DEM Engine Control System
Rotary Engine Electronic Controller

Overview

The Digital Engine Management (DEM) system is a dual-channel, fully redundant unit. This powerful unit is capable of precise control of multi-rotor engines and is readily adaptable to reciprocating engines as well. Stylized aircraft installation is shown in Illustration II.

Two Electronic Control Units (ECU) interactively manage all engine parameters (injection, ignition, wastegate management on turbocharged engines, etc) in real-time for optimal engine management. A single ECU can assume full engine control, offering complete system redundancy. Pilot interface is accomplished through a crisp, sunlight-readable display unit.

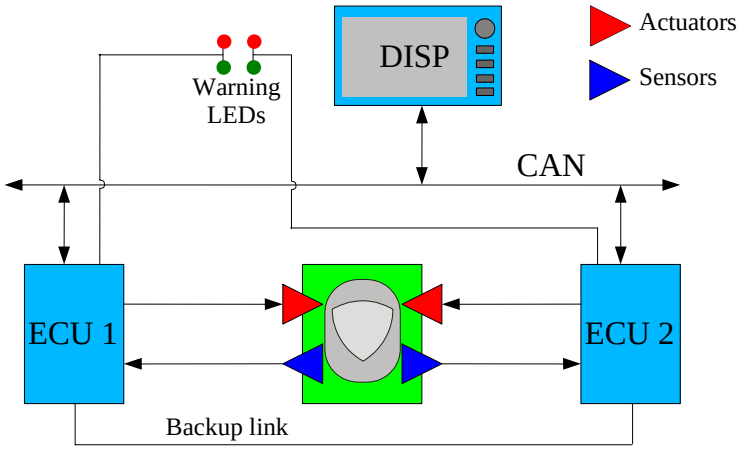


Illustration 1: *Bloc scheme of the system*

The ECUs are linked through a field bus (CAN - Controller Area Network) to exchange data and health status and to arbitrate fuel-injection management. A separate single-wire link serves as back-up in case of a CAN failure.

A separate power switch energizes respective ECUs. Each ECU indicates its functioning mode (normal, degraded or failure) by directly controlling 2 LEDs on the aircraft's instrument panel (one red and one green LED for each unit).

Display

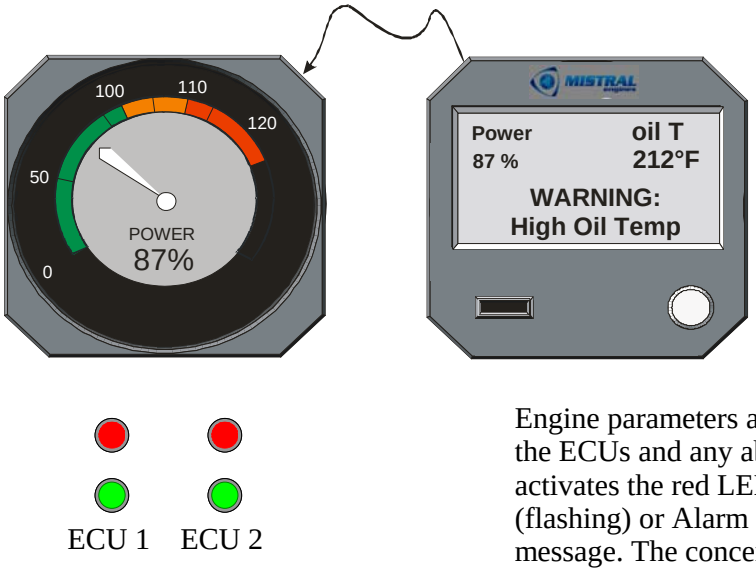
The display is the interface between the engine, the DEM system and the pilot. It communicates the engine state, engine parameters, as well as warning and alarm messages when they occur. All data are transferred from the ECUs via a 2-wire field bus (CAN). A global Master Alarm output feature is provided to drive EFIS or other installer options.

There are 3 display options:

Standard version : (experimental market only)

The Standard version consists of a 3 ATI panel-mounted LCD graphic display unit and of a standard 3 1/8" electro-mechanical gauge linked by an analog 0-5V connection. The display unit has five additionnal analog outputs which can be customized to drive any other analog engine gauges.

Illustration 2: Standard display



The graphic LCD display can also be customized (except in emergency modes) to display any engine parameter the pilot wishes to supervise. Menu functions are controlled by a Twist-N-Push knob. A USB port on the face of the main display allows uploading software updates or downloading data from the DEM system. The system is delivered with a USB-key.

