Edited for PDS archive March 11, 2013



# CCMU-FM
# CONVERSIONS TO PHYSICAL VALUES


| Prepared by: | Signature: |
|---|---|
| A. Cros | |
| **Accepted by:** | **Signature:** |
| R. Pérez | |
| **Approved and Application authorized by:** | |
| M. Saccoccio | |



**Summary**: CCMMU-FM: conversion curves to be used to convert the analog HKs to physical values.
Conversion of physical values to parameters used for commanding.



**Keywords** :


**DISTRIBUTION LIST**

| PROJECT | | EXTERNAL DISTRIBUTION |
|---|---|---|
| M. Saccoccio<br>S. Maurice<br>A. Cros<br>G. Hervet<br>R. Pérez<br>D. Kouach<br>L. Parès<br>JJ. Thocaven<br>M. Bouyé<br>HC. Seran<br>A. Paillet | Y. Parot<br>N. Le Roch<br>B. Dubois<br>N. Striébig<br>Y. Michel<br>JL. Espaignol<br>QM. Lee | <u>LANL</u><br>B. Barraclough<br>R. Wiens<br><br><u>JPL</u><br>E. Miller<br>N. Warner<br>E. Morse |

**DOCUMENT CHANGE RECORD**

| Edition | Revision | Date | Modified pages | Reason for change / Observations |
|---|---|---|---|---|
| 1 | 0 | 2008-April-7 | | Initial release |
| 1 | 1 | 2008-April-30 | | 3.1.2 FM curve added<br>3.1.3 section added |
| 1 | 2 | 2008- July - 08 | | LIBs optical power corrected<br>3.1.4 section added |
| 1 | 3 | 2008- July - 24 | Section 3.1.4 | Updated to take into account VT measurements. |
| 1 | 4 | 2008-October-29 | | Addition of a reference. AD .Typing and formatting corrections |
| 1 | 5 | 2009-December-16 | | 5.2: Correction of unit<br>5.5: Warm-up slope adjusted for FM |
| 1 | 6 | 2010 June 1 | Section 5.4 | Correction of the conversion factor in the formula. |

# - TABLE OF CONTENTS -

# 1. GLOSSARY

| | |
|---|---|
| MSL | Mars Science Lander |
| CCMU | ChemCam Mast Unit |
| CCMU-QM | ChemCam Mast Unit, Qualification Model |
| CCBU | ChemCam Body Unit |
| tbc | to be confirmed |
| tbd | to be defined |
| N/A | Not Applicable |
| E_box | CCMU Electronic box |
| O_box | CCMU Optical box |
| QM | Qualification Model |
| FM | Flight Model |

# 2. INTRODUCTION

## 2.1. Scope of the document

This document presents the results of the measures performed on the CCMU_FM. It defines the conversion factors to be used to translate the analog HKs to physical values and to translate physical values to parameters for commanding.

## 2.2. Applicable Documents (AD)

| AD | Titre | References | Issue |
|---|---|---|---|
| 01 | ChemCam Mast/Body Communications | CCAM-UM-23000-LANL-2194-GEN | 4.9 |
| 02 | ChemCam Mast Unit FM integration - Commanding the laser (I&D | CCAM-TR-21343-CESR-498-FM | 1.0 |

