FPGA-BASED FLIGHT CONTROLLER

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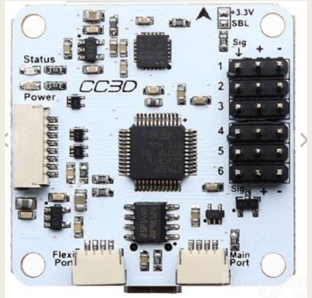
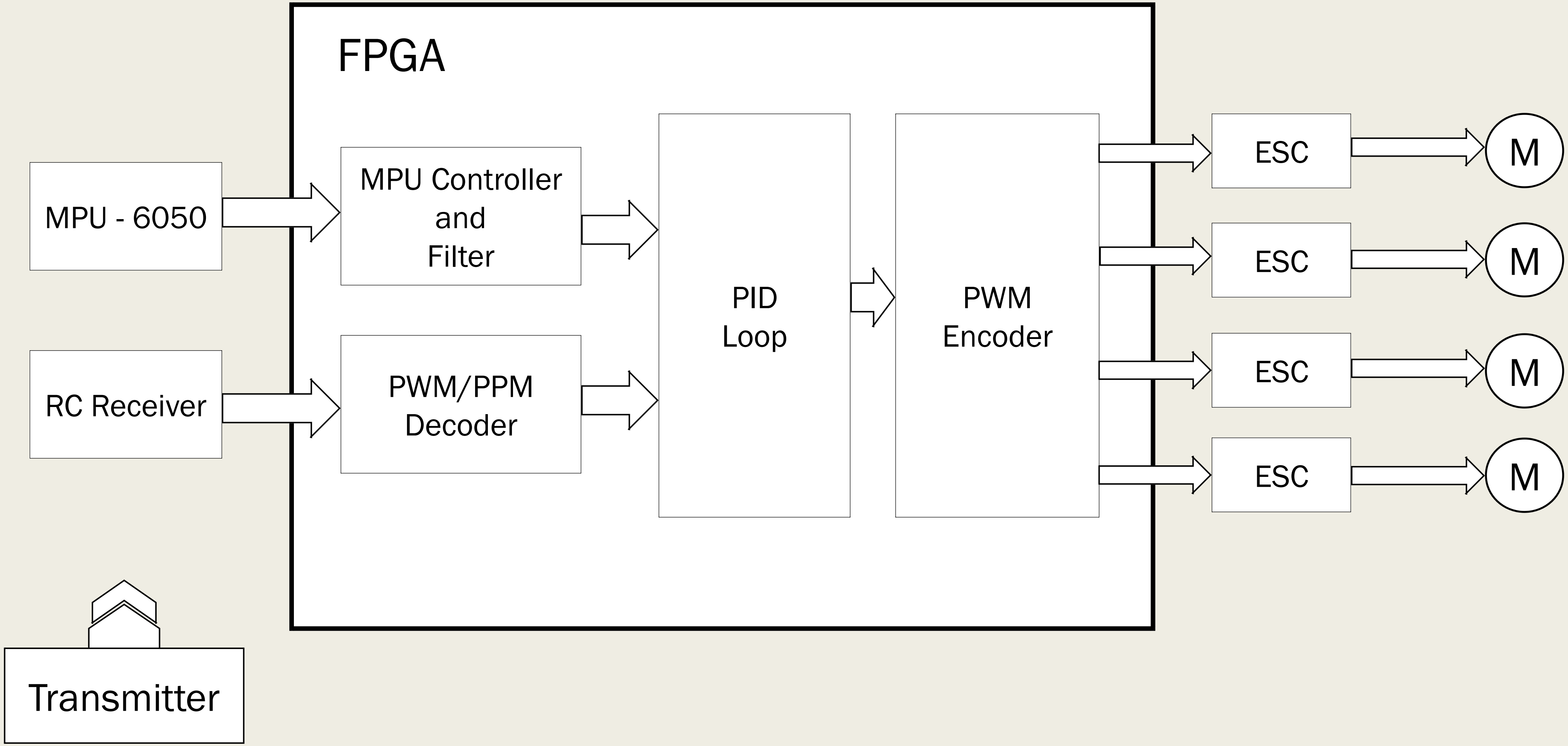
WORKING

- The flight controller is a device used for controlling the flight of a drone which can be fixed wing or rotary wing.
- It works on the basis of inputs from the pilot who controls the device via a remote control and from the inputs of the accelerometers and gyroscopes. The output of the flight controller is used to control the motors of the drone.
- The user sends desired orientation of the drone through the radio transmitter to and these signals will be transmitted to the receiver present in the drone. The output of the receiver will be either pulse position modulated (PPM) or pulse width modulated (PWM) signal. A PPM or PWM decoder in the flight controller decodes these signals and send it to the processor present for calculation of the flight dynamics.
- The accelerometer and gyroscope sensor in the inertial measurement unit (IMU) gives the actual acceleration and orientation of the drone in terms of roll, pitch and yaw values at that instant and after filtering these values to reduce the noise error, these are given to the flight controller processor via I2C protocol.