Engine parameters are monitored in the background by the ECUs and any abnormal condition immediately activates the red LED and is displayed as a Warning (flashing) or Alarm (steady) and a plain English message. The concerned out-of-range parameter is also flashed in the upper right quadrant of the display, while engine % power remains displayed in the upper left quadrant. The pilot acknowledges the message by pressing the Twist-N-Push knob.

Enhanced, color TFT screen version :
(optional for experimental market, standard for certified one)

The 6.5” color transflective TFT screen offers enhanced pilot interface and high readability even in direct sunlight. Any DEM-system generated information can be displayed on the screen in bright, clear graphics, including fuel consumption, fuel used and remaining, etc. The default display and layout of information may be customized, and any parameter can be called by the pilot with the menu buttons.

The display may be installed in vertical or horizontal orientation. The elongated format corresponds to the equivalent dimensions of two 3-ATI standard instruments. It also exists in a configuration sized for a radio-rack.

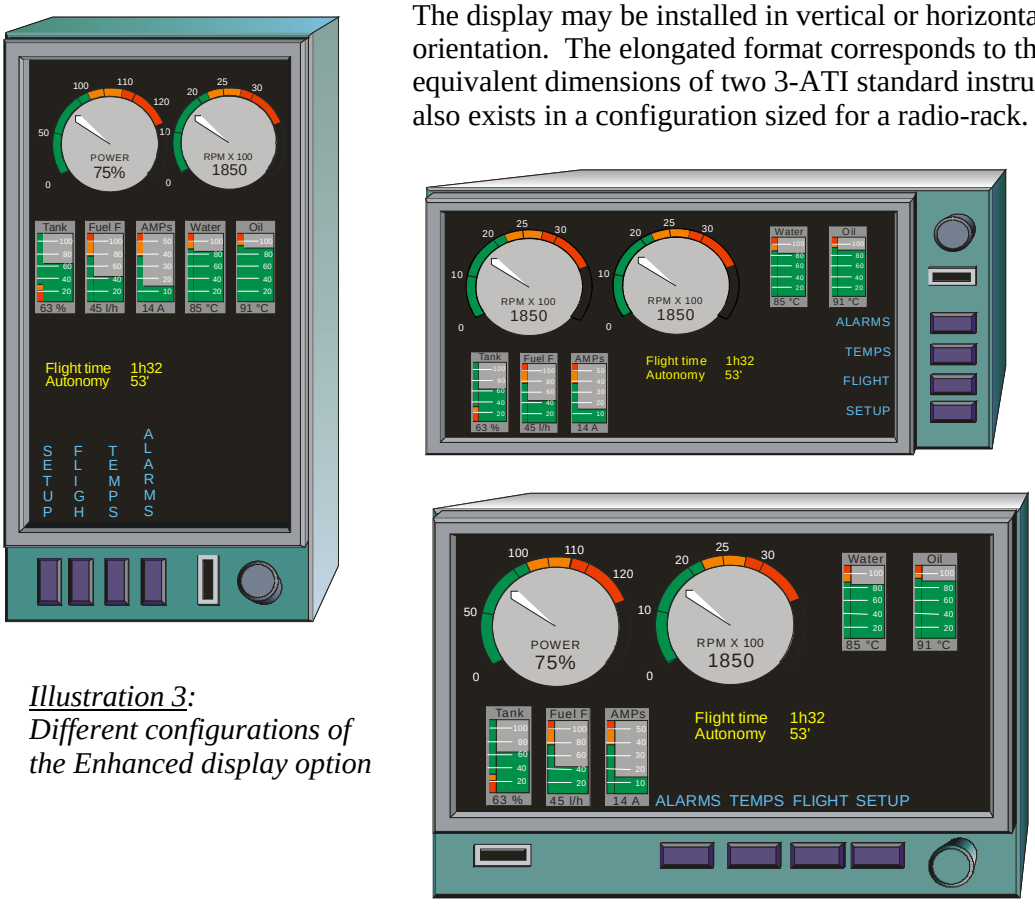


Illustration 3:
Different configurations of the Enhanced display option

EFIS version:

This version is similar to the Standard version without the electro-mechanical gauge. A RS232 link drives the EFIS system, exchanging data available to, or generated by, the DEM system. The Standard version’s display serves as a DEM display back-up in case of an EFIS display failure.