## 2.3. Reference Documents (RD)

| RD | Titre | Référence | Issue |
|---|---|---|---|
| 01 | | | |
| 02 | | | |

## 3. CONVERSION OF ANALOG HKs TO PHYSICAL VALUES

**Conversion to physical values for CCMU_FM analog housekeepings**

| HK# | Description | Function | Unit | Value for 0 | Value for 4095 |
|---|---|---|---|---|---|
| 0 | Digital HKs | Digital status word | see § 4 DHK | | |
| 1 | HK_heatsink_temp | temperature of power board | °C | -57, 47 | 138,92 |
| 2 | HK_current_+3,3v | +3,3v current | mA | 0 | 1126,2 |
| 3 | HK_current_+30v | +30v current (not very accurate) | mA | 0 | 893,5 |
| 4 | HK_current_-5v | -5v current | mA | 31,6 | 228,9 |
| 5 | HK_current_+12v | +12v current | mA | 0 | 321,0 |
| 6 | HK_V_+3,3v | secondary voltage +3,3v (power board) | V | 0 | 3,6838 |
| 7 | HK_V_+5v | secondary voltage +5v | V | 0 | 6,0859 |
| 8 | HK_V_-5v | secondary voltage -5v | V | 0 | -6,7452 |
| 9 | HK_V_+12v | secondary voltage +12v | V | 0 | 14,3745 |
| 10 | HK_V_-12v | secondary voltage -12v | V | 0 | -14,5597 |
| 11 | HK_V_+15v | secondary voltage +15v | V | 0 | 23,6330 |
| 12 | HK_V_+30v | secondary voltage +30v | V | 0 | 32,6611 |
| 13 | CWL diode control power | CW laser power (nominal ~10,63 mW) | mW | 0 | 12,02 |
| 14 | CWL_temp | CW laser temperature | °C | -57,47 | 94,97 |
| 15 | HK_temp_limiter_1 | Temperature of current limiter n°1 | °C | -57,47 | 94,97 |
| 16 | Autofocus_signal_output | Autofocus signal level | mV | 0 | 2500 |
| 17 | LMD18200_Temp | Temperature of motor driver circuit | °C | -57,47 | 138,92 |
| 18 | HK_Temp_Laser_1 | Temperature oscillator laser LIBS n°1 | °C | -57,47 | 94,97 |
| 19 | HK_Temp_Laser_2 | Temperature oscillator laser LIBS n°2 | °C | -57,47 | 94,97 |
| 20 | HK_Temp_Laser_3 | Temperature amplifiers laser LIBS n°1 | °C | -57,47 | 94,97 |
| 21 | HK_Temp_Laser_4 | Temperature amplifiers laser LIBS n°2 | °C | -57,47 | 94,97 |
| 22 | HK_V_Stack_1 | Voltage oscillator (Stack1) laser LIBS | V | 0 | 31,25 |
| 23 | HK_I_Stack_1 | Current oscillator (Stack1) laser LIBS | A | -0,36 | 154,59 |
| 24 | HK_V_Stack_2 | Voltage amplifier 1 (Stack2) laser LIBS | V | 0 | 31,25 |
| 25 | HK_I_Stack_2 | Courant amplifier 1 (Stack2) laser LIBS | A | -0,92 | 160,26 |
| 26 | HK_V_Stack_3 | Voltage amplifier 2 (Stack3) laser LIBS | V | 0 | 31,25 |

| | | | | | |
|---|---|---|---|---|---|
| 27 | HK_I_Stack_3 | Courant amplifier 2 (Stack3) laser LIBS | A | -0,68 | 157,80 |
| 28 | Optical_Flux_Level | Power of laser shots (LIBS) (only valid between 2000 and 4095) | mJ | -3,78 | 60,51 |
| 29 | HK_HV | High voltage pockels | V | 0 | 2500 |
| 30 | HK_Limit Switch | Resistor value of limit switch (See 3.1.2) | Ω | -7,73 | 519,70 |
| 31 | HK_Spare_2 | spare | V | 0 | 2,5 |
| 32 | HK_RMI | Temperature of RMI (PT1000 #1) (Not very accurate: see 3.1.1) | ℃ | -60,6 | 111,8 |
| 33 | HK_temp_FPGA_1 | Temperature FPGA (sensor glued on the top of the FPGA) | ℃ | -57,47 | 138,92 |
| 34 | HK_Telescope_1 | Temperature telescope 1- Motor (sensor glued on the motor of the mechanism) | ℃ | -57,47 | 94,97 |
| 35 | HK_Telescope_2 | Temperature telescope 2- Primary miror (sensor glued at the rear of the primary mirror) | ℃ | -57,47 | 94,97 |
| 36 | 3,3V FPGA | Voltage 3,3V FPGA (FPGA board) | V | 0 | 7,804 |

### 3.1.1. HK_32: HK_RMI

HK_32 measure the temperature of the RMI. It is susceptible to the variations of +3,3V and -5V. The linear conversion curve provided above is not a very accurate conversion curve. To get an accurate measure of the temperature of the RMI, it is necessary to take into account the physical value of HK_6 (secondary voltage +3,3v) and HK_8 (secondary voltage -5v) by using the following formula:

$$T(°C) = (-TC1 + racine( TC1^2 - 4*TC2*(1-(Vout-B*V(-5v))/1000/A/V(3.3v) ))) / (2*TC2)$$

With:

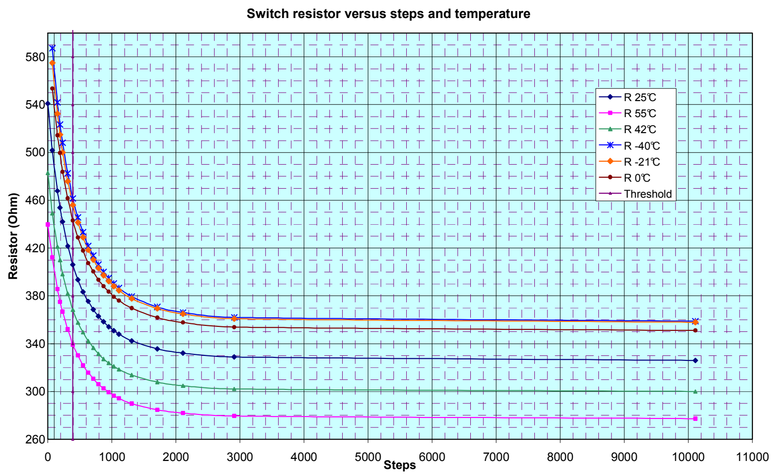
- TC1 = 3.9083e-3
- TC2= -5.775e-7
- A = 104.22 / 9.1 / 10000
- B = (1 + 104.22/9.1) / 22.5
- V(-5v) voltage -5v in volt
- V(3.3v) voltage 3,3v in volt
- Vout = raw value of HK_32/4095*2,5

