SmarAct Metirio Encoder Digital-Interface

Abstract
This document contains information on how to access, interpret and manipulate the Metirio Encoder's internal memory. It further describes the registers used to adjust the encoder's analog output.

ABBREVIATIONS

ASIC Application-Specific Integrated Circuit
MTP Multiple-Times Programmable (Memory)
RAM Random Access Memory
MSB Most-Significant-Byte

INTRODUCTION

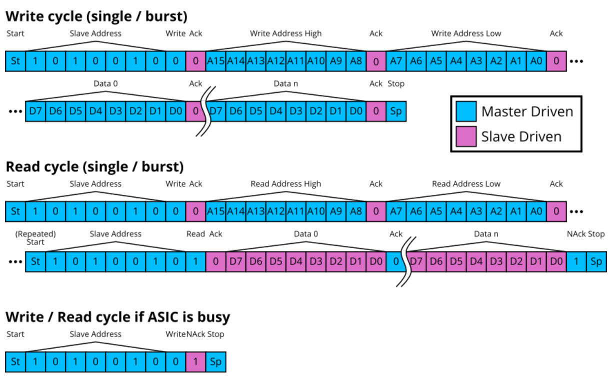
The Metirio Encoder is equipped with a Digital-Interface that allows advanced tuning as well as usage of the encoder's features such as reading the General-Purpose-Input. It further gives access to the internal MTP memory used to store non-volatile settings and general information across sessions.

DIGITAL-INTERFACE DESCRIPTION

The encoder's Digital-Interface conforms to the UM10204 I2C-Bus Specification and User Manual[1].

- The maximum clock speed is *400 kHz*.
- The 7-bit slave address is *0x52 (0b1010010)*.
- Internal Data addresses are *two bytes* in size (MSB first).
- The MTP memory has a page size of *16 bytes*.
- An MTP write operation may take up to 40 ms to complete.

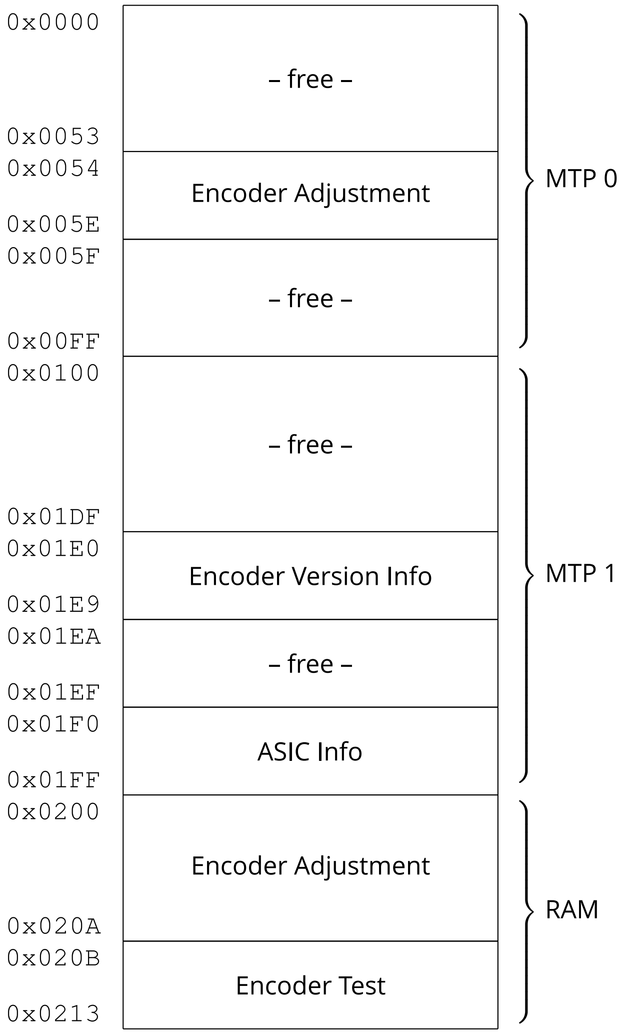
Register read and write operations are supported, as shown in the figure below.



[1] https://www.nxp.com/docs/en/user-guide/UM10204.pdf

MEMORY LAYOUT

A full memory map including occupied and remaining free space is shown below.
Whereas the RAM titled Area is reset to default at each startup (volatile), the MTP memory keeps its data across sessions (non-volatile).