Additionnal DEM system features:

Voice Alerts (optional feature)	The integrated voice generator in the Enhanced display panel will generate voice Warning and Alert messages for the aircraft's audio system.
Data Logging (standard feature)	Each ECU stores engine parameters at 6-second intervals, with a storage capacity of over 100 flight hours. The recorded data can easily be downloaded via the RS232 or USB interfaces for post-flight data-logging and to be transferred to the factory for analysis.
EFIS	The system parameters are available for driving any EFIS display.

Field bus failure

A CAN bus failure does not affect the functioning of the engine, but interrupts the transfer of engine data to the display. The two ECUs continue to run the engine safely, unless there is a multiple failure. The state of each ECU is still displayed to the pilot by the way of two LEDs per ECU (four total). Each ECU LED pair is connected by a single, direct wire to its respective ECU. By modulating the voltage polarity, the red and/or the green LED can be illuminated. This simple, reliable and independent back-up can effectively assist the pilot's decisions in the case of an engine instrument display failure. Should a malfunction occur with the CAN bus operating, then the display will also identify the problem by flashing the Warning or Alarm message in plain English. The following table reflects the indications of *one ECU LED pair*. There are two pair sets.

	State	**Possible errors**	**Red LED**	**Green LED**	**Pilot action**
1	No error		off	**on**	
1a	*Minor* error detected by one ECU	- Minor sensor loss - Engine parameter getting in or moving to yellow range	**flash**	**on**	Acknowledge error by pressing display button; take appropriate pilot actions
2	One ECU has detected a wiring problem *(Major)*	- 1 injector circuit open - 1 ignition circuit open	**flash**	**flash**	No action required on DEM system, plan to land as *soon as practicable*
3	Engine instrument display goes blank *(Minor)*	ECU bus failure (CAN)	off	**flash**	Continued flight is possible but extra caution should be taken in managing the engine
4	ECU detects a severe condition *(Major)*	-Water loss -Low oil pressure	**on**	**on**	Reduce power to minimum required by flight conditions and land *as soon as possible*
5	Wiring problem *(Minor/Major)*	- No power to ECU or bad LED wiring	off	off	Confirm defect from display (if CAN operating). Try restoring power to the ECU, if not successful, land *as soon as practicable/possible*
6	Powered but non-functioning ECU	- Initialisation phase - Software error	**on**	off	- Wait a few seconds if ECU was just turned on - Land *as soon as practicable*

ECU(Engine Control Unit)

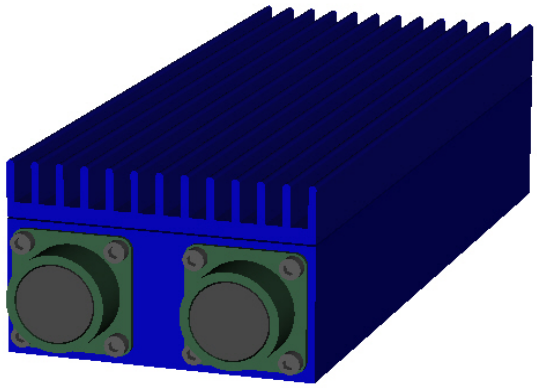


Illustration 4:
Electronic Control Unit (ECU)

The DEM system is composed of two independent and physically separate ECU enclosures to ensure ultimate redundancy. Each ECU acquires signals from a number of sensors, process them and then controls actuators (fuel injectors, ignition coils, propeller governor, turbo wastegate for a turbocharged engine, etc.) to optimize engine operation on a per-revolution basis. Each unit of two can safely run the engine alone at full power. In normal operations, the two units each inject half the total fuel quantity. In case of an ECU failure, the other unit injects the required total quantity to achieve the power selected by the pilot.

Each unit is run by a Motorola MPC-555 high-performance processor which is also available in military-specification version.

Each unit runs a recorded, self-diagnosis and evaluation of its connections to sensors and actuators. This information is exchanged with the partner unit confirming its healthy function. Should either ECU not receive this message from its partner, it concludes a partner ECU failure and instantly asserts overall engine control.

The two ECUs are individually packaged to increase resiliancy against mechanical or chemical intrusions, as well as to increase mounting flexibility. The two units may be mounted side-by-side in a standard radio rack, or separately in the cabin or within the cowl. ECU's sturdy enclosure, as well as the design of their circuitry and their components' specifications, accommodate rigorous engine compartment conditions (not yet a final spec).

Error detection

The ECU is able to detect electrical errors on most connections. For example, the injector driver detects either a short or open circuit of the wiring, and reports this diagnostic to the main processor. Each error is processed so that the system automatically finds a new method which keeps the engine running.