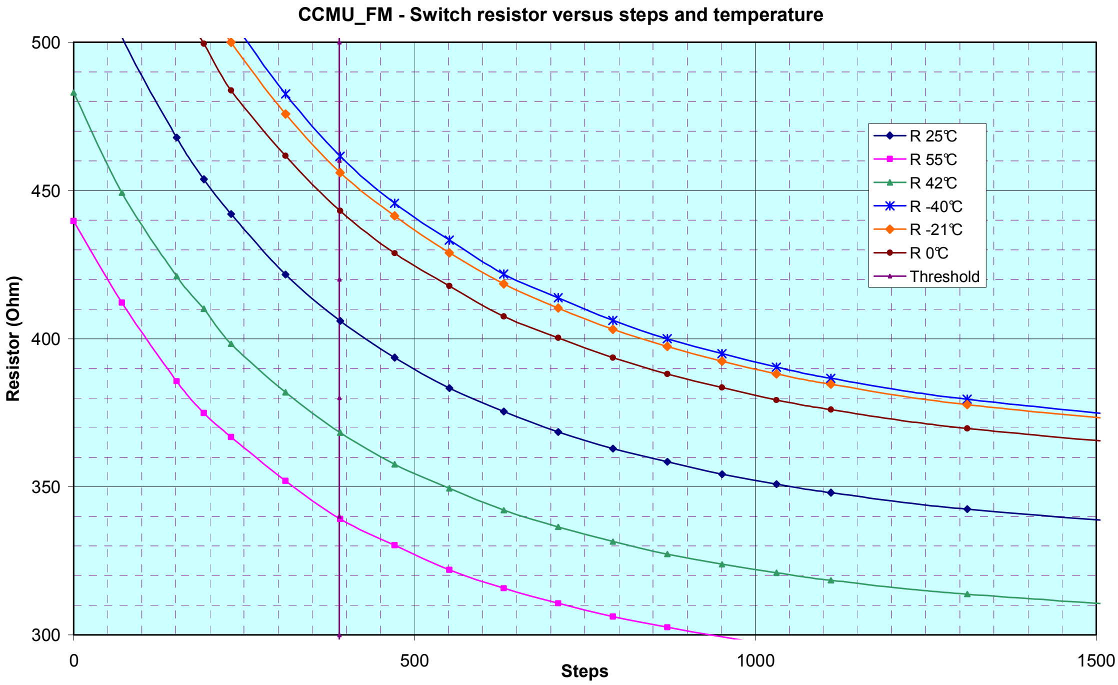
### 3.1.2. HK_30: R limit switch

This HK parameter gives the resistance value of the limit switch placed at the close focus. This resistor varies according to the position and the temperature.
The resistor of the sensor is given by the following equation (N is the raw value of the HK_30).

R (Ohm) = 0,1288*N - 7,7317
N = 0 → R = -7,73 Ohm
N = 4095 → R = 519,70 Ohm

The following figure gives the resistor value of the limit sensor versus the position and the temperature;



### 3.1.3. Temperature sensors type AD590 versus +5v

For this type of temperature sensors, the output is a function of the +5v which is stable. However if a more accurate value is needed, it is possible to correct the pure linear curve by using the following relations:

Temp(°C) = (Vout/Rgain + **V(+5v)**/Roffset) x 1e6 - 273.15

where:
Vout = HK*2,5/4095
Rgain = 16200 Ohms for the AD590 working in the range -57°C +95°C
Rgain = 12730 Ohms for the AD590 working in the range -57°C + 139°C (HKs 1, 17, 31)
V(+5v) is the physical value given by HK 7
Roffset = 23010 Ohms