The different sections are described in more detail later on.

ENCODER VERSION INFO

The following byte field shows the encoder's version info bytes with their corresponding address to the left.

Address	7 6 5 4 3 2 1 0
0x01E0	ENCODER_REVISION
0x01E1	FACTORY
0x01E2	PRODUCTION_YEAR
0x01E3	ENC_LOT_NUM_1
0x01E4	ENC_LOT_NUM_2
0x01E5	ENC_NUM_1
0x01E6	ENC_NUM_2
0x01E7	ENC_NUM_3
0x01E8	CHECK_SUM_1
0x01E9	CHECK_SUM_1

Values that consist of multiple bytes must be assembled MSB first which might look like the following.

```
uint16_t encLotNum = 0;
encLotNum =  encLotNum1 << 8;
encLotNum += encLotNum2;

uint32_t encNum = 0;
encNum =  encNum1 << 16;
encNum += encNum2 << 8;
encNum += encNum3;

uint16_t checkSum = 0;
checkSum =  checkSum1 << 8;
checkSum += checkSum2;
```

Revision
Displayed as hexadecimal number.
E.g. `E1`.

Factory
Displayed as 2-digit decimal number.
E.g.`01`.

Production Year
Displayed as 2-digit decimal number.
E.g. `20` for year 2020.

Lot Number (per year)
Displayed as 3-digit decimal number.
E.g. `002` for second lot in 2020.

Consecutive Number (per Lot)
Displayed as 5- or 6-digit decimal number.
E.g. `00023` for 23rd device in second lot of year 2020.

Putting it all together
The table below shows a fully assembled raw (hexadecimal) version info string as well as its corresponding format displayed by an encoder's label.

Revision	Factory	Prod. Year	Lot Num.	Cons. Num.
0xE1	0x01	0x14	0x0003	0x0001E5
E1	01	20	003	00485

Check Sum
The Check Sum is generated when writing the encoder version info and can later be used to verify the above information using the Fletcher-16 algorithm[2].

Implementation

```
uint16_t Fletcher16( uint8_t *data, int count )
{
   uint16_t sum1 = 0;
   uint16_t sum2 = 0;
   int index;

   for ( index = 0; index < count; ++index )
   {
      sum1 = (sum1 + data[index]) % 255;
      sum2 = (sum2 + sum1) % 255;
   }

   return (sum2 << 8) | sum1;
}
```

Usage

```
// calculate check sum for given data
// result should be 0xAD10
uint8_t versionInfo[] = {0xE1,0x01,
                         0x14,0x00,
                         0x02,0x00,
                         0x00,0x17};
uint16_t checkSum = Fletcher16(
                      versionInfo,
                      sizeof(versionInfo)
                    );
```

[2] https://en.wikipedia.org/wiki/Fletcher%27s_checksum

SIGNAL ADJUSTMENT

The Signal Adjustment registers contain several digital values that define analog settings and can thus be used to configure and optimize the encoders signals after installation (if necessary).

The following byte field shows the (volatile) RAM registers available for the adjustment with the registers addresses to the left and their default values after factory calibration to the right. Reading/Writing these registers can be used to modify the encoder's settings at run-time. Note that not all configuration values need the full width of 8 bits. Unused bits should be ignored when writing and read as zero. Further note that the Encoder Adjustment registers inside the RAM are overwritten by those in the MTP memory section after startup. Thus to save the current RAM settings for following sessions they have to be copied to the corresponding section of the MTP memory (see Saving the Configuration).

	7	6	5	4	3	2	1	0	
0x0200	SIN_OFFSET								0x7F
0x0201	UNUSED				SIN_GAIN_PGA				0x0F
0x0202	COS_OFFSET								0x7F
0x0203	UNUSED				COS_GAIN_PGA				0x0F
0x0204	UNUSED	REF_WIN MSB	REF_WIN						0x40
0x0205	REF THRESH SW1	REF_DIFF1							0x20
0x0206	REF THRESH SW2	REF_DIFF2							0xA0
0x0207	UNUSED		LED_CS						0x15
0x0208	UNUSED	LED SPEED CTRL	I2C_SR		GPI	GPO	LED LOOP EN	REF_POL	0x01
0x0209	UNUSED						REF_INCR RES	REF_EN	0x03
0x020A	UNUSED	LED_DAC							0x60

To simplify the adjustment of the analog settings (e.g. when writing application software), it is advisable for some registers to convert a value after reading and before writing the modified value back to the chip. Below follows a more detailed description including possible conversion routines (if necessary) for all commonly used registers. [3]

Sine/Cosine Offset (value range: `0...255`)
The conversion results in a linear adjustable range for the offset with 0 as minimum and 255 as maximum offset.

