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USER MANUAL

GDI Driver

Document version: 1.2
Firmware version: 2.2 or later
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ECUMASTER

Contents

1. Device description

The GDI Driver is a high-performance aftermarket controller designed to manage modern gasoline direct-injection systems. Capable of driving up to **8 peak-and-hold injectors** and **2 high-pressure fuel pumps**, this module delivers precision and reliability for advanced engine setups.

Key Features:

- **Injector Control**: Converts 12 V to up to 70 V for fast injector response and precise control.
- **Pump Valve Management**: Supports dual high-pressure pump valves at 12 V.
- **SENT Sensor Support**: Handles up to 4 SENT sensors.
- **CAN Bus Connectivity**: Provides diagnostic data for real-time monitoring and data logging.

While the GDI Driver is compatible with any ECU featuring a GDI strategy, it is optimized for use with EMU PRO. When paired, this combination utilizes advanced algorithms and hardware to deliver unmatched precision in fuel control.

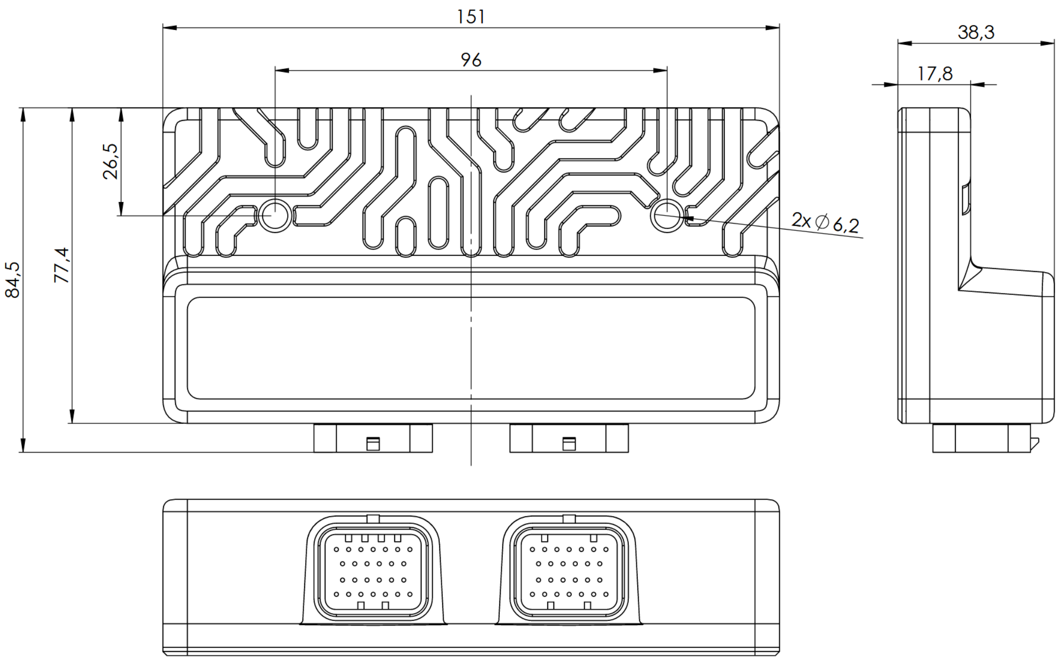
For detailed guidance on integrating the GDI Driver with EMU PRO, refer to the *How-to Tune the GDI Engine* document: https://www.ecumaster.com/files/EMU_PRO/How-to/How-to_Tune_the_GDI_Engine_in_EMU_PRO.pdf

Note:
The GDI Driver is not an Engine Control Unit (ECU); it works alongside an ECU, which is needed for proper control.

2. Specification

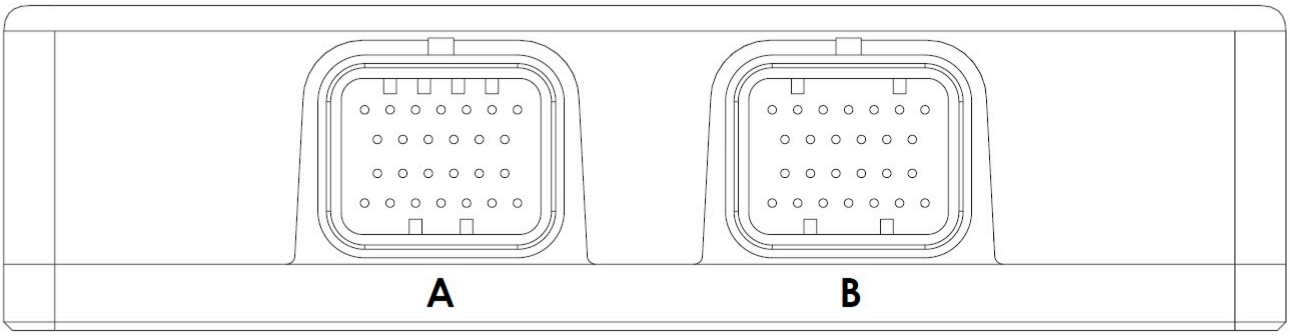
Temperature range	AECQ GRADE 1 (-40°C to +125°C)
Operating voltage	9-22 V, immunity to transients according to ISO 7637
Max boost voltage	70 V
Max boost current	16 A
Max boost duration	800 us
Max peak current	12 A
Max peak duration	1800 us
Max hold current	6 A
Weight	450 g
Dimensions	151 x 85 x 38 mm
Number of CAN buses	1 x CAN 2.0 A/B
SENT communication	4
Number of injector outputs	8
Number of ignition outputs	0
RPM limit	9000 RPM at full capacity (8 injectors, 2 pumps)
Supported injectors	Electromagnetic, low-impedance

All dimensions in mm



3. Pinout

Connector symbols:



Connector part numbers:

Connector series	AMP SUPERSEAL 1.0	
Connector A	1473416-2	26 Positions
Connector B	3-1437290-8	26 Positions
Terminal	3-1447221-3	16-18 AWG
Terminal	3-1447221-4	20 AWG

Power		
Name	**Count**	**Description**
+12V supply	4	Power supply for the module Power should be provided when ECU turns on
+5V source	2	+5V sensor supply Source can provide up to 2 A of current

Ground		
Name	**Count**	**Description**
Power GND	4	Power ground
Digital GND	1	Digital ground for SENT sensors
Analog GND	1	Analog ground for analog outputs

Communication		
Name	**Count**	**Description**
CAN high/low	2	CAN bus, used for communication with PC and peripheral devices. No internal termination resistor. External termination is required.
SENT	4	SENT (Single Ended Nibble Transmission) inputs for sensors.