Specifications

General:

	ECU	Display TFT	Display LCD
Processor	Motorola MPC-555	TBD	TBD
Height	50mm	90mm or 127mm	83mm
Width	79mm	170mm or 159 mm	83mm
Length	200mm		
Power	8-33VDC 7W only ECU	8-33VDC	8-33VDC
Connectors	Power 26-pin MIL-C-26482 Measuring 26-pin MIL-C-26482	26-pin MIL-C-26482 RS232 D-SUB9 USB, RJ-45	26-pin MIL-C-26482 RS232 D-SUB9 USB

Environmental
System design is to the following environmental RTCA/DO-160D standard:

	ECU	**Display or LCD**
Temperature/Altitude	B3	B1
Operating Temperature	-45 to 90°C	–20 to 55°C
Short-Time Operating High	100°C	70°C
Storage Temperature	-55 to 100°C	-30 to 85°C
Operating Ceiling	25’000ft 7600m	25’000ft 7600m
Temperature Variation	A	C
Humidity Category	C	A
Shock	B	B
Vibration	L	M
Explosion	H	X
Waterproofness	R	X
Fluids	F	X
Sand & Dust	S	X
Salt	S	X
Magnetic Effect	B	A
Power Input	B	B
Voltage Spike	B	B
AF Susceptibility	B	B
Induced Signal Susceptibility	Z	Z
RF Susceptibility	TBD	TBD
EMI	L	M
Lightning Indirect Effects	A4E4	A3E3
Lightning Direct Effects	3	X

Redundancy

Failure	***Recovery***
Injector connection	The unit with an injector connection problem stops injecting and puts this information on the bus. The other unit immediatly injects more fuel
Coil connection	Ignition is stopped on the failing unit and ignition sequence is adapted to one spark plug per rotor
MAP sensor failure	Both units measure MAP (there is a total of *three* MAP sensors). If one measure is missing, the unit with the failing part will use the value transmitted through the CAN bus
RPM and crank-angle sensor failure	Both units measure RPM and crank angle. The unit with missing data stops injection and ignition. It is still transmitting sensor values via the bus
Software failure	If a unit software failure is detected, this unit ceases operation. The partner ECU assumes total engine management
Power failure	Each unit is supplied by an independent power circuit (dual bus, dual batteries, optional dual alternators). In case of failure of one of the supply, the other unit assumes total engine management
Internal failure	Each unit evaluatets its temperature and current consumption. In case of abnormal values, the unit ceases engine management and the other unit assumes full engine control
Other sensors	A default value is used in case of a non-critical sensor failure. The engine is tuned so that it can run with these default values
Display	The display has no influence on engine management. Two LEDs per unit (green and red) alerts the pilot regarding problems with either ECU
Field bus	An additionnal wire is used to code injection capacity of each unit, fuel injection stays coordinated between the two units via the CAN

Measurements

	ECU1	**ECU2**	**TFT**	**LCD**	**Diagnostic**
RPM	1	1			software
Manifold Pressure	2	2			yes
Lambda sensor	1	1			yes
Knock-sensor	1	1			yes
EGT	2	2			yes
Intake Air Temperature	1				yes
Water Temperature		1			yes
Water pressure	1				yes
Oil pressure		1			yes
Oil Temperature	1	1			yes
Fuel Pressure	1	1			yes
Throttle position	1	1			yes
Alternator Current	1	1			yes
Bus Voltage	1	1			no (ECU-integrated)
Fuel Flow			2	2	TBD
Outside Air Temperature			1	1	Yes
Auxiliary inputs	1	1	2	2	Yes

Controls

	ECU1	**ECU2**	**TFT**	**LCD**	**Diagnostic**
Outputs					
Injectors (peak-and-hold or saturated)	3	3			open, short
Ignition	3	3			open, short, no spark
Oil injector (saturated)	1	1			open, short
Wastegate control	1	1			open, short
Lambda heater	2	2			open, short
Propeller governor	1	1			open, short
Main switch LED	1	1			No
Alarm output			1	1	No
Analogue outputs, SW configurable			6	6	No
Audio output			1	1	No

Interfaces

	ECU1	**ECU2**	**TFT**	**LCD**	**Diagnostic**
Interfaces					
Internal RS232 for Debug.	1	1			No
RS232 Download and configuration			1	1	
CAN	1	1	2	1	Yes
Link	1	1			Yes
RS232 EFIS				1*	No
USB			1	1	No
Ethernet			1		No
Twist-N-Push knob			1	1	No
Menu buttons			4		No

*only for the EFIS version.