FADEC system-Autostart version

PRELIMINARY

Users guide.

Contents:

Description of the FADEC.

The FADEC (Full Authority Digital Engine Control) is a total system for the control of a model gas turbine engine. Its main function is to control and regulate the fuel pump, providing to the turbine engine the necessary amount of fuel for safe and controlled operation. The FADEC measures the exhaust gas temperature, the relative position of the throttle stick and the rotor speed. It monitors all of the controls necessary to guarantee that the engine stays between the user defined parameters of operation, also providing failsafe shutdown of the engine when it has detected any important anomaly. In order to make this assessment, the FADEC has a rpm sensor, a thermocouple input, a throttle servo input, power connections for the fuel pump, starter, glow plug, fuel and gas valves and the battery and a digital (RS232) serial port to program and read the data in real-time to a PC.

The measurements made by the FADEC are:

- Temperature of the exhaust gas
- Pump battery voltage
- Width of the throttle pulses from the radio transmitter
- Engine rotor RPM
- Engine run time.
- External analog signal.

All of these FADEC measurements can be read into and displayed on the Handheld Data terminal (HDT) that is connected to the FADEC by a RJ-45 connector, or into a personal computer trough a RS232 adapter. The FADEC is totally programmable by the user to adapt the margins of operation of each individual turbine engine. The configuration/setup parameters are stored in the FADEC by the terminal of hand or the PC.

Features:

- RPM input: Hall effect or Infrared. Factory set.
- RPM range up to 250.000 RPM
- Temperature range up to 1000ºC using a "K" type thermocouple
- PWM control of 1024 levels for pump, glow plug and starter motor.
- Battery Voltage from 4,8 to 12V
- Adjustable power for the starter motor
- Build-in electronic brake for the starter motor to help the clutch to disengage.
- Blown glow-plug detector
- Adjustable glow-plug power
- Glow-plug temperature independent of the battery voltage
- Adjustable gas off temperature
- Adjustable rpm starter switch on and off.
- Engine running timers
- 2 status LEDs on the unit plus 2 more remote on option
- RS232 interface to interface to a PC.
- Software upgradable trough the Data Terminal connection.
- Black box function. Record the engine measures each 0.5sec up to 12 minutes.
- User programmable acceleration and deceleration ramps. (8 points each curve in running mode and 3 point in start mode)

Adjusting the parameters:

On this software version there are 2 sets of parameters that can be changed.

The "operator" parameters are adjustable trough the Data Terminal using normal menus. The "manufacturer" parameters are accessible by a special procedure and in some software versions, are only accesible by the manufacturers. The PC software can program all of the parameters if the user have the rights to do it.

The operator parameters are:

- Radio throws adjust.
- Maximum rpm
- Idle RPM
- Stop RPM
- Minimum temperature
- Maximum temperature
- Acceleration time
- Deceleration time
- Stability time
- Pump start point
- Pump start ramp
- Glow plug power

From these parameters, the readings of the engine and the position of the throttle control, the FADEC adjusts the power to the fuel pump in the following way:

First, the FADEC verifies that the control pulse of the transmitter is correct, that is to say, is between the limits set by the user. If the pulse is not correct, or the pulses are not received during 0.5 seconds, the system assumes that there is a trouble with the radio link and shuts down the engine (fail safe). During this time of delay, the system assumes that the throttle is at idle and decelerates the engine to this power.

Once verified that the pulse is correct, the relative position of the throttle stick determined by the limits programmed by the user is calculated. This calculation gives a value between 0% and 100% that can be read on the HDT or a PC. This value is

transformed into a value of equivalent rotor speed from the values of full power speed and idle speed programmed by the user. For example, if we programmed a idle speed of 30.000 rpm and a full power speed of 100.000 rpm, this speed will be reached with the throttle control at 100%. With the throttle stick at 50%, the equivalent speed would be 65.000 rpm (half way between 30Krpm and 100Krpm). This calculated equivalent speed is compared with the one read from the engine and the power to the pump is corrected/adjusted until reaching the desired speed, in this case 65Krpm.

The speed of the slope of spool up is a parameter programmed by the user. To accelerate the engine the FADEC has to raise the power to the pump. The system monitors the exhaust temperature, reducing the rate acceleration if the temperature approaches to the maximum programmed temperature. In case of arriving at this maximum temperature, the system reduces the fuel flow until restoring the motor within its limits of operation, being able to stop the pump if it can not lower the temperature. With this system it is guaranteed that the engine accelerates in the minimum time possible without exceeding the max. temperature or speed, adapting itself to the variations of the engine, room temperature, pump, fuel pressure etc.

With this system, called closed loop, the rotor RPM of the engine tracks linearly with the position of the throttle control, independently of the type of pump, batteries or engine. This benefit is very useful in multiengine aircraft, since the thrust of the engines is always in balance.

Aside from the safeguards of speed out of limits, temperature or radio failure, the system also incorporates two additional safeguards. First is pump shutdown in case that the temperature of the exhaust is lower than the minimum, protecting the engine from flooding itself of non-burned fuel in case of flameout. The second is fuel pump shutdown due to a too low rotor speed. The system stops the fuel pump in case that the rotor speed is less than the programmed stop pressure. This safeguards the engine from continued running in case that rotor speed is less than that required to self-sustain the engine, or in a rpm sensor failure.

The engine can be started manually (semiautomatic) or full autostart system.

In order to start the engine in manual mode, the user must first raise the transmitter throttle trim and leave the throttle stick in idle/minimum position. The green Light Emitting Diode (LED) on the FADEC illuminates, indicating the system is "ready for start". Once in this position, the operator must 1) turn/spin up the engine with the starter motor / blower etc, 2) open the butane/propane gas, and ignite it. When the FADEC registers an exhaust temperature higher than the programmed start/minimum temperature and the rotor turning, the LED begins to blink and, 3) the system begins to pump fuel to the motor, raising the fuel pump power slowly until the idle speed is reached. This final condition is signalled by the system extinguishing the LED.

