Multi-channel Analog to Digital REcorder (MADRE): Data Streaming Output Format

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***Abstract*—The MADRE board, developed by the MOD group, samples 7 analog channels at a 320 Hz sampling rate. It can also receive data from two auxiliary devices (ex: SBE-49) Collected data is send via an RS422 serial port every half-second at a 460800 baud rate. A data block starts with a 61 character header, followed by 0,1 or 2 hexadecimal records of the auxiliary device's data, and concludes with a binary record of the enabled analog channels on the MADRE board**

I. Introduction

THE MADRE board is an embedded system used for analog sampling, sensor interface, data output and storage. It uses a low energy micro controller to interface with 24-bit Analog-to-Digital Converters (ADC), process data and control serial interfaces. MADRE can read the analog input from the Multi-Channel Analog Prototype (MAP) board and 2 auxiliary devices (The default device is a SBE49). The MAP board is a flexible platform for analog front-ends whose output is connected through the header to the MADRE. The devices communicate with MADRE through two RS232 serial ports. MADRE communicates with the user through a RS422 serial port.

In its current configuration, the MADRE microcontroller's core clock is 40MHz. The microcontroller synthesizes a 625KHz clock for the ADC sigma-delta modulators. The ADCs configuration establishes the 320Hz sample word rate and implicit filter roll-off (i.e $sinc^4$). The ADCs are configured for unity gain and unipolar (single-ended) mode. The MAP is configured to receive 2 FPO7 temperature probes and 2 shear probes.

II. Data Output Format

The MADRE can be connected through a RS422 serial port with a 460800 baudrate. After power up, MADRE streams a block of data every half-second. A block is composed of a header, 1 or 2 auxiliary device records (if devices are connected) and a MAP record.

- Header: the Header is a 61 character word containing 7 items separated by ",".
  1) A header identifier ($MADRE) (no coma).
  2) The number of MAP samples since power up (hexadecimal) + ",".
  3) The number of 32768Hz real time clock cycle since power up (hexadecimal) + ",".
  4) The voltage input (hexadecimal)+",".
  5) Checksum of device 1 record (hexadecimal)+",".
  6) Checksum of device 2 record (hexadecimal)+",".
  7) Checksum of the MAP samples (hexadecimal)+",".
  8) carriage return, new line. (\r \n)

  Header example:
  $MADRE00000000,00000000,00000000,00000000,
  00000000,00000000\r \n
- Auxiliary Device record: MADRE gathers and creates half-second records of the device's samples in ASCII code. The length of the record depends on the length of the device's word length and its output frequency. MADRE stores the device's words during the completion of the half-second block. An auxiliary record starts with a record identifier ($AUX1 or $AUX2) followed by a time stamp and the actual device word. The time stamp is the number of MAP samples when MADRE received the device's sample. The structure of the auxiliary record is as follows:

  1) A record identifier ($AUX1)(no coma).
  2) Time stamp (hexadecimal)+",".
  3) The device word (ASCII device word).
  4) Steps 1 and 2 are repeated to record's end

  Example of an auxiliary record with SBE49:
  $AUX100000000,ttttttccccccpppppppvvvv\r \n
- MAP record: A map record corresponds to the MAP samples gathered every half-second. The length of a MAP record depends on the number of analog channels/ADCs enabled. MADRE default state is 2 temperature channels (t1, t2), 2 shear channels (s1, s2) and 3 acceleration channels (ax, ay, az). Each ADC outputs a three-byte (24-bit) sample. Thus, the default sample length is 21 bytes. The MAP record is stored and streamed as a binary word. The structure of a MAP record is as follows:
  - A record identifier ($EPSI).
  - 160 (half-second at 320 Hz) $\times$ MAP sample length= (3360 bytes for the default 7 analog channels).
  - carriage return, new line. (\r \n)

III. Reading a MADRE block

We do provide a python script that opens a serial port and reads the output of the MADRE board ⟨https://github.com/modscripps/MADRE_git⟩

A. Time stamps

The MADRE headers contain two kind of time stamps. One based on the 320 Hz sampling frequency of the ADC and one

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based on an internal RCO 32768 Hz inside the microprocessor. The ADC sampling frequency is based by the 40 MHz core clock which provide a reliable time stamp. These 4 bytes counters start MADRE power up. They are sent through the RS422 serial port as a hexadecimal number: 0x00000000.

N.B: The internal RCO will soon be replaced by an accurate external crystal oscillator.

B. Voltage

Not implemented yet, work in progress.

An ADC inside the microprocessor can read the input voltage. The voltage is sent through the RS422 serial port as hexadecimal number: 0x00000000

C. Check sum

In the MADRE header, the block checksums are define as:

$$\sum_{i=0}^{LengthBlock} chcksum \quad XOR \quad record[i] \tag{1}$$

$record[i]$ is either an auxiliary or MAP record sent from the MADRE. They are sent through the 422 serial port as hexadecimal number: 0x00000000

D. Auxiliary device record

Not implemented yet, work in progress.

E. MAP record

A MAP record consists of a ASCII header ($EPSI) followed by binary data. In the default configuration, the binary record length is 3360 bytes.

The reader routine $read\_MADRE2.1.py$ in the github repository (⟨https://github.com/modscripps/MADRE_git⟩) reads the streaming from MADRE and convert the block into a ASCII hexadecimal word of 42 characters. Here is an example of the output of the reader when only the accelerometer channels are alive:

$MADRE a00, 3d94a, 0, 0, 0, 3f
ffffffffffffffffffffffffa7e484ab44eb645b63
ffffffffffffffffffffffffa7e54dab34b96455e2
ffffffffffffffffffffffffa7ee84ab34a864444b
...

The first 4 channels $\times$ 6 char correspond to t1,t2,s1 and s2 channels, the last 3 channels $\times$ 6 characters correspond the acceleration channels.

a) Counts to Volts conversion: The ADCs send a 3 bytes word. In a unipolar configuration, the ADC word can be converted from Counts to Volts using:

$$Counts = (2^N \times AIN \times Gain)/VREF \tag{2}$$

with $Gain = 1$, $N = 24$ bits, $VREF = 2.5$ Volts and AIN=Signal Input Voltage

b) Volts to Acceleration unit conversion: Once converted in volts, the three acceleration channels can be converted in acceleration unit g ($m\ s^{-2}$) using (from the constructor Kionix):

$$g = \frac{Volt - 1.65}{0.66}; \tag{3}$$

IV. Conclusion

The MADRE board outputs data blocks at a 460800 baud rate. A block is sent every half-second (160 MAP samples). A block contains a MADRE header, a MAP record and, depending on the configuration, one or two auxiliary device records between the header and the MAP record. The MADRE header length is fixed and the length of the records varies with the MADRE configuration and/or the number and kind of devices plugged in MADRE. We do provide a github repository ⟨https://github.com/modscripps/MADRE_git⟩ to read the MADRE output in its simplest (default) configuration: no auxiliary devices and 7 analog channels (temperature 1 and 2, shear 1 and 2 and x,y,z acceleration) .