### 3.1.4. HK-28: Optical Flux Level

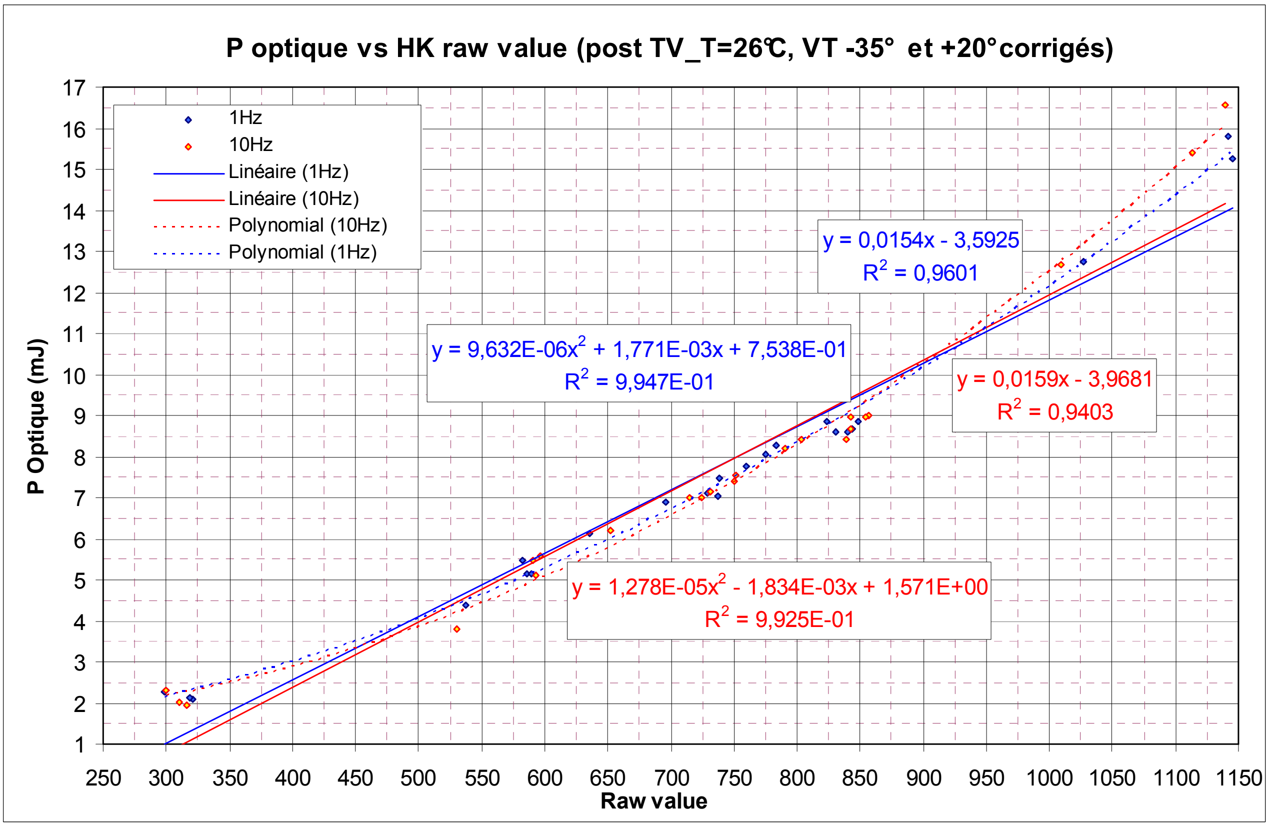
This HK has been calibrated by measuring the energy received by a target situated at 6.5m. The calibration was done during and after thermal vacuum test of the FM. The CCMU was enclosed in the RWEB simulator. For measures done during TV, the transmission of the window (0,87%) is corrected. The calibration was done in two cases: 10 shots at 1HZ and 10 shots at 10Hz. The best fit is obtained with polynomial curves. The calibration curve is slightly different at 1Hz and at 10Hz. For our GSE, we will use a linear conversion which is the mean of the two curves:

**y = 0,0157x - 3,78** where x is the raw value of the HK

For the operation, we suggest to use the following polynomial curves if an accurate measure is needed:

- 1Hz: **y = 9,632E-06x2 + 1,771E-03x + 7,538E-01**
- 10Hz: **y = 1,278E-05x2 - 1,834E-03x + 1,571E+00**

For routine measurements, a mean of the two curves is enough:




### 3.1.5. HK_I_Stack_1, 2, 3: HK 23, 25, 27

We have noted from the calibration of the FM laser board that the HK_I of the LIBS laser decrease slightly with the temperature (about -4,5A when the temperature of the laser board is decreasing from +40° to -40°C). A formula to compute the correct current will be proposed after careful analysis. The linear conversion curve proposed in the table is valid when the laser board is around +45°C (HK 15).

## 4. CONVERSION OF DIGITAL HKs TO STATUS

The following table indicates the status of each of the CCMU subsystem according to the related bit of the digital HK words.

| Bit N° | | Purpose | Value | Meaning | Comment |
|---|---|---|---|---|---|
| 0 (lsb) | | Limit switch status | 0/1 | Closed/ Open/ | Closed means that the limit switch is set Open means that the motor can operate normally |
| 1 | | Thermal flag | 0/1 | Too hot/Cold | When the thermal flag is zero, then the FPGA will switch OFF automatically the +30V motor |
| 2 | | ±15V (+30V) converter status | 0/1 | OFF/ON | Low power converter |
| 3 | | ±12V converter status | 0/1 | OFF/ON | Low power converter |
| 4 | | Limiter oscillator status | 0/1 | OFF/ON | LIBs operations |
| 5 | | Limiter amplifier 1 status | 0/1 | OFF/ON | LIBs operations |
| 6 | | Limiter amplifier 2 status | 0/1 | OFF/ON | LIBs operations |
| 7 | | Floating ±15V status | 0/1 | OFF/ON | LIBs operations |
| 8 | | HV pockels status | 0/1 | OFF/ON | LIBs operations |
| 9 | | +30V motor status | 0/1 | OFF/ON | Motor operations |
| 10 | | CWL power status | 0/1 | OFF/ON | CWL operations |
| 11 | | ±12V autofocus status | 0/1 | OFF/ON | CWL and motor operations |
| 12 | | Camera status | 0/1 | OFF/ON | RMI operations |
| 13 | | Warmup loop 1 status (LIBS oscillator) | 0/1 | Cold/Warm | 0 means that the commanded temperature is not yet reached. 1 means that that the commanded temperature is reached. This bit is set so zero when CCMU is switched ON and when the warm-up loop is commanded to OFF . It is set to 1 the first time that the commanded temperature is reach. |
| 14 | | Warmup loop 2 status (LIBS amplifiers) | 0/1 | Cold/Warm | Same as above |
| 15 (msb) | | Warmup loop 3 status (CWL) | 0/1 | Cold/Warm | Same as above |

# 5. CONVERSION OF PHYSICAL VALUES TO COMMAND PARAMETERS

## 5.1. Command to configure laser

### 5.1.1. I stack level

The current injected in the stacks is given by the following equation (Cmd is the related parameter of the command).