To start the engine automatically, the user should cycle the throttle from idle to full power and back to idle again. In this moment the start procedure is triggered and the autostart sequence progress until the engine is at idle. The user can abort the start process by lowering the trim or commanding other power different to idle.

A pump prime system is added. Wen, in the start phase, the user raise the throttle stick up to 100% during 5 sec, the pump is switched on at 25% of power for 1 second maximum. This allows to prime the pump and the fuel tubes before the start.

4. Installation of the FADEC.

Connections:

- Throttle input: JR type servo cable. (Other types on demand)
- Propane/butane valve: JR type connector receptacle
- Fuel valve: JR type connector receptacle. The central cable is negative and the two of the sides positive.
- RPM sensor: JR type connector receptacle
- Thermocouple: JR type connector receptacle
- Battery input: Red/black cable
- Fuel pump: Red/Green cable
- Glow plug: Red/Yellow cable
- Starter: Red/Blue cable

*Note: In all power cables the red is the common and positive. This means that all the red cables are connected internally together and to the positive of the pump/starter battery.

Connect all of the cables in his places. Note that some of the JR type connectors used can be connected in wrong place or inverted. Use the coloured labels on the FADEC body to connect all the connectors in his place. The configurations of the pins have done in the way that no damage can be produced to the electronics in the case of a bad connection.

Please note that:

- The solenoid valves connectors have the central pin (red) negative and the external pins (brown and orange) to positive. They can be connected in any position. If you use a fuel or gas valve from other manufacturer remove the internal diode that these valves have, or invert the polarity on the plug cables. The negative (usually brown) cable of these valves should be connected to the central pin, and the orange cable left disconnected. Damage to the ECU can occur if left connected.
- If the thermocouple connector is connected inverted, the temperature will decrease wen heated, and the FADEC will fail in to recognise the gas ignition.0
- If the RPM sensor is connected inverted, no RPM will be read.
- Use a adequate starter motor, and use a battery voltage adequate for this motor. If bigger voltages are used, then the high current from the motor can damage the ECU. If after a start attempt you feel that the ECU becomes warm, this is a sign that something is wrong. The ECU should be cold all of the time.
- The glow plug is connected to the engine body. This means that the whole turbine is connected to the positive of the pump battery. Take this on account if you plan to connect the negative in other place.

4.1 FADEC main unit

Because the FADEC is an electronic piece of equipment, the installation in the model aircraft is similar to that of the radio receiver. It has to be in an accessible location within the airframe, with limited vibration and far from the heat of the engine. Also because the pump motor uses DC power, that can produce sparks in the collector when operating, it is highly recommended that the installation of all of the electrical equipment is done as far as possible from the R/C receiver. Keep the power cables at the minimum

possible length and avoid installing the antenna near them. Also anti-spark capacitors must be installed on the pump motor.

4.2 Selection of the Pump/starter battery.

The FADEC needs for its operation two different power supplies. The first is taken from the radio receiver through the throttle servo connection and the second is the battery that supplies the pump**. Reversing the polarity of the battery causes the destruction of the semiconductors of the FADEC**.

The FADEC can work with pump battery voltages between 1.2v and 15v in manual start mode and from 4,8V to 15 in autostart mode. The selection of the number of battery elements is due in consideration of the real needs of the ancillary equipment like starter motor, solenoid valves and pump motor. As a rule, the voltage requirements of all the accessories should be as matched as possible. Usually, the minimum usable voltage is 4,8V, limited only by the available solenoid valve voltages. A common error is to use a high voltage of 6-8,4V to have good starter power and a low voltage pump, that is very difficult to control in low regime due at the big voltage difference

This battery does not need an on/off switch in the airframe since the FADEC has an internal electronic switch, which disconnects it when the power to the receiver is switched off.

The NiMh batteries are not recommended due at his high internal resistance.

4.3 Receiver of radio.

The FADEC is connected to the radio receiver like a standard throttle servo, inserted in the channel for the throttle, receiving the information of the throttle control pulses and the receiver battery supply.

4.4 Thermocouple

The FADEC use a thermocouple of type " K ", apt until 1100ºC. The provided standard thermocouple consists of a wire of Inconel of 1.5mm of diameter finished in a connector who fits directly on the FADEC. The recommended installation consists of practising a drill of 1,5 mm in the exhaust nozzle of the engine and inserting the end of the thermocouple so that it be 2mm within the flow of exhaust gases. Because the sensible zone to the temperature is the end of the thermocouple **in any case DO NOT CUT it since it will be destroyed. Also, do not bend it with pliers or other utensils that cause very acute angles of curvature.** The installation is due by hand and the curves must have the greater radius possible. In principle any type of thermocouple " k " can be installed, but it is necessary to consider the thermal inertia of it, since the temperature of the engine can raise much quickly that the one of the thermocouple and cause not controlled situations of overheating.

4.5 Fuel pump

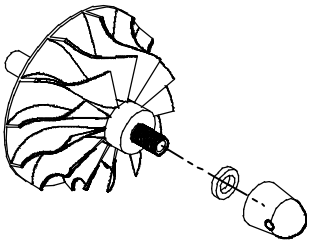
The fuel pump must have a Radio Frequency Filter installed, in order to prevent it to generate interference to the radio receiver. The minimum recommended filter must be made with 3 ceramic capacitors of 10KpF, one between the terminals of the pump and the other two between each terminal and the housing of the motor.

It is necessary to watch that the pump does not have too much friction and the starting is smooth.