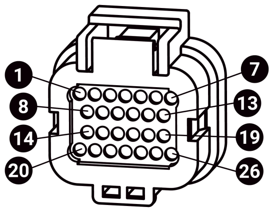
Input		
Name	**Count**	**Description**
Injector Control	8	Activated by connecting ground Internal pull up to +12V
Pump Control	2	Activated by connecting ground Internal pull up to +12V

Analog outputs		
Name	**Count**	**Description**
Analog output	8	Outputs can be controlled by values from SENT or CAN Output voltage range: 0-5 V Voltage resolution: 12 bit

High side outputs		
Name	**Count**	**Description**
Injector high side	4	Output for direct injectors Low side output Common high side output for a pair of injectors Injectors in a pair cannot have pulse width overlap
Pump high side	2	Output for pump control valves High side output

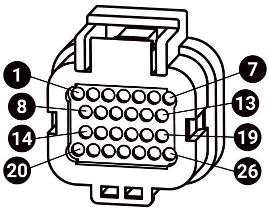
Low side outputs		
Name	**Count**	**Description**
Injector low side	8	Output for direct injectors Low side output
Pump low side	2	Output for pump control valves Low side output

Connector A:



Pin	Name	Description
A1	Injector C, D high side	Common high side output for injectors C and D
A2	Injector A, B high side	Common high side output for injectors A and B
A3	Injector D low side	Low side output for injector D
A4	Injector C low side	Low side output for injector C
A5	Injector B low side	Low side output for injector B
A6	Injector A low side	Low side output for injector A
A7	Pump 1 low side	Low side output for pump 1
A8	Pump 1 control	Control input for pump 1
A9	Injector D control	Control input for injector D
A10	Injector C control	Control input for injector C
A11	Injector B control	Control input for injector B
A12	Injector A control	Control input for injector A
A13	Pump 1 high side	High side output for pump 1
A14	Power GND	Power ground
A15	Analog output 4	Analog output 4
A16	Analog output 3	Analog output 3
A17	Analog output 2	Analog output 2
A18	Analog output 1	Analog output 1
A19	+12V supply	Power supply
A20	Power GND	Power ground
A21	+5V source	+5V sensor supply
A22	Analog GND	Analog ground
A23	Digital GND	Digital ground
A24	SENT 1	SENT 1 sensor input
A25	SENT 2	SENT 2 sensor input
A26	+12V supply	Power supply

Connector B:



Pin	Name	Description
B1	Pump 2 low side	Low side output for pump 2
B2	Injector E low side	Low side output for injector E
B3	Injector F low side	Low side output for injector F
B4	Injector G low side	Low side output for injector G
B5	Injector H low side	Low side output for injector H
B6	Injector E, F high side	Common high side output for injectors E and F
B7	Injector G, H high side	Common high side output for injectors G and H
B8	Pump 2 high side	High side output for pump 2
B9	Injector E control	Control input for injector E
B10	Injector F control	Control input for injector F
B11	Injector G control	Control input for injector G
B12	Injector H control	Control input for injector H
B13	Pump 2 control	Control input for pump 2
B14	+12V supply	Power supply
B15	Analog output 5	Analog output 5
B16	Analog output 6	Analog output 6
B17	Analog output 7	Analog output 7
B18	Analog output 8	Analog output 8
B19	Power GND	Power ground
B20	+12V supply	Power supply
B21	SENT 3	SENT 3 sensor input
B22	SENT 4	SENT 4 sensor input
B23	CAN low	CAN bus low, used for communication with PC and peripheral devices.
B24	CAN high	CAN bus high, used for communication with PC and peripheral devices.
B25	+5V source	+5V sensor supply
B26	Power GND	Power ground

The following wire gauges are recommended for proper operation of GDI Driver:

Name	AWG
+12 V power supply	16
Power ground	16
Injector high side	20
Injector low side	20
Pump high side	20
Pump low side	20

4. Installation

Note:
Ecumaster GDI Driver does not support piezoelectric injectors.

When installing the GDI Driver, ensure it is mounted in a secure location where temperatures do not exceed 70 degrees Celsius (160 degrees Fahrenheit) and avoid areas with excessive vibrations. The cables connecting to the injectors should be kept short, with a maximum length of 1.5 meters (5 feet), to ensure optimal performance and signal integrity.

There are four high-side outputs. For engines with more than four cylinders, the injectors must be connected in pairs. Paired injectors cannot be turned on at the same time. The GDI driver will not allow it, no matter the state of control inputs. Direct injection can only happen on intake and compression stroke, so pairing injectors offset by 360 degrees of the engine cycle will naturally eliminate any possibility of pulse width overlap.

The decision on which injectors to pair can be made by looking at the engine's firing order. Splitting the firing order in the middle creates two groups of cylinders that are offset by half the engine cycle. Injectors that are first in both groups have to be paired together, injectors that are second in both groups have to be paired together, and so on.

To ensure optimal performance, the load should be kept equal and spread across the device. We recommend using both connectors symmetrically.

Example 1:

Four-cylinder. In this example, we will pair injectors, to show this concept. In other way, each of the injectors could be connected to separate high side.

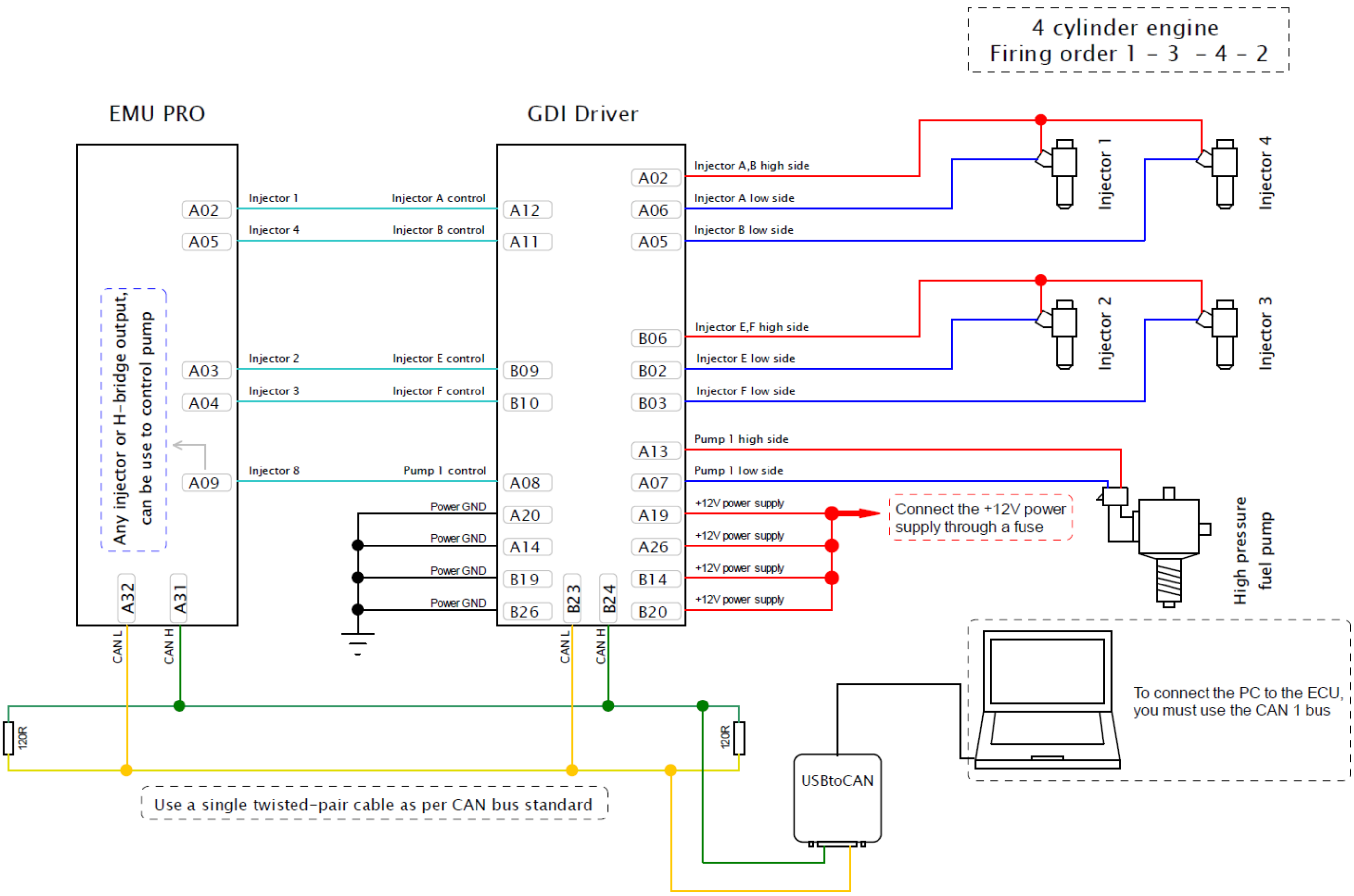
Firing order: 1-3-4-2

First half of firing order: 1-3

Second half of firing order: 4-2

Injector pair 1 (A, B): 1 & 4

Injector pair 2 (E, F): 3 & 2



Example 2:

Six-cylinder

Firing order: 1-5-3-6-2-4

First half of firing order: 1-5-3

Second half of firing order: 6-2-4

Injector pair 1 (A, B): 1 & 6

Injector pair 2 (C, D): 5 & 2

Injector pair 3 (E, F): 3 & 4

Example 3:

Eight-cylinder

Firing order: 1-5-4-8-6-3-7-2

First half of firing order: 1-5-4-8

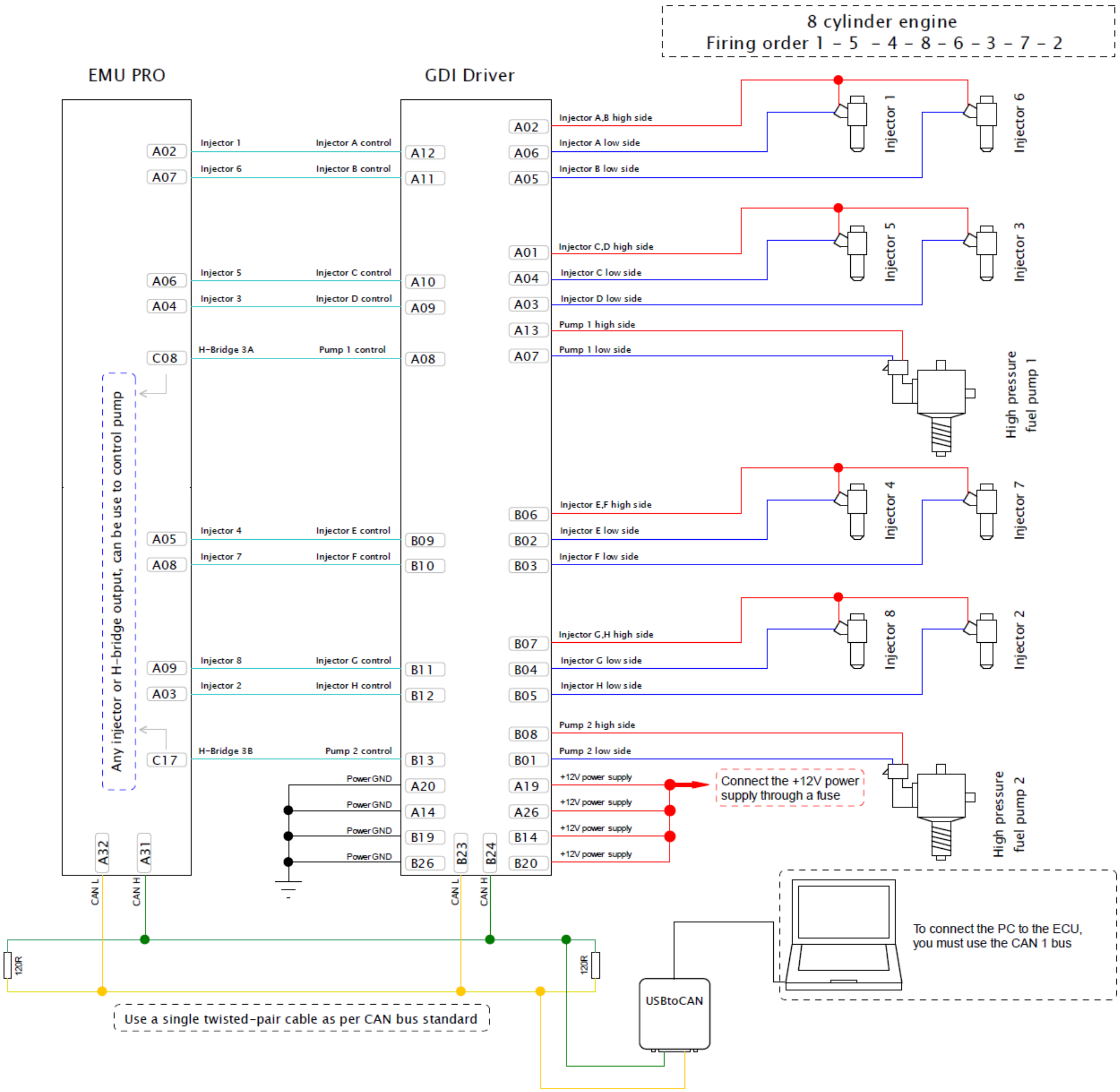
Second half of firing order: 6-3-7-2

Injector pair 1 (A, B): 1 & 6

Injector pair 2 (C, D): 5 & 3

Injector pair 3 (E, F): 4 & 7

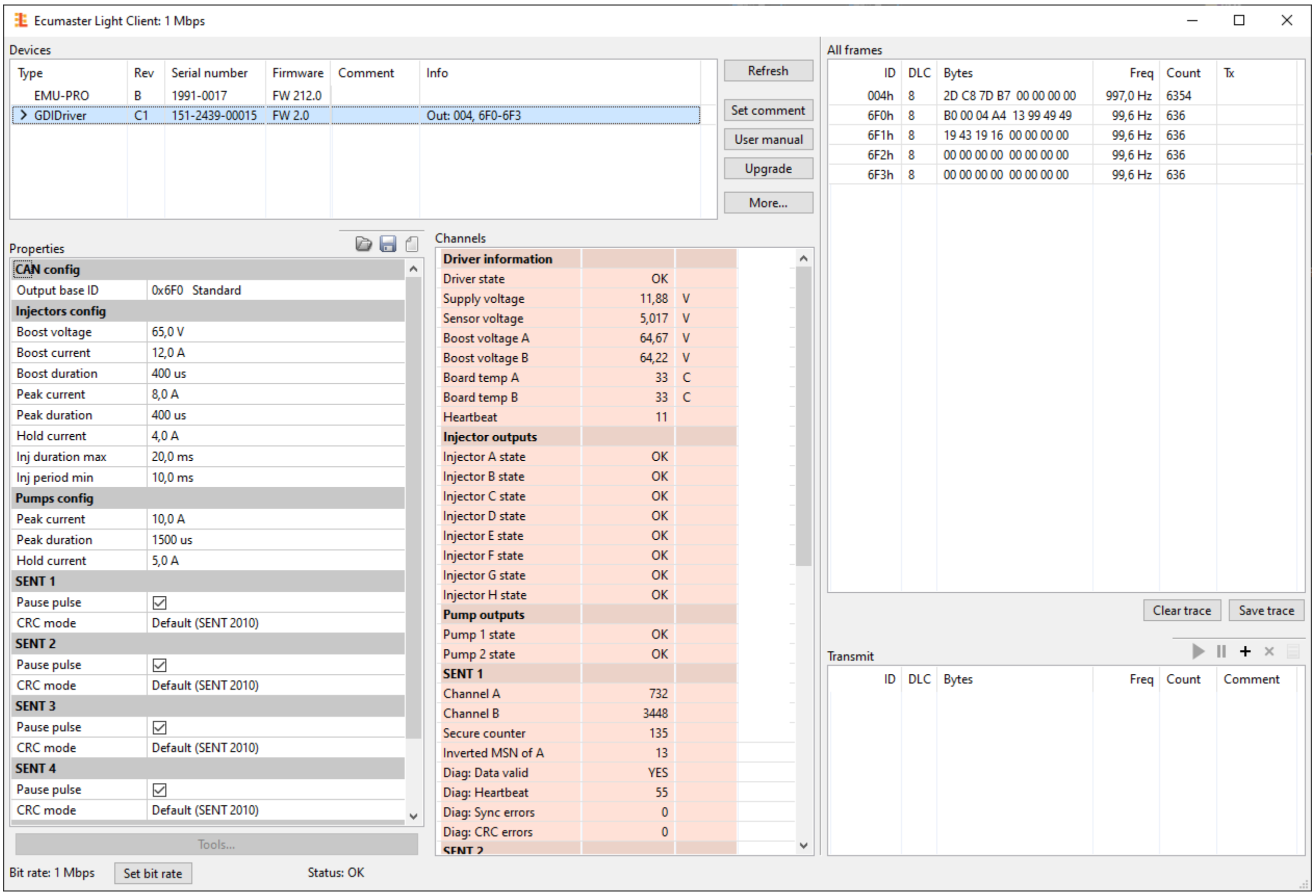
Injector pair 4 (G, H): 8 & 2



5. Light Client

The configuration of the GDI Driver is done through the Light Client. Light Client v2.3 or later is necessary to configure the device. Details on measuring the injectors and pump parameters are described in the How-to Tune the GDI Engine document: https://www.ecumaster.com/files/EMU_PRO/How-to/How-to_Tune_the_GDI_Engine_in_EMU_PRO.pdf

5.1. Light Client Parameters



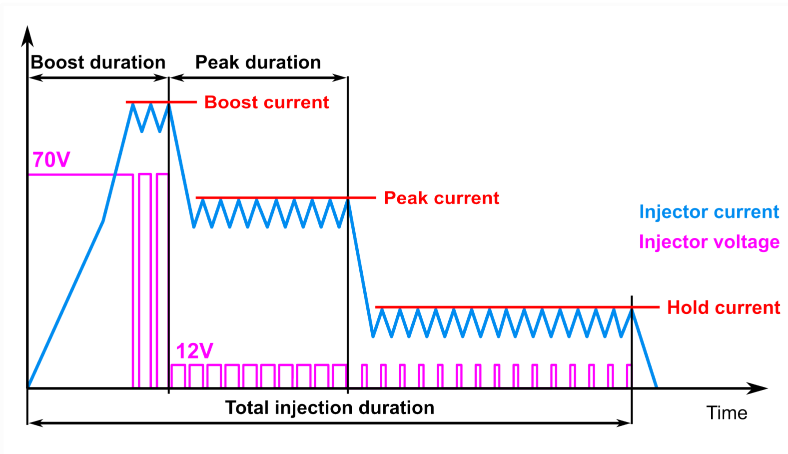
CAN configuration parameters

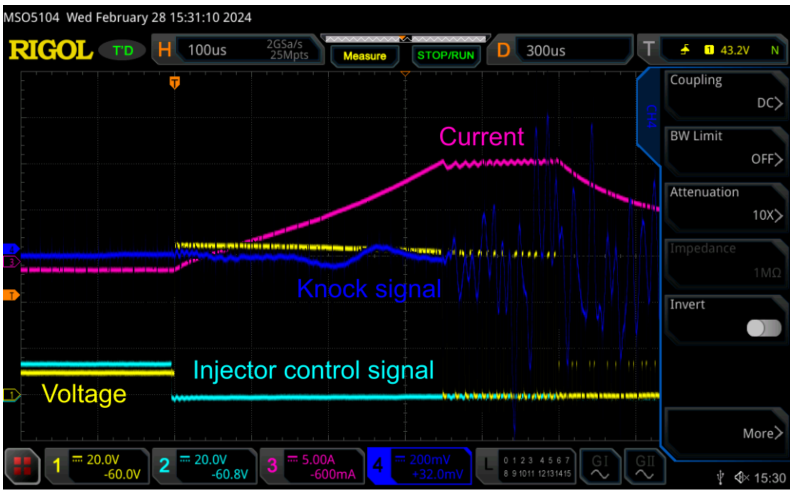
Parameter	Description
Output base ID	ID of the CAN frame over which GDI Driver diagnostics is transmitted

Injector configuration parameters

To ensure optimal performance of the injector, you should configure the following six key parameters:

Parameter	Description
Boost voltage	The voltage applied to the injector during the boost phase
Boost current	The maximum current applied to the injector during the boost phase
Boost duration	The time period for which the boost voltage and current are applied
Peak current	The maximum current applied during the peak phase
Peak duration	The time period for which the peak current is applied
Hold current	The current maintained to keep the injector open after the peak phase
Inj duration max	A safety feature that defines the maximum injector opening time. Even if the ECU requests a longer duration, the injector will close after this time limit to prevent overheating and potential damage.
Inj period min	A safety feature that defines the minimum interval between activations of the same injector.





Pumps configuration parameters

Parameter	Description
Peak current	The peak current is a high level of electric current used to quickly open a valve. It is the initial surge of current that provides enough power to move the valve from a closed to an open position.
Peak duration	The peak duration is the time period during which the peak current is applied. It lasts just long enough to ensure that the valve fully opens.
Hold current	The hold current is a lower level of electric current used to keep the valve open after it has been activated. This current is maintained for as long as the valve needs to stay open.