Oscillator: I (A) = 0,0325 x Cmd + 1,949 Cmd = 29,85 x I (A) – 58,2
Amplifier 1: I (A) = 0,0336 x Cmd + 2,2016 Cmd = 29,76 x I (A) – 65,5
Amplifier 2: I (A) = 0,0335 x Cmd + 1,5713 Cmd = 29,85 x I (A) – 46,9

| y (current) (A) | x (Oscillator) cmd param. | x (Amp1) cmd param. | x (Amp2) cmd param. |
|---|---|---|---|
| 50 | 1434 | 1423 | 1446 |
| 55 | 1584 | 1571 | 1595 |
| 60 | 1733 | 1720 | 1744 |
| 65 | 1882 | 1869 | 1893 |
| 70 | 2031 | 2018 | 2043 |
| 75 | 2181 | 2167 | 2192 |
| 80 | 2330 | 2315 | 2341 |
| 85 | 2479 | 2464 | 2490 |
| 90 | 2628 | 2613 | 2640 |
| 95 | 2778 | 2762 | 2789 |
| 100 | 2927 | 2911 | 2938 |
| 105 | 3076 | 3059 | 3087 |
| 110 | 3225 | 3208 | 3237 |
| 115 | 3375 | 3357 | 3386 |
| 120 | 3524 | 3506 | 3535 |
| 125 | 3673 | 3655 | 3684 |
| 130 | 3822 | 3803 | 3834 |
| 135 | 3972 | 3952 | 3983 |
| 140 | 4121 | 4101 | 4132 |
| 141 | 4151 | 4131 | 4162 |
| 142 | 4181 | 4160 | 4192 |
| 143 | 4210 | 4190 | 4222 |
| 144 | 4240 | 4220 | 4252 |

### 5.1.2. Duration function of command parameter

The effective duration of the current pulse injected in the stacks, for a nominal injection of 100 A, is given by the following equation (X is the related parameter of the command).

Duration for I =100A (µs) = 0,3897X + 119,72
Cmd = 2.566 x Duration (µs) – 307.2

Nominal for laser FM: 65

| y (duration) (µs) | x cmd param. |
|---|---|
| 120 | 1 |
| 122 | 6 |
| 125 | 14 |
| 130 | 26 |
| 135 | 39 |
| 140 | 52 |
| 145 | 65 |
| 150 | 78 |
| 155 | 91 |
| 160 | 103 |
| 165 | 116 |
| 170 | 129 |
| 175 | 142 |
| 180 | 155 |
| 185 | 168 |
| 190 | 180 |
| 195 | 193 |
| 200 | 206 |
| 205 | 219 |
| 210 | 232 |
| 219 | 255 |

#### 5.1.3. Maximum value of N according to the rate of laser shots

The following table shows the maximum value for parameter 09 (N) to be used according to the commanded frequency (cps) of the laser shots. It is a good practice to use a lower value for N in order to not loose laser shots if the clock generating the fire the laser signal is not very accurate or not stable.

| Laser rate (cps) | Interval between shots = 1/cps (ms) | Max value for N | Resulting min interval between shots (ms) |
|---|---|---|---|
| 20 | 50,0 | 1 | 48,6 |
| 19 | 52,6 | 2 | 52,3 |
| 18 | 55,6 | 2 | 52,3 |
| 17 | 58,8 | 3 | 56,1 |
| 16 | 62,5 | 4 | 59,8 |
| 15 | 66,7 | 5 | 63,6 |
| 14 | 71,4 | 7 | 71,0 |
| 13 | 76,9 | 8 | 74,8 |
| 12 | 83,3 | 10 | 82,3 |
| 11 | 90,9 | 12 | 89,7 |
| 10 | 100,0 | 14 | 97,2 |
| 9 | 111,1 | 17 | 108,4 |
| 8 | 125,0 | 21 | 123,4 |
| 7 | 142,9 | 26 | 142,1 |
| 6 | 166,7 | 32 | 164,5 |
| 5 | 200,0 | 41 | 198,2 |
| 4 | 250,0 | 54 | 246,8 |
| 3 | 333,3 | 77 | 332,9 |
| 2 | 500,0 | 121 | 497,4 |
| 1 | 1000,0 | 255 | 998,6 |

### 5.2. Command current level to drive the motor

The maximum current injected in the coils of the motor is given by the following equation (N is the parameter of the command A4).