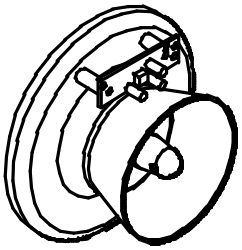
4.6 Fuel system.

If the fuel pump used too much powerful for the real engine needs, it is recommendable to install the fuel system with a "bypass ". This consists of a " T " fitting installed on the fuel line between the pump and the turbine that allows it to return fuel back to the fuel tank, regulating the volume of this through an adjustable valve. This adjustment function is to limit the maximum fuel volume sent to the motor. Also it has additional safeguard function, in case of failure of the FADEC, the engine never receive more fuel than the maximum possible allowable flow volume.

4.7 R.P.M. sensor installation



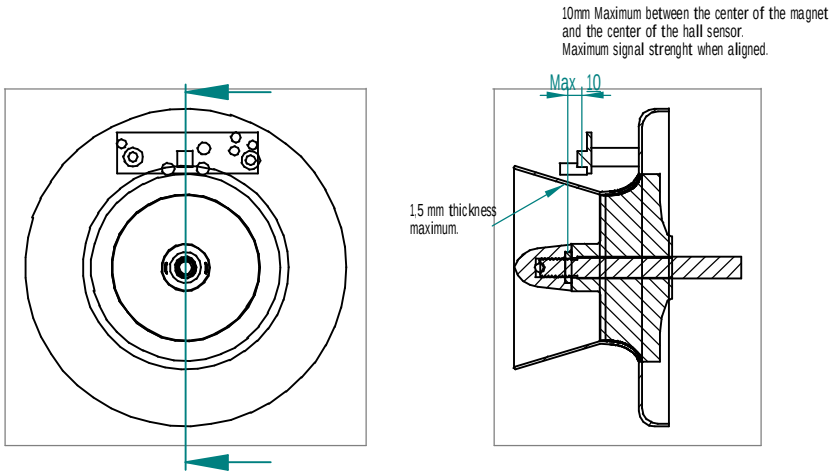
Place the magnet inside the compressor nut. The nut or the compressor should be machined to have room inside for the magnet. Do not install it like a washer.



Fix the hall sensor over the front cover using spacers. See the drawing below for the correct alignment.

Important notes:

-The magnet is custom made from Neodymium. Although it is from a temperature tolerant variety, it can loose its magnetic properties if heated beyond 150ºC.
-The magnet has a metallic appearance, but the mechanical properties aren't the same. Think of it as a type of ceramic. In particular, it can be broken if force is applied. Install it inside the nut (or the compressor) ensuring that there's enough room so as not to be crushed when tightening the nut. Fit it with epoxy to avoid movement. Never install it as a washer because it can break into pieces when tightening the nut, and fly apart when the engine begins to run.
- On engines with aluminium cover, keep the thickness of it in the area between the magnet and the hall sensor under 1.5mm. The aluminium attenuates the magnetic signal 6 times more at 120Krpm than at 10Krpm, so a test on low speed doesn't guarantee full performance.
-Try to align the magnet plane with the hall sensor plane as much as possible to have the maximum magnetic strength on it.



5. Programming of the FADEC.

The programming of the FADEC can be done using the HDT or the PC. The programmable parameters are as follows:

FADEC user programable parameters:

Parameter	Function	Range
Full speed RPM	Sets the maximum rotor speed that will be reached by the engine with the throttle control at 100%	0-250.000 RPM.
Idle RPM	Sets the rotor speed at idle	0-250.000 RPM.
Stop RPM	Sets the minimum rotor speed which the engine can run. If the speed is lower, the FADEC will shut down the engine.	0-250.000 RPM.
Start/Minimum Temperature	Minimum temperature at which the engine can work. In the start phase, the FADEC will begin to provide power to the fuel pump. In the running/operating phase, it will stop the engine if the temperature is less this setting.	0-999 ºC
Max. Temperature	Maximum Temperature of operation of the engine. The FADEC will try to maintain the EGT temperature below this value, finally stopping the motor in case it can't be obtained	0-999 ºC
Acceleration delay	This parameter allows the adjustment of the time of acceleration ramp / delay of the engine. The higher the value, the more slowly the engine will respond. The total time of acceleration is not fixed, since it depends on other parameters as they depend on the present temperature and speed.	0-255
Deceleration delay	Just as the acceleration delay, this parameter defines the time required for deceleration. This parameter must be increased if the motor tends to flame out when going abruptly from maximum power to the idle.	0-255
Stability delay	This parameter allows stabilising the power once the system has arrived at the value set by the throttle control. The value must be increased if the power setting is not stable.	1-255
Pump start point	This parameter sets the minimum pump voltage where the pump just begins to turn. This value is dependant on the voltage of the battery and the pump motor.	0-255
Start Ramp	Sets the rate of increase of fuel flow during the start-up phase. The higher the value, more quickly the motor will accelerate up to idle. High values along with a under-powered starter can cause the engine to blow	0-255

	flames out the exhaust.(Wet/Hot starts) Low values imply a slow starting.	
Stick travel adjusts.	This parameter sets up the throttle limits at the three key points. Stop, Idle and maximum power.	
Glow Plug power	Sets the brightness of the glow plug.	

5.1 Programming the FADEC with the terminal of data (HDT)

The HDT has a LCD with 16 characters x 2 rows and four buttons which allow you to move through the various menus and to change the data settings in each menu page. The presentation of data has been organised in screens. The first two displays the engine status readings in real time and the following screens allow you to modify the operating parameters as above table. All of the parameters can be modified while the engine is running, so it is easy to tune the engine without having to start it again to test the new settings. Both left buttons allow you to move through the different screens in an ascending mode (Menu Up) or descending mode (Menu Down). Both right buttons allow you to change the data in increasing value (Up Data) or decreasing value (Down Data).