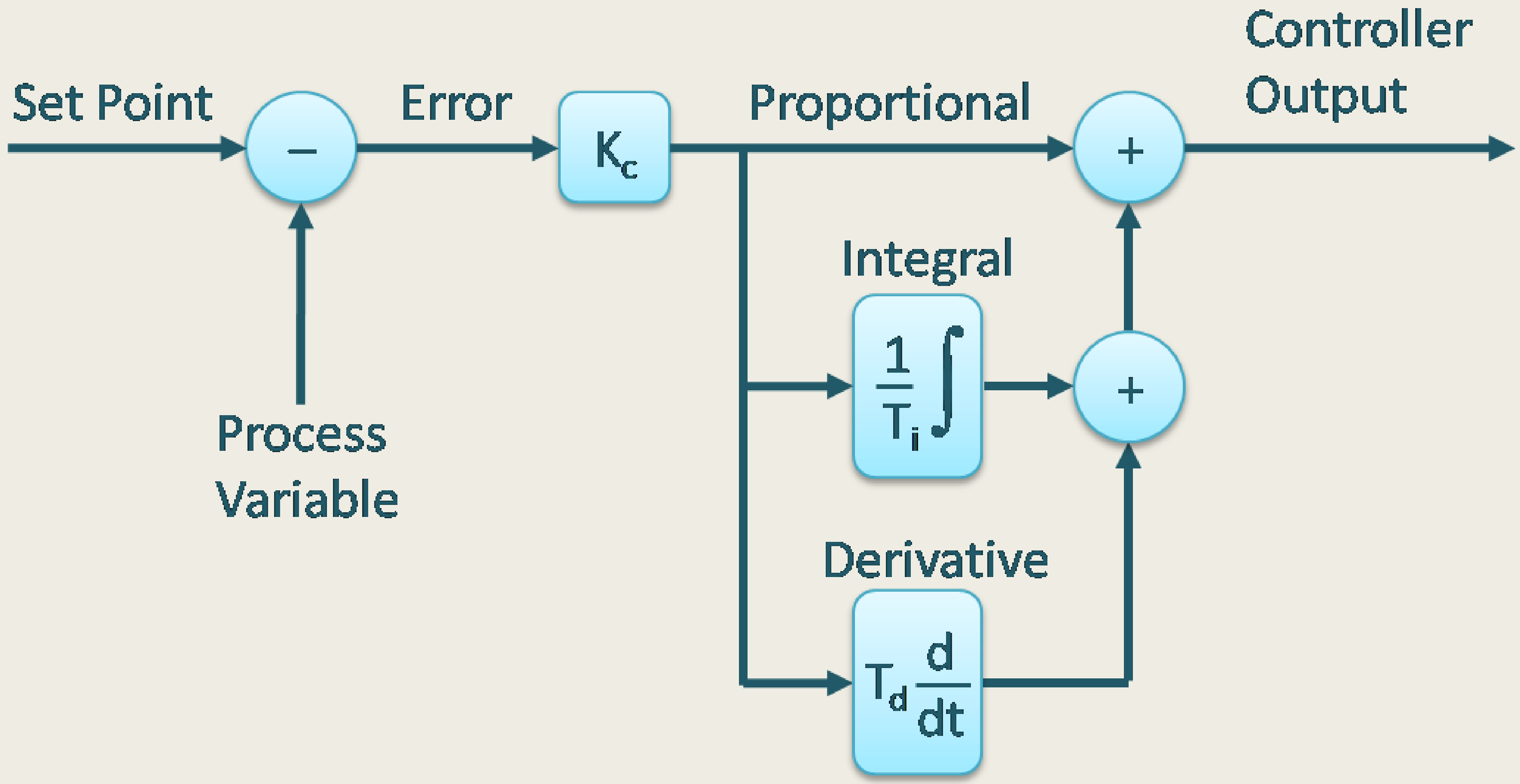
- The roll, pitch and yaw values in degrees generated from the IMU are sent to the processor and these values are used in the proportional-integral-derivative (PID) loop.
- The PID loop present in the processor takes these inputs and calculates particular signal values according to input.
- The output of the PID loop is modulated using PWM technique and is given to the electronic speed controller.
- The motor speed is controlled by these signals and this directs the drone to the requested orientation.
- Most commonly used flight controllers are Pixhawk 4, CC3D, Naze32, etc.