Conversion Example

```
value = readRegister(0x200)
if value < 128
  value = 255 - value
else
  value = value - 128

...

if value < 128
  value = 128 + value
else
  value = 255 - value
writeRegister(0x200, value)
```

[3]For more information on internal design and electrical characteristics of all in-/outputs please refer to the associated DataSheet.

Sine/Cosine Gain (value range: `0...15`)
The conversion results in an adjustable range for the gain with 0 as minimum and 15 as maximum gain.

Conversion Example

```
value = readRegister(0x0201)
value = 15 - value

...

value = 15 - value
writeRegister(0x0201, value)
```

Reference Window (value range: `0...63`)
REF_WIN_MSB should be kept 1 at all times. The conversion thus results in an adjustable range for the window threshold with 0 as minimum and 63 as maximum threshold.

Conversion Example

```
value = readRegister(0x0204)
value = value & ~0b00111111

...

value = value | 0b01000000
writeRegister(0x0204, value)
```

Reference Diff1/2 (value range: `0...255`)
The conversion results in a linear adjustable range for the diff threshold with 0 as minimum and 255 as maximum threshold.

Conversion Example

```
value = readRegister(0x0205)
if value < 128
  value = value + 128
else
  value = 255 - value

...

if value < 128
  value = 255 - value
else
  value = value - 128
writeRegister(0x0205, value)
```

LED Current Source (value range: `0...63`)
This register can either be used to

- directly control the current of the LED (if LED Control-Loop is inactive)
- change the regulation loop gain (if LED Control-Loop is active)

Reference Polarity
This bit selects the reference marks' polarity and must be configured to match with the used sensor stripe.

0 Absorbing Reference Mark

1 Reflective Reference Mark

LED Loop Enable
This bit enables/disables the internal LED Control-Loop.

0 Control-Loop inactive

1 Control-Loop active

GPO
This bit sets the voltage level for the General Purpose Output.

0 GPO set to Low

1 GPO set to High

GPI
This bit holds the voltage level of the General Purpose Input.

0 GPI read as Low

1 GPI read as High

I2C Slew Rate (value range: `0...3`)
This register can be used to adjust the I2C slew rate by adding the following values to 430 kΩ.

0 Add 180 kΩ

1 Add 120 kΩ

2 Add 60 kΩ

3 Add 0 Ω

LED Speed Control
This bit sets the speed of the LED Control-Loop.

0 Normal Speed

1 Low Speed

Reference Enable
This bit enables/disables the analog reference path.

0 Reference Disabled

1 Reference Enabled

Reference Increased Resolution
This bit selects the resolution for the reference mark adjustment using `REF_DIFF1/2`. Note that an increased resolution comes along with an overall smaller adjustment range.

0 Default Resolution / Wide Adjustment Range

1 Increased Resolution / Smaller Adjustment Range

LED DAC (value range: `0...127`)
This register can be used to adjust the setpoint of the regulation loop if the LED Control-Loop is active. Note that because of the analog structure a setpoint lower than 0x40 switches off the LED current. Therefore it is recommended to keep the MSB high in this mode.

SAVING THE CONFIGURATION

To save the final adjustment settings, the RAM registers have to be copied to the corresponding MTP memory section that is used to initialize the RAM at startup. A copy routine that saves all relevant registers to MTP might look the following.

```
num_of_registers = 11
ram_base = 0x0200
mtp_base = 0x0000

for (address_offset = 0;
     address_offset < num_of_registers;
     address_offset++) {
  // read byte from ram
  value = read_byte(ram_base+address_offset)
  // write byte to mtp
  write_byte(mpt_base+address_offset, value)
  // wait for mtp write delay
  delay(40ms)
}
```

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