Screen 1

Screen 1 always appears first when starting (switched on/off) the HDT and shows the main primary parameters of operation of the engine. The representation of the screen is as follows:

S	**t**	**a**	**t**	**u**	**s**				**T**	**=**	**y**	**y**	**y**	**º**	**C**
R	**p**	**m**	**w**	**w**	**w**	**w**	**w**	**w**		**P**	**w**	**z**	**z**	**z**	**%**

The values displayed are:

Status	A eight character word indicating the state of the FADEC. (Ready, Fuel Ramp,...)
yyy	Temperature of exhaust in ºC
wwwwww	Speed (R.p.m.)
zzz	Power of the pump. This reading allows to know % the applied voltage the pump, and therefore, its relative power.

Screen 2

Screen 2 shows the secondary parameters of operation, they are the information received from the radio transmitter and the voltage of the battery.

P	**u**	**l**	**s**	**e**	**=**	**X**	**x**	**x**	**x**	**µ**	**S**		**y**	**y**	**%**
V	**b**	**=**	**z**	**z**	**.**	**Z**	**V**		**V**	**e**	**r**	**w**	**.**	**W**	

The values displayed are:

Xxxx	Duration of the pulse of control received from the receiver. This it is a absolute value read from the radio transmitter. The usual values are between minimum 800-1000µS and 2000-2200 µS maximum.
Yy	Calculated value relative to the position of the throttle control. The FADEC uses the programmed values of maximum and minimum along with the real reading to calculate the relative power setting for the control of the fuel pump.
zz.z	Voltage of the battery supplying fuel pump
w.w	Software version

Following screens:

The following screens have all the same structure, except they are used of the programming of the FADEC control parameters, and allow you to change the operating parameters, even with the engine running. As an example the first next screen that appears, is the maximum speed.

F	**U**	**l**	**l**		**p**	**o**	**w**	**e**	**r**		**S**	**p**	**e**	**E**	**D**
						x	**.**	**x**	**x**						

The expression x.xx indicates the value stored in the FADEC. In order to change it is necessary it to use the right buttons " Data Up " to increase the value and " Data Down " to decrease it.

The programming of all the data is made sequentially, changing to the next screen using the button " Menu Up". The programming of the radio transmitter is a special case and needs a different procedure, described next.

Programming of the radio transmitter setting with the HDT.

For the programming of the radio you need to have the FADEC and the HDT working with the radio receiver with its battery pack and the transmitter. It is not necessary to install the thermocouple, the pump or RPM sensor.

Preparation and verification of the transmitter.

The transmitter must not have programmed any reduction of throw, trim, slow movement, the center value or the linearity modified. In case of doubt it is recommended to connect a servo to verify that the movement is correct from end to end and fast. Once the transmitter is OK, connect the FADEC and by means of the key " Menu Up " change to screen 2. With the trim and stick of the transmitter raised (Full power) the reading of "Pulse = xxxx" must be between 1900-2200. With stick and the trim lowered, the reading must be between 800 and 1000. In case that the readings are inverted, like in some Futaba transmitters, it is necessary to change the sense of the movement in the transmitter. (Servo reverse). If the reading does not arrive at these values means that the transmitter has some function of limitation of throw applied to the throttle channel. Once verified the transmitter, the FADEC can be programmed. In

order to do it, the HDT has 4 screens.

Move to the screen 'Transmitter programming'. This first menu is only informative and it warns us of the entrance in the screens of programming of the throttle control. Press the button 'Data Up' to enter in the programming menus. Next it appears the screen of programming the full throttle position. In order to program this parameter locate the trim and stick in the superior position. Once located in this position, push the button "Data Up". At this moment the FADEC will record the received order of the radio as the position of full power and, in the HDT, the following phase of adjustment is shown. If it is not wanted to modify this adjustment, is enough with pushing the key "Menu up". This also causes the change of screen but the throw is not programmed.

The following screen allows programming the lower limit (Stop). In order to do it is enough with locating the trim and stick to the minimum and push the button "Data Up ". Also in this case pushing the button " Menu up " will cause the change of screen without varying the previous adjustment.

The last screen of adjustment of the transmitter is the position of the trim that will correspond to the idle of the engine. In order to make this adjustment it is sufficient with locate the stick to the minimum and the trim to maximum and push the button " Data Up". Just as in the previous adjustments, the button " Menu up " will cause the change of screen without varying the last recorded adjustment.

Once finished the programming of the transmitter, this can be verified by means of the second screen of the HDT.

To the right of the value of the received pulse of the transmitter appears a value from the 0 to 100%. This value must correspond to the relative position of the throttle stick, corresponding 0% to stick and the trim to the minimum and 100% to stick and trim to the maximum. If it were not arrived at these values, or the limits of the 0 or 100% were reached before arriving stick in the end, the calibration process is due to repeat.

When the superior and inferior limits are verified, the adjustment of the trim can be verified. This it is made through the green LED that incorporates the FADEC.

With the FADEC in start mode, that is to say, just started, locating the trim and the stick at lower side the LED must be off. When raising the trim slowly, the LED must lit approximately to half of the throw of the trim. From this point the FADEC considers that the motor must be running and below this, stopped.

5.2 Timers

The last screen of the HDT shows the 3 timers included in the FADEC. The first is the total engine time in minutes, the second the last run time in seconds, and the third is the start/stop cycles counter. These timers can be only cleared by a special PC software.