BLOCK DIAGRAM



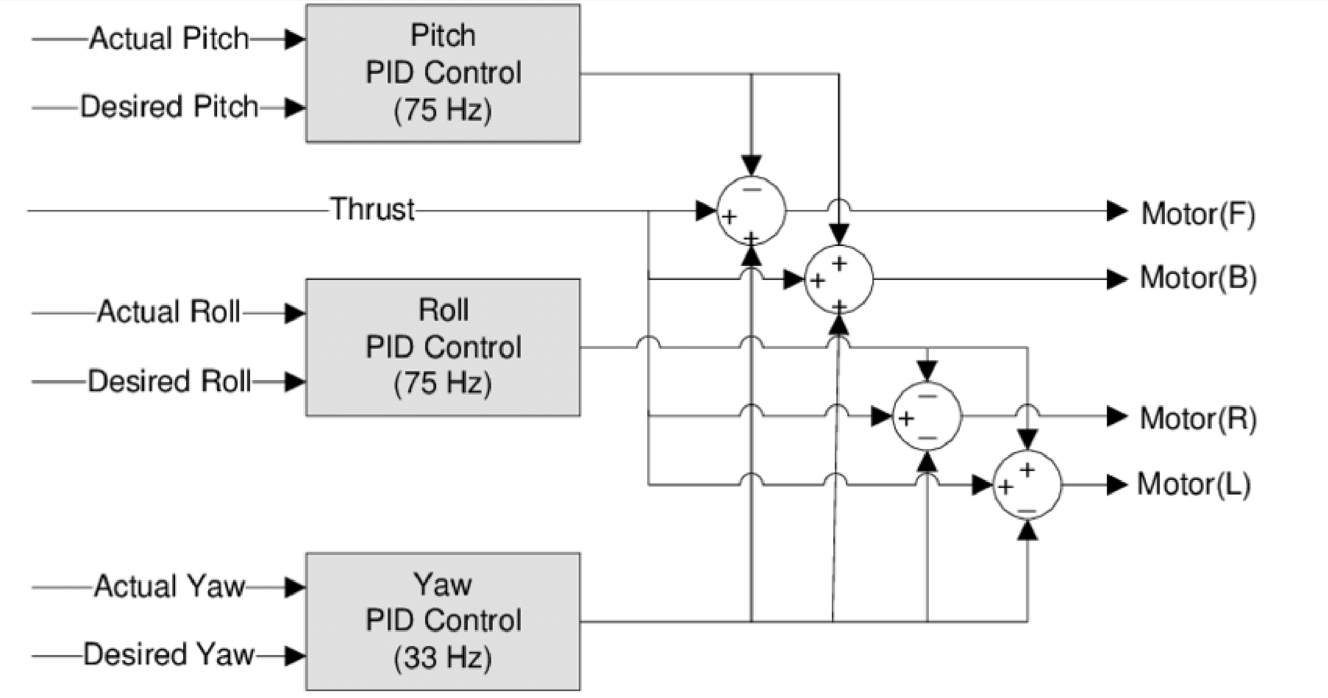
PID Controller Loop



IMPLEMENTATION

- The complex functions of the flight controller can be implemented in an FPGA as they feasible for implementing time-critical concurrent processing functions.
- The signal from the receiver should be decoded. For that, in the FPGA, we need to implement the decoder for the received PWM/PPM signal which decodes the desired orientation which was transmitted from the radio remote control transmitter. This decoded value will be given as the desired input to the PID loop.
- The IMU sensor gives the actual roll, pitch and yaw values in degrees and a filter need to be implemented in the FPGA to reduce noise errors. The sensor also need to be interfaced with the FPGA so that it can process these values and give it to the PID loop.
- The main control mechanism of the flight controller is done by the PID loop. In FPGA, this need to be implemented for each of the orientation values separately. The loop generates an output which is capable of orienting the drone in the required direction.

- The thrust for each motors are added now and these values will now be given to the PWM encoder which also need to be implemented in the FPGA. The output of this encoder will be PWM signals and are given to the ESCs which are connected to the motors.
- These modules need to be implemented in the FPGA for converting an FPGA into a flight controller and proper functioning of the same. For SoC-FPGAs, implementation of the PID loop can be excluded from the FPGA and can be implemented in the processor.



APPLICATIONS & FUTURE SCOPE

- From entertainment to military purposes, drones are used in various applications and the scope of drone technology is limitless.
- Drones now are made using ASIC flight controllers. Autonomous flights using these flight controllers requires an extra system for giving inputs. This trend is currently shifting and it is clearly visible when Aerotenna launches OcPoC, the first ever commercial SoC-FPGA based flight controller. The SoC-FPGA used is Intel’s Altera Cyclone V which contains a dual-core ARM Cortex A9 MPCore as the processor on board.
- Another custom-made SoC-FPGA is PynqCopter which uses Zynq Z-7020 SoC which contains ARM Cortex A9 MPCore as the processor on board.
- There is a large scope for SoC-FPGA based flight controllers considering the innumerable application of the drones.