SENT # parameters The details of the SENT communication protocol are described in Appendix A - SENT communication *(on page 22)*.

Parameter	Description
Pause pulse	The Pause Pulse is an optional gap between SENT frames, used in some OEM signals. Ensure it is enabled or disabled according to the specific protocol configuration. Incorrect settings will cause the *Sync Errors* counter to increase.
CRC mode	This setting determines which CRC calculation method is used. An incorrect configuration of the CRC mode will result in a growing *CRC Errors* counter, signaling data validation issues.

SENT over CAN parameters

Parameter	Description
Channel 1+2 (3+4): Enable	Activates the transmission of packed SENT frames over CAN. These frames can then be used by the EMU PRO. For detailed setup instructions, refer to the chapter SENT communication between GDI Driver and EMU PRO *(on page 16)*
Channel 1+2 (3+4): CAN ID	Defines the frame ID over which the CAN frames are transmitted. Signals from critical sensors (e.g. Throttle position) sent over CAN should have a low ID to be received with a high priority.

5.2. Light Client Channels

Channels

This section provides important information about different parts of the device. It serves as a central dashboard for monitoring key settings.

Channel	Description
Driver state	Current status of the device.
Supply voltage	Device supply voltage - unstable voltage can lead to incorrect operation of the device.
Sensor voltage	Output sensor supply voltage - it should be stable around 5V.
Boost voltage A - B	The voltage at the output of the converter, it should be stable and close to the value set in the *Boost voltage* parameter.
Board temp A	Temperature of the left side (Connector A) of the device. The load should be balanced to ensure that both sides of the device maintain similar temperatures.
Board temp B	Temperature of the right side (Connector B) of the device. The load should be balanced to ensure that both sides of the device maintain similar temperatures.
Heartbeat	Transmitted CAN frame counter.
Injector A - H state	Current state of the device.
Pump 1 - 2 state	Current state of the pump.
Channel A	SENT Signal 1 value.
Channel B	SENT Signal 2 value.
Secure counter	If the SENT Format is *Single Signal* or *Single Secure*, this will display an incrementing value with each incoming SENT frame. For the *Dual Sensor* format, this will show inconsistent data.
Inverted MSN of A	The binary inversion of the Most Significant Nibble (MSN), where each bit is flipped (e.g., 0001 in binary becomes 1110). In hexadecimal, this means 0x01 will be inverted to 0x0E. If the SENT Format is *Single Signal* this will show 0 consistently.
Diag: Data valid	If the SENT data is correctly received, this channel will display 1; it will show 0 if the data is invalid.