5.5 User's manual , software updates and user's support

For the users with access to Internet there is a page with the versions of the user's manual and the PC software in different languages. The URL is**: http://www.espiell.com/users1.htm,** and the e-mail for FADEC related questions is **gaspar@espiell.com**

6. Starting the engine and tuning the system.

6.2 Adjustment of the point of starting of the pump (Pump start point).

Each pump has a minimum voltage of operation, below that the motor of this doesn't turn. The FADEC needs to know this point since below him the pump is stopped and it does not provide any fuel, and it is the same as stop. This point depends on the pump and of the elements of the battery. Therefore, if we change the pump or the number of cells of the battery, we will have to adjust this parameter.

Adjust:

Install the complete system with pump, thermocouple and fuel but with the exit of the pump towards the fuel tank so that this can work without filling of fuel the engine. Set the parameter "Pump start point " to a value of 10 and the one of " Start ramp " to 0. Set the trim of the radio up. The LED of the FADEC must ignite indicating the "Ready to start" phase.

Warm up the thermocouple with a lighter or set the "Start-Min. temperature" parameter below to the present temperature. When the read temperature is higher than the programmed "Start-Min. temperature", the LED will begin to blink, indicating the state of " Fuel Ramp". In this point the pump will begin to receive voltage, which will be confirmed by a sound like a buzzer in it. Raise the value of " Pump start point" until the motor of the pump begins to turn. Once found this point, verify it raising and lowering the trim the pump starts at the minimum possible speed, lowering or raising it a little to be sure that the pump starts each time and at minimum possible speed. The normal values of this point usually are between 10 and 30. Higher values than 35 indicate that the pump is " hard " and it has some problem of friction or inadequate motor. It is advised to repair or to replace a pump in this state, since surely it will cause excessive power consumption and a great difficulty of regulation, along with an abrupt starting. When this point is fit, set the value of " Start ramp " to 4.

This test is only possible wen the HDT shows the "pump start point" screen. In all other screens the pump doesn't start if the rpm rotor is zero to prevent to flood the engine.

6.3 Adjustment of the valve " Bypass " (if installed).

To control the engine in an efficient way and to obtain to a stable operation along with minimum times of acceleration (<3s for a JG100), the FADEC uses a system of "fuzzy logic" combined with an intelligent system that learns the engine variable parameters when it is in operation. These parameters are stored in the non-volatile memory to use them in the future. Therefore it is important to follow the order of the indicated adjustment procedure and to consider that any external variation of the operation of the system, as it is the adjustment of the by-pass valve, change of pump, battery voltage, etc. implies that the memorized values will be no longer valid and the FADEC needs some time to adapt.

Adjustment:

Set all of the system ready to start and set the bypass valve half open. Set the parameter "Acceleration delay" to 120, "Deceleration delay" to 30 and "Stability delay" to 4

6.4 Engine start-up:

Start the engine. Once in idle, slowly raise the control of the gas until arriving to the maximum power. When arriving at full throttle, three situations can occur:

1, The valve of bypass is too open, the voltage of the battery is too low or the pump is too small and the engine does not give all of its power. The red LED will be off. In this case, the indicator of power of pump of screen 1 will indicate 100%. Close the bypass valve slowly until the engine arrives at its maximum power programmed, moment at which the red LED will lit and the indication of pump power will begin to lower when regulating the FADEC the power. Fit the valve until at the maximum power of the turbine the indication of pump power is of 80-95 %. In this point the red LED will lit continuously wen the engine is at full power.

2, The bypass valve is too much closed, the pump battery voltage is too high or the pump is too much powerful. In this case, the motor will be giving all its power but the indication of pump power will be lower than 50%. The LED red will be blinking, indicating the full power speed but with a pump relative power lower than 75%. In this case, open bypass until the led led lit continuously. If at the end of this adjustment the valve is more than half-open, it is recommendable to reduce the battery voltage if possible.

3, The red LED lit continuously. Nothing to do.

When starting for the first time after fitting the valve of bypass or change the battery voltage, it is possible to value the starting slope (start ramp) and already change the values to obtain a more or less fast fuel ramp. This value usually has a value of between 2 and 10, depending on the starter and the turbine.

After the adjustment of bypass or any other modification that can influence in the relation of power of the pump / fuel flow, it is necessary to go from idle to full power slowly, in order that the FADEC can acquire new data of the behavior of the engine and store it. In this first start, the data stored in the FADEC is not correct and some delays in the acceleration or slow variations of the power without moving the stick can be done, This is done because the FADEC is making the fine adjustment of the curve of power of the engine. It is necessary to test the system in all of the range of power of the turbine in order that the FADEC have data of all the margin of operation.

The FADEC continuously corrects the values of operation, adapting to the possible changes of voltage of battery, level of the tank, etc. Once the bypass and the battery voltage is adjusted and the engine run OK, set the parameter “Acceleration delay” to 60, “Deceleration delay" to 30 and “Stability delay” to 10

6.5 Adjustment of the values of speed of acceleration (Acceleration delay), deceleration (Deceleration delay), and stabilization (Stability delay)

Habitually these values do not need adjustment and the recommended values are useful to most of the engines, but with the purpose of being able to use the FADEC with any type of turbine they are included in the parameters adjustable by the user.

Time of acceleration (Acceleration delay)

The FADEC calculates the speed of acceleration depending of the exhaust temperature, the current rotor speed and this parameter (Acceleration Delay), and therefore, it is possible to modify the global time of acceleration modifying it. With values of 20 an acceleration of 3s is obtained in a standard KJ-66 from 7N to 75 N , lowering to 2s of 17N to 75N. This times are temperature dependants and is assumed a EGT of 550ºC of the engine and 800ºC programmed maximum. If the engine is running hotter or the programmed max. temperature is lower, the time will be much longer. Increasing the value of this parameter the time of acceleration is longer and diminishing it, lower. A too long time does not have any repercussion for the engine, but the aircraft is much more difficult to fly. A too short time implies that the FADEC tries to accelerate the engine fastest than it can. Because the FADEC controls the exhaust temperature, there is no trouble for the engine, but when having the thermocouple a thermal inertia, it can be a momentary overheat that causes that the acceleration is not continuous when being reached the maximum temperature at some moment.

