D-9 to the unit (J3) and female SUB-D-9 to the computer.
- Connect the primary power cable (230VAC) to the unit (J1).
- Connect the backup power cable (+24VDC) to the unit (J2).
- Optionally, connect the device to ground (J4).
- Switch on the unit (S1).

2.6. Recommendations

- Warm-up FemtoStepper several hours before to start any applications.
- To reduce warm-up time, keep FemtoStepper powered-up at all times even when an input reference signal is not available.
- To ensure a continuous operation, connect a uninterruptable backup 24V power source."
- Avoid locations of the unit with variable air flow and temperature changes.
- Avoid to place FemtoStepper close to vibration environment and high magnetic fields changes.

2.7. System Power-Up

- Switch on the unit (S1).
- If the primary power is connected, L1 indicator is green.
- If the backup power is connected, L2 indicator is green.
- The alarm indicator (L3) is red while warming-up.
- During the first five seconds, the microprocessor is performing an initialization. At the end of the initialization sequence, L5 switches off.
- After approximately fifteen minutes, the alarm (L3) indicator have to switch off. If still red, check if an input reference is connected (J5).
- When ready to operate the running indicator (L4) becomes green.
- When a frequency offset is applied, the running indicator (L4) is blinking.

3. System Control

The device is controlled remotely through an RS-232 serial link, which provides a prompt with a defined list of commands. All commands are parsed for correct syntax and operational range prior to execution. Commands that contain errors are rejected.

The RS232 protocol is:	9600 bits/s 8 data bits No parity 1 stop bit No handshake

FemtoStepper accepts the following ASCII commands: Data is in decimal ASCII code.

Command Name	Syntax Command	Data Field (if any)	Response Syntax	Response Data (if any)
Identification	ID<CR><LF>	–	TNTMPS-aaa/rr/s.ss<CR><LF>	aaa: 001 rr: revision number s.ss: software version
Serial Number	SN<CR><LF>	–	xxxxxx<CR><LF>	xxxxxx : 6 digits serial nbr
Status	ST<CR><LF>	–	yyxx<CR><LF>	yy : always 00 (for future use) xx : HEX ASCII Bit signification : Bit 7 :- Bit 6 :backup power active Bit 5 :primary power active Bit 4 :frequency drift not 0 Bit 3 :frequency offset not 0 Bit 2 : stepping activity Bit 1 : OOL − Bit 0 : OOL +
Single Phase Step	PSs<CR><KF>	s= + : Positive Step s= − : Negative Step	s<CR><LF>	s: signe s= + : Positive Step s= − : Negative Step
Packet Phase Step	PSsdddddd<CR><LF>	s=+ : Positive Packet Step s=- : Negative Packet Step dddddd: number	sdddddd<CR><LF>	s:signe s=+ : Positive Packet Step s=- : Negative Packet Step dddddd: value
Actual Phase Offset	PH<CR><LF>	–	sdddddd<CR><LF>	s:signe s=+ : Positive Packet Step s=- : Negative Packet Step dddddd: value From 000000 To 500000
Frequency Offset	FAsdddddddd<CR><L F>	s= + : Positive offset s= − : Negative offset dddddddd: number	sdddddddd<CR><LF>	s= + : Positive offset s= − : Negative offset dddddddd: value
Actual Frequency Offset	FR<CR><LF>	–	sdddddddd<CR><LF>	s= + : Positive offset s= − : Negative offset ddddddd: value

Frequency Drift	FDsddddd<CR><LF>	s= + : Positive drift s = − : Negative drift	sddddd<CR><LF>	s= + : Positive drift s= − : Negative drift ddddd : value in 1E-17/day frequency drift
Align PPSOUT to PPSREF	ALd<CR><LF>	d= 1 : align d= ? : alignment status	d<CR><LF>	d= 0: ready for alignment d= 1: alignment in progress d= 2 : no PPSREF
Set PPSOUT delay (rounded to 200ns)	DEddddddddd<CR>< LF>	ddddddddd=delay in ns. Max 999999800 ????????? :interrogation	ddddddddd=delay in ns. Max 999999800 ????????? :interrogation	ddddddddd=delay in ns. Min 000000000 Max 999999800
Send Information Every Second	BTx<CR><LF>	x= 0 : Stop to send x= 3 : PPSRef position x= 5 : Status	x= 3 : aaaaaaaaa sbbb<CR><LF> x= 5 : yyxx<CR><LF>	aaaaaaaaa= PPSOUT vs PPSREF delay in ns. sbbb= fine phase comparator value in approx. ns yyxx= see ST command