Channel	Description
Diag: Heartbeat	With each SENT frame received, the value of this channel will increment.
Diag: Sync errors	If the received data frame doesn't have the correct structure, the value in this channel will increment.
Diag: CRC errors	If the received data frame has a CRC/checksum error, the value in this channel will increment.

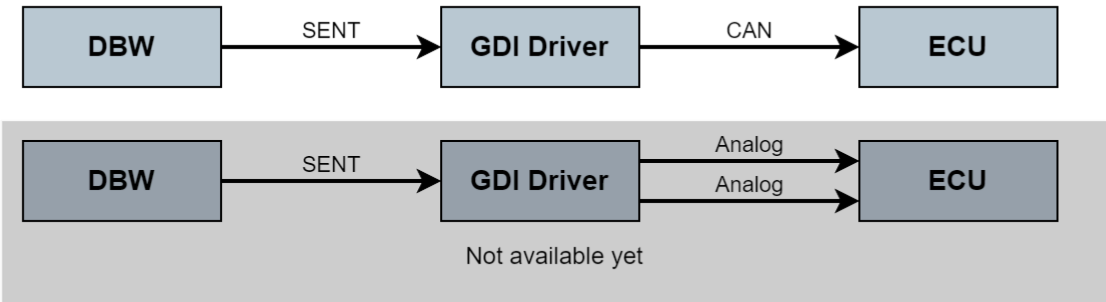
6. SENT communication between GDI Driver and EMU PRO

The details of the SENT communication protocol are described in Appendix A - SENT communication *(on page 22)*.

SENT through the GDI Driver

There are two primary ways to receive SENT data using the GDI Driver:

- CAN: The GDI Driver can receive data using the SENT protocol and send it over the CAN-bus without any interpretation. In this mode ECU decodes and interprets the SENT data. Each frame contains SENT frames counter used to detect the missing ones.
- 2 Analog signals: The GDI Driver can also interpret the SENT data and output it to ECU as ready-to-use analog signals. *[NOT AVAILABLE YET]*



Supported ***Fast channel*** frames in EMU PRO:

- Single Sensor
- Dual Sensor 12/12 bit
- Single Secure

EMU PRO control loop works with 500 Hz regardless of SENT messages frequency.

SENT configuration in EMU PRO:

- ***Communication / SENT over CAN bus / SENT 1+2 enable (SENT 3+4 enable)*** – activates SENT communication over the CAN bus.
- ***Communication / SENT over CAN bus / SENT 1+2 CAN ID (SENT 3+4 CAN ID)*** – indicates the CAN frame ID over which SENT channels 1 and 2 are transmitted. This should match the setting in the Light Client, described in chapter Light Client Parameters *(on page 12)*
- ***Communication / SENT over CAN bus / GDI Driver CAN output base ID*** – indicates the CAN frame ID over which SENT diagnostics is transmitted from the GDI Driver

Then, to use the SENT channel as a source for given sensor, you should select the ***Source*** to *Voltage over SENT*. This enables specific options for SENT configuration:

- ***Sensors / [Specific Sensor] / Input*** - selection of SENT channel
- ***Sensors / [Specific Sensor] / Input / SENT message / Format*** - selection of SENT frame format:
  - Single Sensor
  - Dual Sensor 12/12 bit
  - Single Secure

Note:
The SENT message format is determined for the entire SENT interface, not for individual SENT channels.

In EMU PRO SENT is available for the following sensors:

- Temperature sensors
- Pressure sensors
- Accelerator position
- Throttle position

Identification of SENT frame format

There are easy to identify differences between supported frame formats. Channel 1 always contains data while Channel 2 function differently according to frame format.

Dual Sensor 12/12 bit:

- Channel 1 data
- Channel 2 data

Single Secure:

- Channel 1 data
- Channel 2 counter (0-255)
- 6th nibble MSN inverted

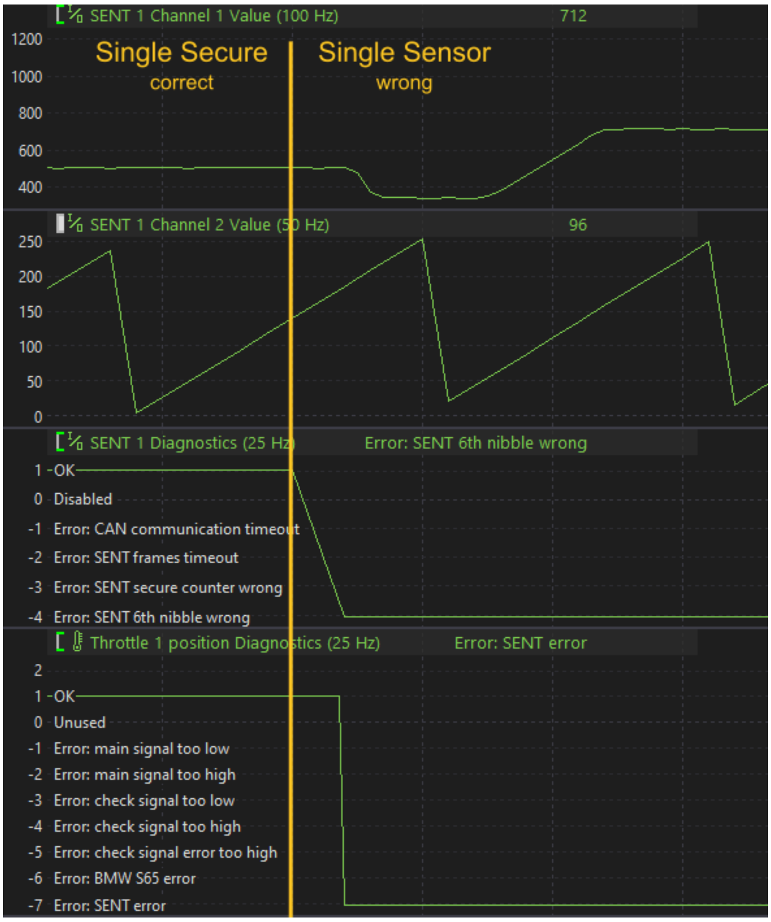
Single Sensor:

- Channel 1 data
- Channel 2 counter (0-255)
- 6th nibble 0x00

Following EMU PRO channels would be useful for frame format identification:

- ***SENT # Channel 1 Value***
- ***SENT # Channel 2 Value***
- ***SENT # Diagnostics***

If *SENT # Channel 2 Value* contains data, set *Format* to *Dual Sensor 12/12 bit*.
If *SENT # Channel 2 Value* contains counter visible as saw signal, set *Format* to *Single Secure* and check *SENT # Diagnostics* channel. If its value is set to "*Error: SENT 6th nibble wrong*", change *Format* to *Single Sensor*.