The tuning is made by fast accelerating the engine from idle to maximum power and regulating this value until the motor accelerates fast and continuously.

Time of deceleration (Deceleration delay)

For the calculation of the speed of deceleration the FADEC considers the same parameters as in the acceleration, unless the fixed value is this other parameter. In principle there is no mechanical limitation or of temperature referring to the speed of slope, but it has been found that some engines tend to flameout when the fuel flow is reduced suddenly. The habitual value is 20, but the user can increase this parameter to extend the time in case that the engine is extinguished. The test is made in sense in opposition to the previous one, with the engine in full power lower the stick suddenly to idle. The motor must decelerate quickly without extinguishing itself.

Stability delay

Once the engine has reached approximately the power corresponding to the value of the throttle setting, the FADEC adjusts the fuel flow with the purpose of match the exact value of thrust. The speed what the FADEC make this adjustment can be programmed with this parameter. The habitual values vary between 4 and 20, depending on the time of programmed acceleration / deceleration, the temperature and the inertia of the whole system including pump, engine, tubes, etc. If a too low time is programmed, the engine will not become stabilized and will be raising and lowering to the power when correcting the FADEC more quickly than the response time of the turbine. If the time is very long, the FADEC will take more time to adapt itself to the engine in case of change in the bypass valve, batteries, pump, etc.

7. Recommended values of the parameters on known engines in Autostart Mode

Engine:	KJ66	JG100	MW54		
Maximum speed:	120.000 Rpm	126.000 RPM	160.000		
Idle speed	37.000 Rpm	32.000 Rpm	45.000		
Stop speed	25.000 Rpm	20.000 Rpm	30.000		
Maximum temperature	800ºC	800ºC	800ºC		
Minimum temperature	100ºC	100ºC	100ºC		
Pump:	Haüsl 28020	Haüsl 30020	Haüsl 28020		
Battery voltage	6V	6V	6V		
Pump start point	25	18	25		
Starter type	Speed400 RACE 4,8V	Speed400 6V Speed400/4,8VR	Speed300		
Start Ramp	6	6	6		

Aplication	First Start	Test bench	Normal fly	Sport fly
Acceleration delay	120	60	40	30
Deceleration delay	30	30	30	15
Stability delay	4	10	20	20

8. Warranty:
The FADEC unit has one-year warranty. This includes only the repair/replacement of the main unit and the HDT.
Improper use like polarity reversal, short-circuit or crash damage are not included.
This warranty does not include any damage to the engines, airframes, people, or anything else.
The user must provide an emergency shut-off (i.e. a servo operated cut-off valve) for increased security.
Please read and follow the GTBA code of practice. (http://www.gtba.cnuce.cnr.it/CODE.HTM)

9. Specifications:

Measures:

Temperature sensor	K type thermocouple
Temperature range:	0-999 ºC.
Temperature resolution:	2 ºC
Temperature accuracy:	2%
R.P.M. range:	0-250.000 R.P.M.
R.P.M. resolution:	100 R.P.M.
R.P.M. accuracy:	0.05 %
Pump Battery measure voltage range	0-10 V
Voltage measurement resolution:	0.1 V
Voltage measurements accuracy:	2 %

Supply:

Receiver battery voltage:	4 to 10V
Receiver battery supply current:	30 mA.
Pump battery voltage:	1.2 to 15 V
Pump current:	6 A Max. Continuous. 50A peak

Remote measures and configuration:	Asynchronous serial digital link
Mechanical measures:	Plastic Box of 78 x 40 x 22 mm.
Weight:	60 g.

Autostart & advanced setup.

Apart from the operators parameters that are usually set by the users, exist another parameters reserved to manufacturers and advanced users.

These parameters are:

?? Temperature calibration
?? Timers reset
?? Absolute maximum RPM. Limit the maximum RPM that can be programmed by the operator.
?? Started reduced power (%) in the ignition phase
?? Starter RPM window (min and max rpm) in the gas ignition phase
?? Starter switch-off RPM. Speed of the rotor were the starter will be switched-off
?? Starter switch-on RPM. Speed of the rotor were the starter will be recconected if the fuel ramp phase if the RPM's decay below this point.
?? Gas Switch-off temperature.
?? Minimum RPM to start. Minimum rpm that the rotor should have after 1,5s of starter switch on. If the rpm are below this limit, a "bad start" label will appear and the start process aborted. Useful to detect starter/clutch failure.
?? Starter power at the beginning of the fuel ramp.
?? Rpm were the starter power is at 100%. Wen the system detects the ignition had occurred, it starts the starter motor at reduced power and this power is increased during the fuel ramp until arrive at the value of this parameter, that is set at 100%. This feature allows to use small/ low voltage rated starter motors without the risk of burning them due at too much power in the low speed phase.
?? Starter ramps. The rpm range from 0 to idle are divided in 3 sectors by 2 rpm points. In each sector, a defined fuel/time slope is applied. So the real fuel increase in each rpm range depends on the current rpm, the slope value for this rpm range and the "pump start ramp" parameter, that is added to the ramp value for each rpm sector. For example, if the rpm points are set to 16.000 and 30.000 RPM, the ramp1 at 3, ramp2 at 1, ramp3 at 4 and the "pump start ramp" at 2, then the real fuel ramp applied from 0 to 16.000 will be ramp1 + "pump start ramp" = 3+2=5. From 16.000 to 30.000 will be ramp2 + "pump start ramp" = 1+2=3 and from 30.000 to idle ramp3 + "pump start ramp" = 4+2=6. Adding the "pump start ramp" parameter to all values allow at the operator to modify the whole start time without modifying the "manufacturer" parameters.