I(mA) = 3,3275xN + 0,1704
N = 0 → 0,17 mA
N = 255 →848,7 mA

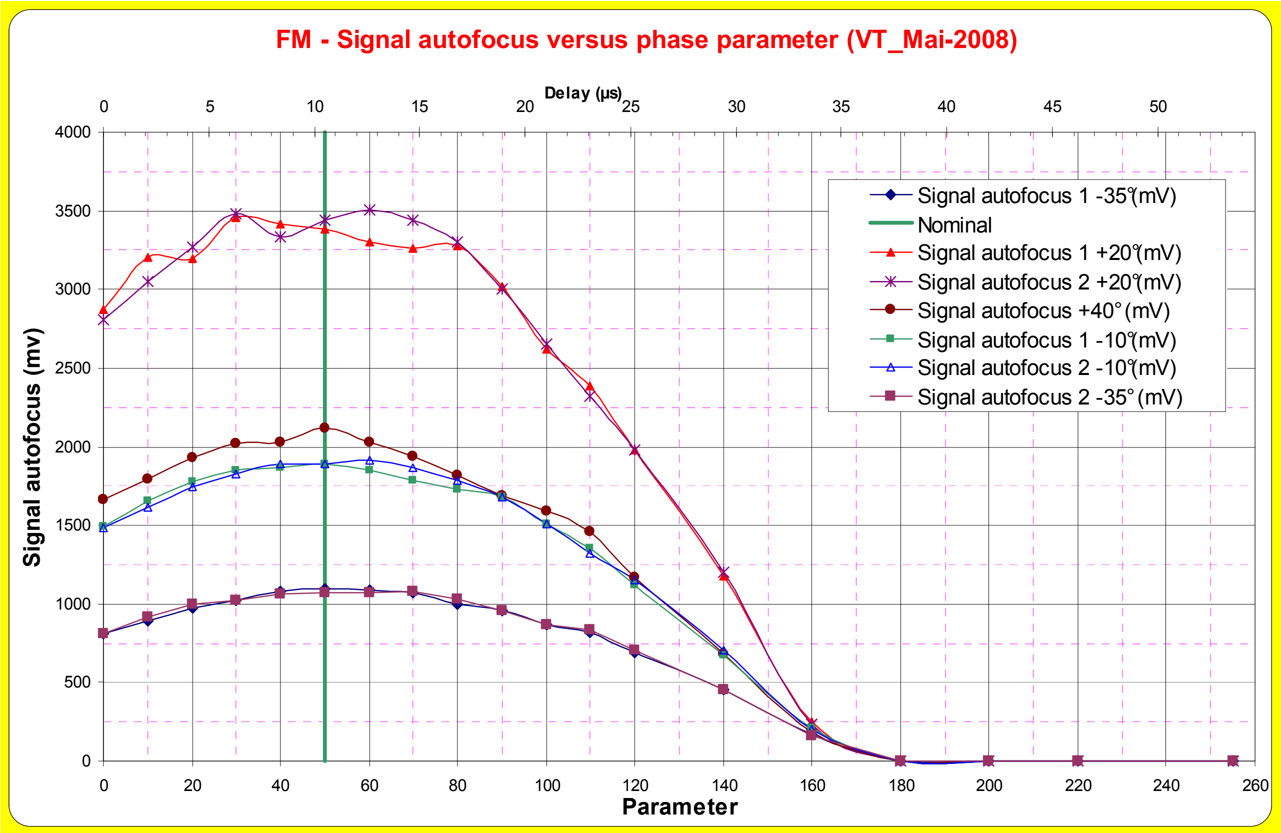
The nominal current for the motor is 600 mA. So the nominal value of the parameter of the command A4 that shall be used for standard operations of the motor is:

**N = 180 -> 599,1** mA

## 5.3. Command for demodulation clock delay/modulation clock

| | | |
|---|---|---|
| 0 → 0 µs | N → N*0,21 µs | 255 → 53,55 µs |

Nominal: 60
(This value gives the maximum level for the autofocus signal)



### 5.4. Command to set point temperature for loop regulation

| | | |
|---|---|---|
| 0 → -57,47°C | Temperature= -57,47 + (N*0,5978) °C | 255 → 94,97 °C |

Nominal: LIBS oscillator: -19,8°C → 63
LIBS Amplifiers: -19,8°C → 63
CWL: +10,1°C → 113