SENT communication diagnostics

The following channels are helpful when diagnosing the communication between the EMU PRO and the GDI Driver:

Sent # Transmission errors counter will increase every time one of the following errors occur:

- *SENT Frames Timeout*: CAN frames are received, but the heartbeat value does not increase
- *CAN Frames Timeout*: CAN frames are not received
- *Secure Counter Jumps*: The secure counter jumps beyond the established limit
- *Heartbeat Jumps*: The heartbeat value jumps beyond the established limit
- *Uneven Increase*: The secure counter and heartbeat do not increase evenly

Sent # Sync errors counter will increase every time the received SENT data frame doesn't have the correct structure

Sent # CRC errors counter will increase every time the received SENT data frame has a CRC/ checksum error

7. CAN Stream

Byte	Bit	Channel	Data Type	Range	Multiplier/ Divider	Factor	Offset	Unit
Output base ID+0 (default: 0x6F0)								
0	4 (0xF0)	Heartbeat	4-bit U	0-15	1/1	1	0	
	0 (0x0F)	Driver state[1]	4-bit U	enumeration	1/1	1	0	
1		Sensor voltage	8-bit U	3-6	3/255	0.012	3	V
2..3		Supply voltage	16-bit U	0 – 655.35	1/100	0.01	0	V
6		Board temp A	8-bit U	-40 – 215	1/1	1	-40	C
7		Board temp B	8-bit U	-40 – 215	1/1	1	-40	C
Output base ID+1 (default: 0x6F1)								
0..1		Boost voltage A	16-bit U	0 – 655.35	1/100	0.01	0	V
2..3		Boost voltage B	16-bit U	0 – 655.35	1/100	0.01	0	V
4	4 (0xF0)	Injector B state[2]	4-bit U	enumeration	1/1	1	0	
	0 (0x0F)	Injector A state[2]	4-bit U	enumeration	1/1	1	0	
5	4 (0xF0)	Injector D state[2]	4-bit U	enumeration	1/1	1	0	
	0 (0x0F)	Injector C state[2]	4-bit U	enumeration	1/1	1	0	
6	4 (0xF0)	Injector F state[2]	4-bit U	enumeration	1/1	1	0	
	0 (0x0F)	Injector E state[2]	4-bit U	enumeration	1/1	1	0	
7	4 (0xF0)	Injector H state[2]	4-bit U	enumeration	1/1	1	0	

Byte	Bit	Channel	Data Type	Range	Multiplier/ Divider	Factor	Offset	Unit
	0 (0x0F)	Injector G state[2]	4-bit U	enumeration	1/1	1	0	
Output base ID+0 (default: 0x6F2)								
6	4 (0xF0)	Pump 2 state[3]	4-bit U	enumeration	1/1	1	0	
	0 (0x0F)	Pump 1 state[3]	4-bit U	enumeration	1/1	1	0	
Output base ID+3 (default: 0x6F3)								
0		Diag: Sync errors1	8-bit U	0 – 255	1/1	1	0	
1		Diag: CRC errors1	8-bit U	0 – 255	1/1	1	0	
2		Diag: Sync errors2	8-bit U	0 – 255	1/1	1	0	
3		Diag: CRC errors2	8-bit U	0 – 255	1/1	1	0	
4		Diag: Sync errors3	8-bit U	0 – 255	1/1	1	0	
5		Diag: CRC errors3	8-bit U	0 – 255	1/1	1	0	
6		Diag: Sync errors4	8-bit U	0 – 255	1/1	1	0	
7		Diag: CRC errors4	8-bit U	0 – 255	1/1	1	0	
Channel 1+2: CAN ID+0 (default: 0x004)								
0..3	20 (FFF00000)	Value A1	12-bit U	0.0 – 4095	1/1	1	0	
0..3	12 (0xFFF000)	Value B1	12-bit U	0.0 – 4095	1/1	1	0	
0..3	12 (0x3FC00)	Secure counter1	8-bit U	0-255	1/1	1	0	
0..3	8 (0x100)	Inverted MSN of A1	4-bit U	0-15	1/1	1	0	
0..3	7 (0x80)	Diag: Data valid1[4]	1-bit	enumeration	1/1	1	0	
0..3	0 (0x7F)	Diag: Heartbeat1	7-bit U	0-127	1/1	1	0	
4..7	20 (FFF00000)	Value A2	12-bit U	0.0 – 4095	1/1	1	0	
4..7	12 (0xFFF000)	Value B2	12-bit U	0.0 – 4095	1/1	1	0	
4..7	12 (0x3FC00)	Secure counter2	8-bit U	0-255	1/1	1	0	
4..7	8 (0x100)	Inverted MSN of A2	4-bit U	0-15	1/1	1	0	
4..7	7 (0x80)	Diag: Data valid2[4]	1-bit	enumeration	1/1	1	0	
4..7	0 (0x7F)	Diag: Heartbeat2	7-bit U	0-127	1/1	1	0	
Channel 3+4: CAN ID+0 (default: 0x005)								
0..3	20 (FFF00000)	Value A3	12-bit U	0.0 – 4095	1/1	1	0	
0..3	12 (0xFFF000)	Value B3	12-bit U	0.0 – 4095	1/1	1	0	
0..3	12 (0x3FC00)	Secure counter3	8-bit U	0-255	1/1	1	0	
0..3	8 (0x100)	Inverted MSN of A3	4-bit U	0-15	1/1	1	0	
0..3	7 (0x80)	Diag: Data valid1[4]	1-bit	enumeration	1/1	1	0	

Byte	Bit	Channel	Data Type	Range	Multiplier/ Divider	Factor	Offset	Unit
0..3	0 (0x7F)	Diag: Heartbeat1	7-bit U	0-127	1/1	1	0	
4..7	20 (FFF00000)	Value A4	12-bit U	0.0 – 4095	1/1	1	0	
4..7	12 (0xFFF000)	Value B4	12-bit U	0.0 – 4095	1/1	1	0	
4..7	12 (0x3FC00)	Secure counter4	8-bit U	0-255	1/1	1	0	
4..7	8 (0x100)	Inverted MSN of A4	4-bit U	0-15	1/1	1	0	
4..7	7 (0x80)	Diag: Data valid4[4]	1-bit	enumeration	1/1	1	0	
4..7	0 (0x7F)	Diag: Heartbeat4	7-bit U	0-127	1/1	1	0	

[1]Values for channel: **Driver state**

Value	Description
0	OK
1	Init error
2	Supply volt error
3	Sensor volt error
4	Boost volt error
5	Board temp too high
6	Control error
7	Injector error
8	Pump error

[2]Values for channel: **Injector # state**

Value	Description
0	OK
1	Error

[3]Values for channel: **Pump # state**

Value	Description
0	OK
1	Error

[4]Values for channel: **Diag: Data valid#**

Value	Description
0	NO
1	YES

8. Troubleshooting

We will expand this section in the future.

9. Appendix A - SENT communication

Modern engines are increasingly using the SENT communication protocol, so the GDI module has been equipped to support this technology.

By integrating SENT support in the GDI Driver, we can handle critical sensor data effectively, ensuring high priority and accuracy in engine management.

SENT stands for **S**ingle **E**dge **N**ibble **T**ransmission and is defined by the SAE J2716 standard.