Starting the engine:

The present version of Autostart uses only one channel to all of the engine functions: To trigger the autostart cycle, the process is as follows:

?? The user raises the trim. "Ready" will appear on the HDT (Hand data terminal) screen wen the engine is supposedly to be to idle. If the trim is on "stop" position, "Trim low" will be read on the HDT. If higher than idle, "StickLo!" will be read.
?? Wen "Ready" is displayed, the user raise the stick to full power.
?? Once at full power, if the stick is left in this position more than 5 seconds, the pump prime function is triggered, and the pump

and fuel valve are energized at the 25% of his power for one second as much. The user can switch off it before this time by lowering the stick.

- ?? Wen the stick is at idle again, the start sequence begins.
- ?? The glow-plug is checked, and if OK, the starter is engaged at reduced power (soft start) to test it. If the glow test fail, a "Glow Bad" message is displayed, and the red led blinks.
- ?? Wen the rotor arrives at more than the "ignition max rpm" programmed parameter (default 4000), the starter is disconnected and the brake applied. At the same time the gas valve is opened and the glow plug powered.
- ?? Wen the RPM are lower than the "ignition min. Rpm" parameter (default 1000), the starter is switched on again to raise the rotor speed to the "ignition max rpm" and the cycle is repeated.
- ?? Wen the thermocouple register a increase of 50ºC in temperature or it is higher than the “start/minimum temperature”, that mean that the ignition have occurred, the starter is switched on immediately at reduced power, increasing his power accordingly to the real rotor rpm. At the same time the pump is switched on, and the fuel valve is opened.
- ?? The engine begin to accelerate at the "fuel ramp" values, depending on the real RPM. Once the exhaust temperature (EGT) arrives at a predefined value (usually 400ºC) the gas valve is closed, and wen the RPM arrive at the predefined "starter off" value, the starter is switched off and the brake applied to it. The engine continues accelerating alone until the idle RPM are reached.
- ?? The user can finish the sequence in any moment, simply setting the trim to "off" position. If the engine was on "running", a cooling sequence will be triggered, cycling the starter motor until the EGT is below the minimum programmed temperature.
- ?? If the engine is hot (EGT higher than the minimum temperature) at the moment that the user triggers the autostart cycle, then the FADEC will begin a cooling cycle until the temperature is below the minimum programmed temperature. At this moment it will continue with the normal autostart cycle.

¡Caution!

The current software is a "Beta" version, and extra care should be applied. There aren't activated the "time-outs". This is useful wen testing the starter or other parts, because it isn't necessary to "Reset" the unit continuously to repeat a test. But this mean that the FADEC can have a problem in a phase, like a empty gas can, or fuel tank, or battery weak and try to start it forever.

At present time, the recommended starter motors are the Speed 300(6V) and the Speed 400 RACE (4,8V). Although the unit can work with lower voltages, the recommended battery voltage should be of at least 6V to allow the solenoid valves to operate reliably.

Programming the manufacturer parameters:

- ?? First adjust the “operator” parameters, specially the radio throws.
- ?? Set the trim and stick to “low”. “Trim low” readout should appear.
- ?? Switch off and on again the FADEC. Wen the initial screen appear (“Fadec autostart....”) press the “data down” button (located in the right hand low side) and then the “menu down” (located in the left hand, low side). This should be done quickly, and before that the normal screen appear.
- ?? It will appear a screen with a number of parameter and the data. To change the parameter number use the left hand button, and to change the data use the right hand buttons.
- ?? Raise the stick or reset the FADEC to return to the normal screens

Caution: The parameters are stored in the same time that are modified, so be careful before to modify any parameter.
The meaning of each parameter is: (These recommended values are for a KJ66 engine.)

Parameter Nr.	Rec. Value	Units	Mnemonic	Description
1		ºC *2	OFFSTEMP	Temperature sensor offset calibration. This value is subtracted from the one read on the fadec.Changes only are read after reset. Factory set, do not change.
2 to 15				Not Used
16	2	Rpm*1000	RPMINICI	Minimum safe rpm in the fuel ramp phase. Lower RPM than this value than this will abort the sequence.
17	153	0 to 255	POWERSTA	Starter power in the ignition phase. Real power is full power * this value/255.
18	3	Rpm*1000	RPMIGN	Rpm where the starter is switched off in the ignition phase
19	1	Rpm*1000	RPMSTOGA	Rpm where the starter is reconnected in the ignition phase
20	0	Cycles	NUMINTEN	Maximum ignition cycles. (not operative in the current release)
21	0	Sec	TEMSTAR	Start sequence maximum time.(not operative in the current release)
22	100	ºC *4	T_STOP_G	Propane switch off temperature. Real temperature is this value multiplied by 4.
23	20	Rpm*1000	R_STOP_S	Starter switch off RPM
24	153	0 to 255	POWSTIR	Starter power at the beginning of the fuel ramp. Real power is full power * this value/255.
25	16	Rpm*1000	RPMERAM	RPM where the starter power arrive at 100%
26	17	Rpm*1000	RPM1TRA	First Rpm point in the fuel ramp. From 0 to this value the RAMP1 value will be applied
27	25	Rpm *1000	RPM2TRA	Second Rpm point in the fuel ramp. From the 1st RPM point to this value the RAMP2 value will be applied. Above this value to idle, RAMP3 will be used.
28	0		RAMP1	1st. Fuel ramp. The real value used will be this value added to the "Pump start ramp" value.
29	2		RAMP2	2on. Fuel ramp. The real value used will be this value added to the "Pump start ramp" value.
30	2		RAMP3	3th Fuel ramp. The real value used will be this value added to the "Pump start ramp" value.
31	15	Rpm*1000	RPMONFU	Rpm where the starter is reconnected in the fuel ramp phase if the rpm fall below this point..