Table 3: Serial commands summary

RS232 Commands

4.1. Identification

ID<CR>[<LF>] :	Identification
Answer :	TNTMPS-aaa/rr/s.ss<CR><LF> aaa : 001 rr : revision number s.ss : software version
Example :	ID<CR> answers TNTMPS-001/01/1.00<CR><LF>

4.2. Serial Number

SN<CR>[<LF>]:	Serial number
Answer :	xxxxxx<CR><LF> Xxxxxx : 6 digits serial number
Example :	SN<CR> answers 000015<CR><LF>

4.3. Status

ST<CR>[<LF>] :	Status
Answer :	yyxx<CR><LF> yy : always 00 (reserved for future use) xx : HEX ASCII status : bit 7 :– bit 6 : backup power active bit 5 : primary power active bit 4 : frequency drift not 0 bit 3 : frequency offset not 0 bit 2 : stepping activity bit 1 : OOL negative loop bit 0 : OOL positive loop
Example :	ST<CR> answers 0068<CR><LF> (backup and primary power active, frequency offset applied, no frequency drift, system locked)
Note :	BT5<CR> send status once per second in the same format.

4.4. Single Phase Step

PSs<CR>[<LF>] :	: Single phase step s = +: 1 positive phase step of 10-13 second – : 1 negative phase step of 10-13 second
Answer :	s<CR><LF> s : sign of the single phase step
Example :	PS+<CR> answers +<CR><LF>
Note :	Phase adjustment are not absolute value.

4.5. Packet Phase Step

PSsdddddd<CR>[<LF>] :	Packet phase step s = +: positive phase adjustment – : negative phase adjustment dddddd : phase adjustment in 10-13 second 000000 to 500000 000001 : minimum phase adjustment (±1×10-13 s) 500000 : maximum phase adjustment (±5×10-9 s) 000000 : no phase adjustment
Answer :	sdddddd<CR><LF> sdddddd :phase adjustment value
Example :	PS+000100<CR> answers +000100<CR><LF> (a positive phase adjustment of 10-11 second is asked)
Note :	Phase adjustment are instantaneous phase changes and are cumulative with previous phase changes.

4.6. Actual Phase Adjustment

PH<CR>[<LF>] :	Actual phase adjustment
Answer :	sdddddd<CR><LF> s = +: positive phase adjustment – : Negative phase adjustment dddddd : phase adjustment value in 10-13 second step
Example :	PH<CR> answers -000020<CR><LF> (an total actual negative phase adjustment of 2×10-12 second has been applied)
Note :	The actual phase is the accumulated phase changes from the starting of the system. A frequency offset different from 0 reset the phase adjustment to 0.
Example :	At To the command PS+000002<CR> has been sent, At T1 the command PS-000007<CR> has been sent, At T2 the command PS+000009<CR> has been sent, At T3 the command PH<CR> answers +000004 which corresponds to the total accumulated phase adjustment applied until T3 (2-7+9=4×10-13 second).

4.7. Frequency Offset

FAsdddddddd<CR>[<LF>] :	Frequency offset s = +: positive frequency offset -: Negative frequency offset dddddddd : frequency offset in 10-17 step 00000000 to 10000000 00000001 : minimum frequency offset (±1×10-17) 99999999 : maximum frequency offset (±9.9999999×10-10) 00000000 : no frequency offset
Answer :	sdddddddd<CR><LF> sdddddddd : frequency offset value
Example :	FA+00010000<CR> answers +00010000<CR><LF> (a positive frequency offset of 10-13 relative to input reference frequency is asked)
Note :	Frequency offset are absolute value from input reference frequency. A new frequency offset overwrite the previous one.

4.8. Actual Frequency Offset

FR<CR>[<LF>] :	Actual frequency offset
Answer :	sdddddddd<CR><LF> s = +: positive frequency offset – : negative frequency offset dddddddd : frequency offset in 10-17 step
Example :	FR<CR> answers -00100000<CR><LF> (a negative frequency offset of 10-12 relative to input reference frequency is applied)
Note :	Frequency offset are absolute value from input reference frequency. A new frequency offset overwrite the previous one.
Example :	At T0 the command FA+00600000<CR> has been sent, At T1 the command FA-00020000<CR> has been sent, At T2 the command FR<CR> answers -00020000 which is the actual frequency offset (it corresponds to the last frequency offset command applied before T2.)

4.9. Frequency Drift

FDsddddd<CR>[<LF>] :	: Change the frequency during time s = + : positive frequency drift – : negative frequency drift ddddd : frequency drift in 1E-17/day -32768 to +32767 +00000 no drift ?????? Interrogation
Answer:	sddddd : just asked drift or drift actually active
Example:	FD??????<CR> answers +00100<CR><LF>. The frequency is increased of 1E- 17 every 864 seconds and this value can be read back with the command FR.