Key characteristics:

- High resolution (12 bits)
- 1 or 2 values in one frame
- Data rate up to 30 kbit/s
- Requires 3 wires: power 5 V, ground and signal
- Replacement for analog output and PWM
- One-way communication - no collisions
- Encoded in the variable timing between two falling edges
- *Slow channel* transmission for additional data (not supported yet)

SENT replaces older analog and PWM methods, offering better accuracy and reliability. It is commonly used for various sensors:

- Throttle position
- Pedal position
- Mass air flow
- Pressure
- Temperature

SENT frame

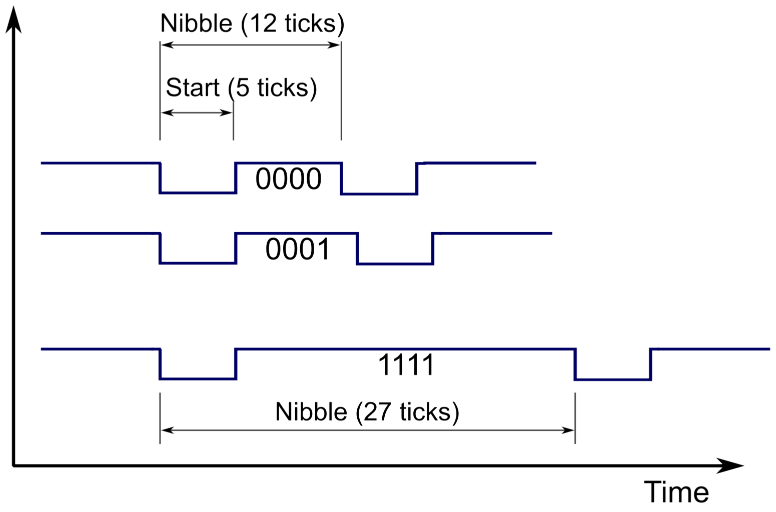
In SENT communication, each unit of data, called a "nibble," encodes 4 bits and varies in width. The timing between signal pulses is key to decoding the information. This method ensures high precision and minimizes errors.

Tick - time unit for SENT, 3 µs to 90 µs

Nibble - single data unit with variable width, encodes 4 bits

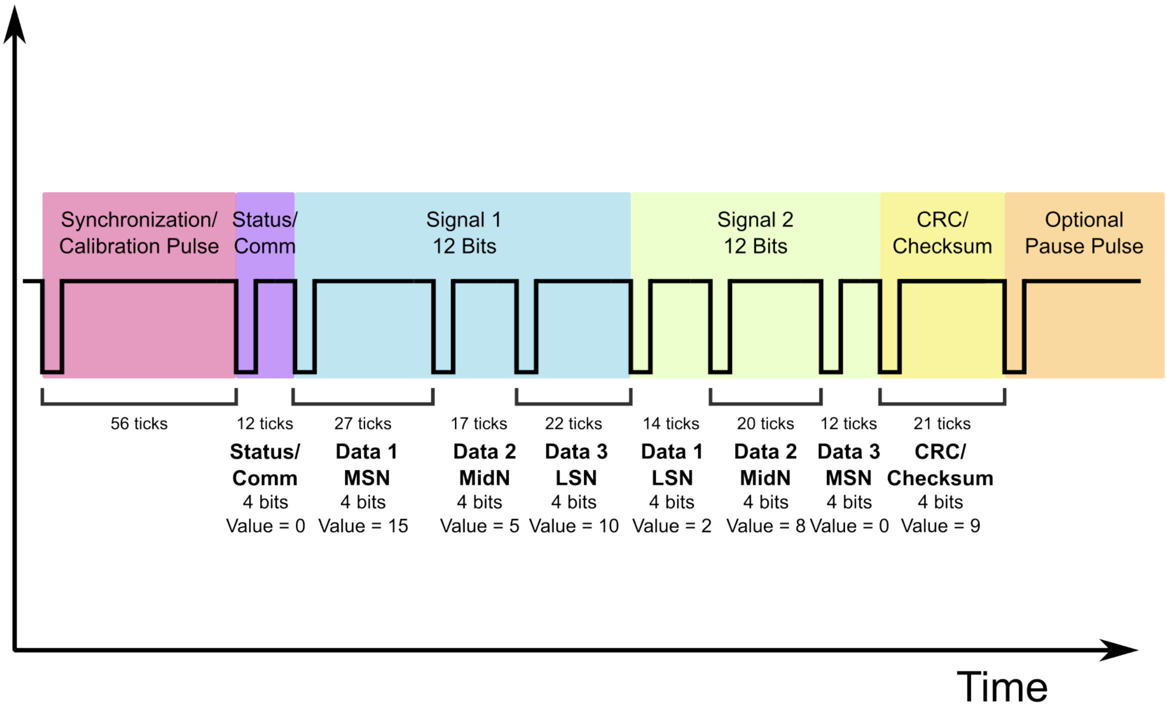
Sync pulse - fixed length nibble with 56 ticks width

Basic SENT encoding: nibble width in ticks = 12 ticks + (decimal value of 4 bits of data)

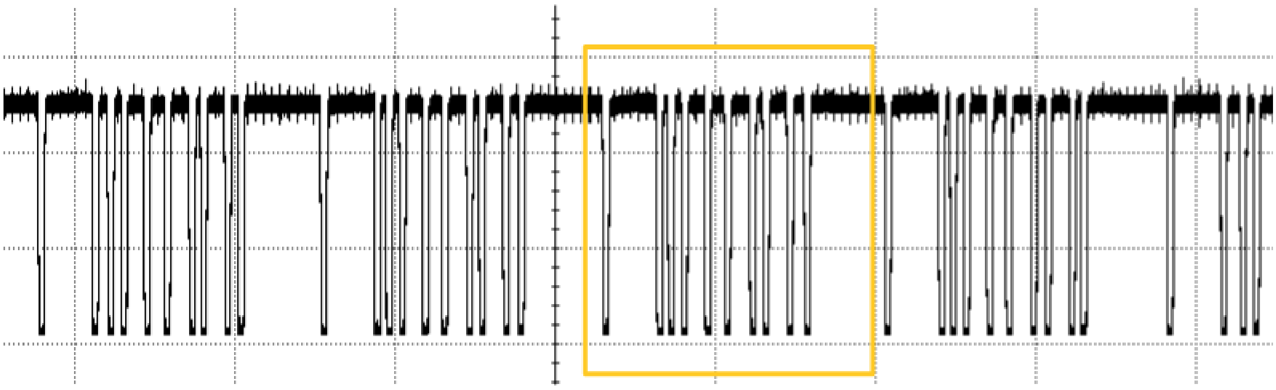


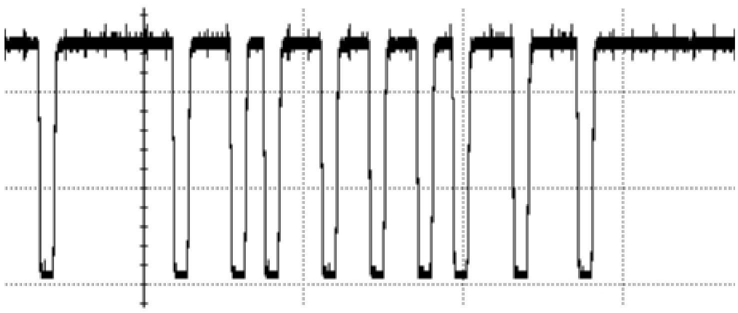
Basic SENT frame contains following nibbles:

- **Synchronization** - 56 ticks
- **Status** - 12 to 27 ticks
- **Signal 1** - 3 nibbles 12 to 27 ticks each
- **Signal 2** - 3 nibbles 12 to 27 ticks each
- **CRC** - 12 to 27 ticks
- **Pause Pulse** - variable length pulse between frames (optional)