It is available a Excel spreadsheet to calculate and store all of the parameters.

10. Troubleshooting:

10.1 Start:

Problem:	Cause:	Solution:
Wen raising the trim of the radio, the LED is not illuminated	FADEC in stop mode after a running.	Switch off an then o
	Bad adjustment of the radio transmitter	Program the parame
	Supply failure	Verify the voltage connections, switch,
After cycling the throttle “Glow bad” message appear	-Blown glow plug or disconnected -Pump battery disconnected.	Check glow plug an
After cycling the throttle nothing happens and later the “Start bad” message appear	-Starter motor bad/disconnected	Check starter
	Starter power too low	Check starter power
After cycling the throttle the rotor turns but later the “Start bad” message appear	RPM sensor failure	Check RPM
	Starter power too low or ignition rpms set to low	Check the autostart
The RPM are cycling but the gas doesn’t ignite.	Gas can empty or gas solenoid valve disconnected or blocked	Check the gas comi
	Glow plug brightness too low	Check/adjust glow p turns pulled out, an the correct brightens
	Gas tube incorrectly set inside the engine	Ask the engine man
Wen the start gas is ignited the “start bad” message appear	The starter failed to have the minimum RPM to continue the sequence.	-Check the RPMINI -Raise the starter po
Wen the start gas is ignited, the FADEC does not begin to pump fuel nor the LED blinks.	The temperature read by the FADEC is lower to the programmed start temperature due at that the start gas flow is insufficient to reach start the temperature.	Check the exhaust t -Increase the gas fl lower programmed s
Wen the start gas is ignited the LED of the FADEC begins to blink but the pump does not work	Adjustment of the pump start point defective.	Repeat the adjustm the pump.
		.
Excessive fuel flow at the beginning of the starting. Start very hot.	Adjustment of the pump start point defective.	Repeat the adjustm the pump. This must start smo
Once the pump is started and the engine is running in fuel, it takes too much time in arriving to idle	The fuel Start Ramp value is too low.	Raise the “*start ram*
Once the pump is started an the engine is running in fuel, the exhaust temperature is excessive	The fuel Start Ramp value is too high or weak starter motor	Lower the “*start ran*
Once the pump is started an the engine is running in fuel, the exhaust temperature is excessive and the engine doesn’t arrive at idle.	Too low top RPM of the starter motor and it cannot push the engine to self above to self sustain.	Change starter, ch battery.
Wen the engine arrives at idle the system changes to automatic mode, extinguishing the LED, but the speed is higher than the programmed , lowering slowly until arriving at idle	The fuel Start Ramp value is too high.	Lower the “*start ran*

10.2 Running:

Problem:	Cause:	Solution:
10.2.1 The engine does not reach the maximum power.	Maximum speed badly fit.	Verify the Maximum speed and r
	Too open Bypass, battery of the pump empty or with too low cells, defective or insufficient pump, defective plumbing, including the fuel injectors inside the turbine obstructed.	Verify the indicator of power of tl bypass valve until it indicates 80 arrive at full power, check the pu
10.2.2 Instability of the power at medium and and low power.	Too much closed Bypass. The FADEC has little margin of regulation.	Open the bypass valve until th maximum power of the turbine ir
	Pump too much powerful.	Change the pump or install a by
	Stability delay too low.	Increase the "Stability delay". V problems.

10.3 Acceleration:

Problem:	Cause:	Solution:
10.3.1 When changing quickly the throttle from idle to full power, the engine accelerates quickly until an intermediate point and later the power raises slowly until arriving at the maximum power.	An external change to the FADEC in the circuit of fuel supply has taken place from the last normal start/stop cycle, as it can be the adjustment of bypass, change of pump, change of the number of elements of the battery, or change in the engine. The internally stored data do not agree with the real ones, reason why the FADEC must find the new values. This case is habitual when the bypass valve is opened.	Wait until the engine accelerate of the power of the pump in adjustment of this, lower the pow it slowly until the maximum po FADEC can find the data of all t like 10s minimum. Once this is engine responds immediately. S that the FADEC keeps the new
10.3.2 Too slow acceleration	The value of acceleration delay is excessive.	Lower the delay. The habitual v engine.
	The exhaust temperature is very high or the maximum programmed temperature is too low. The FADEC modifies the time of acceleration on the basis of the margin of temperature between the maximum and the current one. If this difference is small, the acceleration will be slower since a greater risk exists of exceeding the maximum temperature.	Verify the adjustment Maximum
10.3.3 Acceleration does not uniform. When accelerating quickly the engine from idle to the maximum, this accelerates quickly to an intermediate point in which it becomes stabilized during a second, raising to maximum power next.	The value of acceleration delay is too low. The FADEC tries to accelerate the engine more quickly than it allows, causing that the temperature raises excessively, moment in which the FADEC reduces the fuel flow to maintain the temperature controlled. This effect is harnessed with the use of thermocouples with an excessive diameter that cause a considerable delay between the changes of temperature and the reading and correction of the fuel flow by the FADEC.	Increase the value of the acc without steps. Check that the thermocouple is installed in the hottest part of t improve this problem, since th temperature.

10.4 Deceleration:

Problem:	Cause:	Solution:
10.4.1 Extinguished of the engine. When lowering quickly the throttle from maximum power to idle, the engine is stopped.	The value of the deceleration delay too low. In some engines the abrupt reduction of the fuel flow causes a flame out.	Increase the value of the "Dec standard KJ-66 is between 20 a