| Command parameter N to achieve temperature T | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **N decimal** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| **Température** | -57,5 | -56,9 | -56,3 | -55,7 | -55,1 | -54,5 | -53,9 | -53,3 | -52,7 | -52,1 |
| **N decimal** | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| **Température** | -51,5 | -50,9 | -50,3 | -49,7 | -49,1 | -48,5 | -47,9 | -47,3 | -46,7 | -46,1 |
| **N decimal** | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| **Température** | -45,5 | -44,9 | -44,3 | -43,7 | -43,1 | -42,5 | -41,9 | -41,3 | -40,7 | -40,1 |
| **N decimal** | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
| **Température** | -39,5 | -38,9 | -38,3 | -37,7 | -37,1 | -36,5 | -35,9 | -35,3 | -34,8 | -34,2 |
| **N decimal** | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 |
| **Température** | -33,6 | -33,0 | -32,4 | -31,8 | -31,2 | -30,6 | -30,0 | -29,4 | -28,8 | -28,2 |
| **N decimal** | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 |
| **Température** | -27,6 | -27,0 | -26,4 | -25,8 | -25,2 | -24,6 | -24,0 | -23,4 | -22,8 | -22,2 |
| **N decimal** | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 |
| **Température** | -21,6 | -21,0 | -20,4 | -19,8 | -19,2 | -18,6 | -18,0 | -17,4 | -16,8 | -16,2 |
| **N decimal** | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 |
| **Température** | -15,6 | -15,0 | -14,4 | -13,8 | -13,2 | -12,6 | -12,0 | -11,4 | -10,8 | -10,2 |
| **N decimal** | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
| **Température** | -9,6 | -9,0 | -8,4 | -7,9 | -7,3 | -6,7 | -6,1 | -5,5 | -4,9 | -4,3 |
| **N decimal** | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 |
| **Température** | -3,7 | -3,1 | -2,5 | -1,9 | -1,3 | -0,7 | -0,1 | 0,5 | 1,1 | 1,7 |
| **N decimal** | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 |
| **Température** | 2,3 | 2,9 | 3,5 | 4,1 | 4,7 | 5,3 | 5,9 | 6,5 | 7,1 | 7,7 |
| **N decimal** | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 |
| **Température** | 8,3 | 8,9 | 9,5 | 10,1 | 10,7 | 11,3 | 11,9 | 12,5 | 13,1 | 13,7 |
| **N decimal** | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 |
| **Température** | 14,3 | 14,9 | 15,5 | 16,1 | 16,7 | 17,3 | 17,9 | 18,5 | 19,1 | 19,6 |
| **N decimal** | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 |
| **Température** | 20,2 | 20,8 | 21,4 | 22,0 | 22,6 | 23,2 | 23,8 | 24,4 | 25,0 | 25,6 |
| **N decimal** | 140 | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 |
| **Température** | 26,2 | 26,8 | 27,4 | 28,0 | 28,6 | 29,2 | 29,8 | 30,4 | 31,0 | 31,6 |
| **N decimal** | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 |
| **Température** | 32,2 | 32,8 | 33,4 | 34,0 | 34,6 | 35,2 | 35,8 | 36,4 | 37,0 | 37,6 |
| **N decimal** | 160 | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 |
| **Température** | 38,2 | 38,8 | 39,4 | 40,0 | 40,6 | 41,2 | 41,8 | 42,4 | 43,0 | 43,6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **N decimal** | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 |
| **Température** | 44,2 | 44,8 | 45,4 | 46,0 | 46,5 | 47,1 | 47,7 | 48,3 | 48,9 | 49,5 |
| **N decimal** | 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 |
| **Température** | 50,1 | 50,7 | 51,3 | 51,9 | 52,5 | 53,1 | 53,7 | 54,3 | 54,9 | 55,5 |
| **N decimal** | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 |
| **Température** | 56,1 | 56,7 | 57,3 | 57,9 | 58,5 | 59,1 | 59,7 | 60,3 | 60,9 | 61,5 |
| **N decimal** | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 |
| **Température** | 62,1 | 62,7 | 63,3 | 63,9 | 64,5 | 65,1 | 65,7 | 66,3 | 66,9 | 67,5 |
| **N decimal** | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 |
| **Température** | 68,1 | 68,7 | 69,3 | 69,9 | 70,5 | 71,1 | 71,7 | 72,3 | 72,9 | 73,5 |
| **N decimal** | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 |
| **Température** | 74,0 | 74,6 | 75,2 | 75,8 | 76,4 | 77,0 | 77,6 | 78,2 | 78,8 | 79,4 |
| **N decimal** | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 |
| **Température** | 80,0 | 80,6 | 81,2 | 81,8 | 82,4 | 83,0 | 83,6 | 84,2 | 84,8 | 85,4 |
| **N decimal** | 240 | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 |
| **Température** | 86,0 | 86,6 | 87,2 | 87,8 | 88,4 | 89,0 | 89,6 | 90,2 | 90,8 | 91,4 |
| **N decimal** | 250 | 251 | 252 | 253 | 254 | 255 | | | | |
| **Température** | 92,0 | 92,6 | 93,2 | 93,8 | 94,4 | 95,0 | | | | |

## 5.5. Command to set warmup slope

The following table shows the **slope of the temperature** according to the commanded interval between microsteps (s) and also the time (mn) necessary to achieve the requested temperature versus the value of the parameter and versus the difference between the beginning and the end temperature. The nominal slope to use is 5,12°C/mn.