Oscilloscope plot



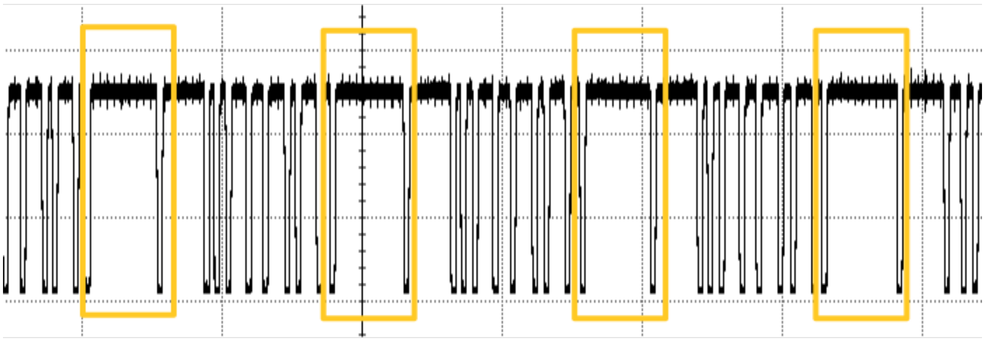


Repeated sequence:

- fixed width sync pulse
- series of 8 or 9 variable width pulses
- pause pulse (optional)

Pause pulse

The pause pulse is an optional variable gap between consecutive SENT frames, used to equalize the length of each frame. It ensures proper timing and spacing between frames when present. On the oscilloscope, the Pause Pulse can be identified in the highlighted sections of the plot:



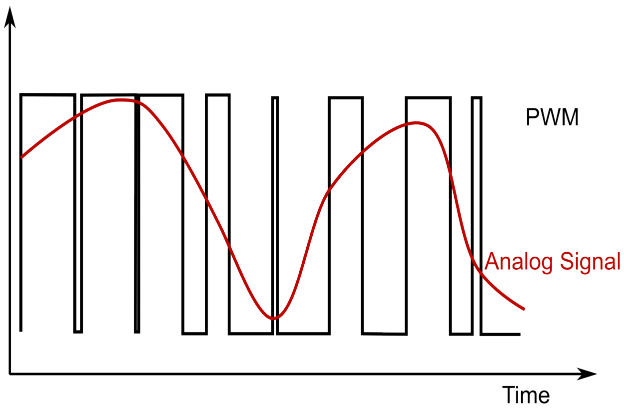
Analog vs PWM vs SENT

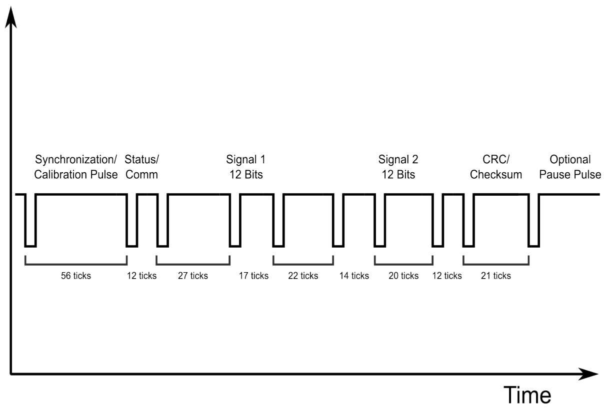
Analog, PWM (Pulse Width Modulation), and SENT (Single Edge Nibble Transmission) are three distinct methods for sensor signal transmission in automotive applications.

Analog signals transmit information as continuous voltage levels, offering simplicity but are susceptible to noise and signal degradation.

PWM, on the other hand, conveys data through varying the duty cycle of a square wave, providing better noise immunity and more precise control over signal interpretation.

SENT, a more modern protocol, sends data digitally using time intervals between signal edges, ensuring high accuracy and reliability, especially in high-noise environments.



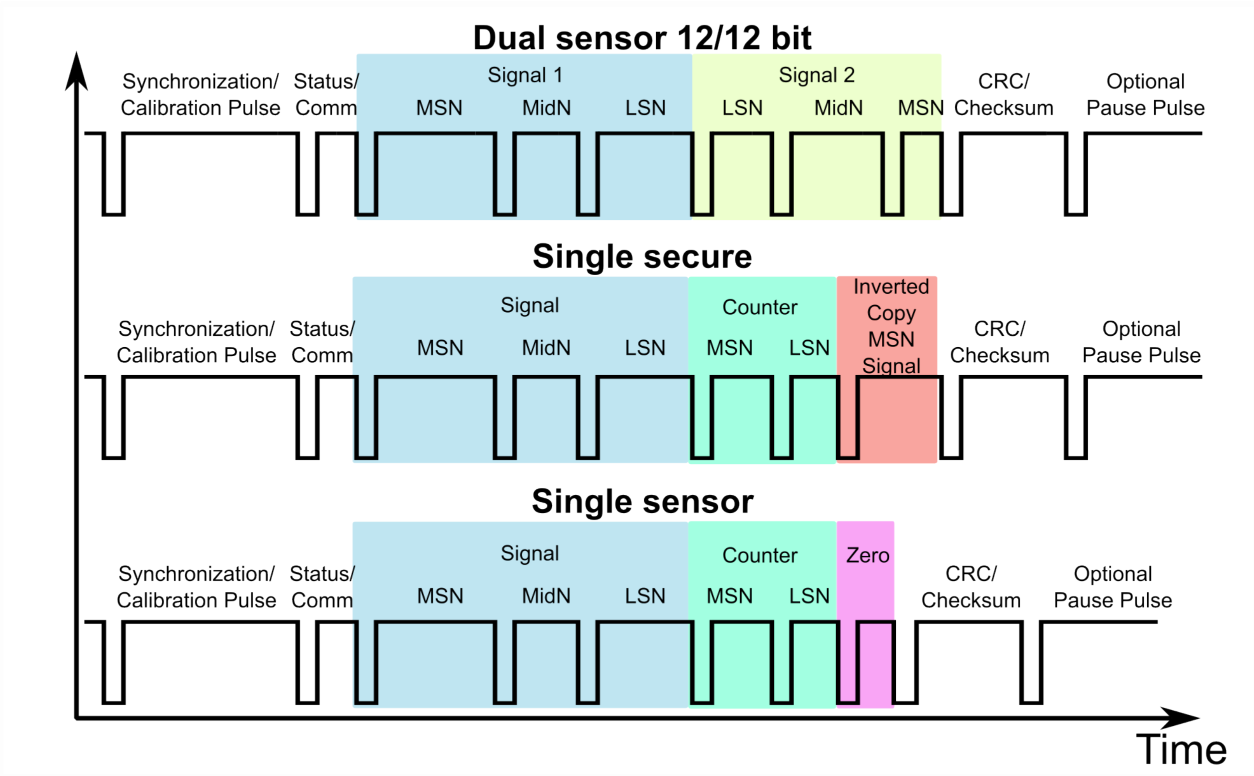


	Analog	PWM	SENT
Accuracy	Full	Moderate (~10-bit)	High (12-bit)
Security	Noise sensitive	No error detection	CRC + counter (single sensor)
No of signals	1 signal	1 signal	Up to 2 signals + 1 slow channel
Requirements	ADC	PWM decoder	SENT decoder

SENT frames formats

There are two main formats of SENT frames:

- Dual sensor 12/12 bit - contains two independent sensor values
- Single secure / Single sensor - contains only one sensor value and frame counter to ensure security



10. Document history

Version	Date	Changes
0.1	2024.08.14	Initial release
1.0	2024.12.20	Public release
1.1	2024.12.23	Minor wiring diagram correction. EMU PRO pin A01 changed to A02
1.2	2025.01.16	Added key features of the device in the "Device description" section