4.10. Pulse Per Second Alignment

ALd<CR>[<LF>] :	PPSOUT alignment to PPSREF d = 1 : align ? : interrogation
Answer :	d<CR><LF> 0: ready for alignment 1: alignment in progress 2: no PPSREF
Example :	AL1<CR> answers 1<CR><LF>
Notes:	While the command is in progress, an internal PPSLOCAL is aligned to PPSREF. This can take up to 30 seconds. The alignment is done within +/- 200 ns. After an alignment DE????????? answers 000000000<CR><LF> This command has no influence on the 10 MHz output.

4.11. PPSOUT Delay

DEdddddddddd<CR>[<LF>] :	Set a PPSOUT delay ddddddddd : delay in ns 000000000 to 999999800 000000000 : no delay 000000200 : minimum delay 999999800 : maximum delay ????????? : interrogation
Answer :	ddddddddd<CR><LF> ddddddddd : just asked delay
Example :	DE?????????<CR> answers 000000000<CR><LF>
Notes :	After power on / Reset, the PPSOUT position is random. After the command AL1, the PPSOUT is aligned to PPSREF and the delay is settled to 0. This command has no influence on the 10 MHz output.

4.12. Information Every Second

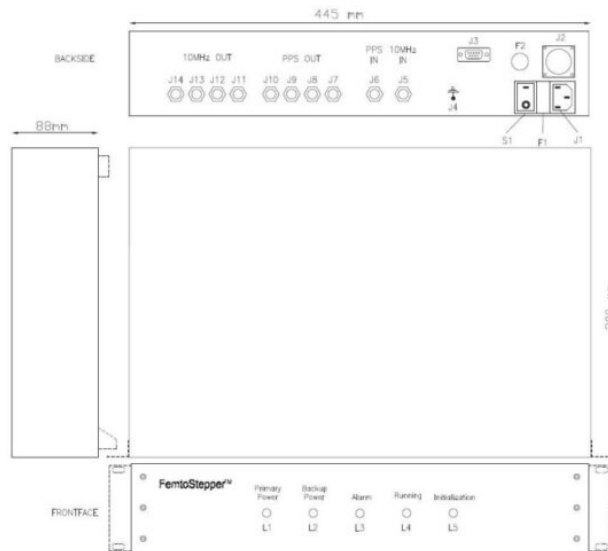|	
BTx<CR>[<LF>] :	send information once per second on the serial port x= 0 : stop to send
Answer :	none x = 3 : PPSOUT vs PPSREF position
Answer :	aaaaaaaaa sbbb<CR><LF> once per second aaaaaaaaa : raw PPSOUT vs PPSREF position in ns, rounded to 200 ns steps 000000000 : PPSOUT aligned to PPSREF 000000200 : minimum value 999999800 : maximum value ????????? : no PPSREF sbbb : s : sign +/- ; bbb : analog fine PPS comparator value in approximately ns. PPSLOCAL vs PPSREF. +000 : PPSLOCAL and PPSREF are perfectly aligned. -500 : lowest value +500 : highest value
Remark :	the command AL1<CR><LF> must be sent first to bring the PPSLOCAL in the PPS phase comparator working range. x = 5 : Status
Answer :	yyxx<CR><LF> once per second See Status command for details

Mechanical

Figure 6

Safran Technical Support

For technical support, you can visit **https://safran-navigation-timing.com/support-hub/** to submit a support request.

For product specifications and additional documentation, visit our product page at **https://safrannavigation-timing.com/product/femtostepper/**

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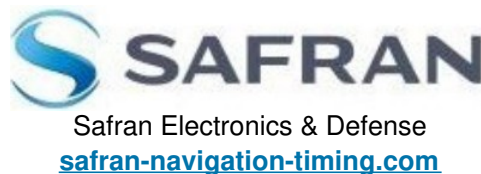
Documents / Resources

SAFRAN FemtoStepper 100fs Resolution Phase Stepper [pdf] User Manual
FemtoStepper 100fs Resolution Phase Stepper, FemtoStepper, 100fs Resolution Phase Stepper, Resolution Phase Stepper, Phase Stepper, Stepper

References

- [The World Leader in Resilient PNT - Safran - Navigation & Timing](#)
- [The World Leader in Resilient PNT - Safran - Navigation & Timing](#)
- [Support Hub - Safran - Navigation & Timing](#)
- [User Manual](#)