| FM/QM Microstep (°C) = 0,5978 | | | Duration (mn) to achieve the requested temperature versus the delta (°C) temperature (beginning - end temperature) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters for command B6 = Interval between microsteps (s)** X_Slope | **Resulting temperature slope** CCAM_X_SLOPE = (0.5978/X_slope)*60 (°C/mn) | **# of microsteps/mn** | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| **60** | **0,60** | 1,00 | 8,36 | 16,73 | 25,09 | 33,46 | 41,82 | 50,18 | 58,55 | 66,91 | 75,28 | 83,64 | 92,00 |
| **55** | **0,65** | 1,09 | 7,67 | 15,33 | 23,00 | 30,67 | 38,34 | 46,00 | 53,67 | 61,34 | 69,00 | 76,67 | 84,34 |
| **50** | **0,72** | 1,20 | 6,97 | 13,94 | 20,91 | 27,88 | 34,85 | 41,82 | 48,79 | 55,76 | 62,73 | 69,70 | 76,67 |
| **45** | **0,80** | 1,33 | 6,27 | 12,55 | 18,82 | 25,09 | 31,37 | 37,64 | 43,91 | 50,18 | 56,46 | 62,73 | 69,00 |
| **40** | **0,90** | 1,50 | 5,58 | 11,15 | 16,73 | 22,30 | 27,88 | 33,46 | 39,03 | 44,61 | 50,18 | 55,76 | 61,34 |
| **35** | **1,02** | 1,71 | 4,88 | 9,76 | 14,64 | 19,52 | 24,40 | 29,27 | 34,15 | 39,03 | 43,91 | 48,79 | 53,67 |
| **30** | **1,20** | 2,00 | 4,18 | 8,36 | 12,55 | 16,73 | 20,91 | 25,09 | 29,27 | 33,46 | 37,64 | 41,82 | 46,00 |
| **25** | **1,43** | 2,40 | 3,49 | 6,97 | 10,46 | 13,94 | 17,43 | 20,91 | 24,40 | 27,88 | 31,37 | 34,85 | 38,34 |
| **20** | **1,79** | 3,00 | 2,79 | 5,58 | 8,36 | 11,15 | 13,94 | 16,73 | 19,52 | 22,30 | 25,09 | 27,88 | 30,67 |
| **15** | **2,39** | 4,00 | 2,09 | 4,18 | 6,27 | 8,36 | 10,46 | 12,55 | 14,64 | 16,73 | 18,82 | 20,91 | 23,00 |
| **14** | **2,56** | 4,29 | 1,95 | 3,90 | 5,85 | 7,81 | 9,76 | 11,71 | 13,66 | 15,61 | 17,56 | 19,52 | 21,47 |
| **13** | **2,76** | 4,62 | 1,81 | 3,62 | 5,44 | 7,25 | 9,06 | 10,87 | 12,69 | 14,50 | 16,31 | 18,12 | 19,93 |
| **12** | **2,99** | 5,00 | 1,67 | 3,35 | 5,02 | 6,69 | 8,36 | 10,04 | 11,71 | 13,38 | 15,06 | 16,73 | 18,40 |
| **11** | **3,26** | 5,45 | 1,53 | 3,07 | 4,60 | 6,13 | 7,67 | 9,20 | 10,73 | 12,27 | 13,80 | 15,33 | 16,87 |
| **10** | **3,59** | 6,00 | 1,39 | 2,79 | 4,18 | 5,58 | 6,97 | 8,36 | 9,76 | 11,15 | 12,55 | 13,94 | 15,33 |
| **9** | **3,99** | 6,67 | 1,25 | 2,51 | 3,76 | 5,02 | 6,27 | 7,53 | 8,78 | 10,04 | 11,29 | 12,55 | 13,80 |
| **8** | **4,48** | 7,50 | 1,12 | 2,23 | 3,35 | 4,46 | 5,58 | 6,69 | 7,81 | 8,92 | 10,04 | 11,15 | 12,27 |
| **7** | **5,12** | 8,57 | 0,98 | 1,95 | 2,93 | 3,90 | 4,88 | 5,85 | 6,83 | 7,81 | 8,78 | 9,76 | 10,73 |
| **6** | **5,98** | 10,00 | 0,84 | 1,67 | 2,51 | 3,35 | 4,18 | 5,02 | 5,85 | 6,69 | 7,53 | 8,36 | 9,20 |
| **5** | **7,17** | 12,00 | 0,70 | 1,39 | 2,09 | 2,79 | 3,49 | 4,18 | 4,88 | 5,58 | 6,27 | 6,97 | 7,67 |
| **4** | **8,97** | 15,00 | 0,56 | 1,12 | 1,67 | 2,23 | 2,79 | 3,35 | 3,90 | 4,46 | 5,02 | 5,58 | 6,13 |
| **3** | **11,96** | 20,00 | 0,42 | 0,84 | 1,25 | 1,67 | 2,09 | 2,51 | 2,93 | 3,35 | 3,76 | 4,18 | 4,60 |
| **2** | **17,93** | 30,00 | 0,28 | 0,56 | 0,84 | 1,12 | 1,39 | 1,67 | 1,95 | 2,23 | 2,51 | 2,79 | 3,07 |
| **1** | **35,87** | 60,00 | 0,14 | 0,28 | 0,42 | 0,56 | 0,70 | 0,84 | 0,98 | 1,12 | 1,25 | 1,39 | 1,53 |