Y-CYC-ESC

Version 1.4

USER GUIDE

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Contents

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1 Overview

Y-cyc-ESC *(Yoga-cycle-Electronic Speed Controller)* is a modern motor drive for BLDC/PMSM motors. Y-CYC-ESC uses ***sensorless FOC (field-oriented control)*** suitable for general purpose motor control applications.

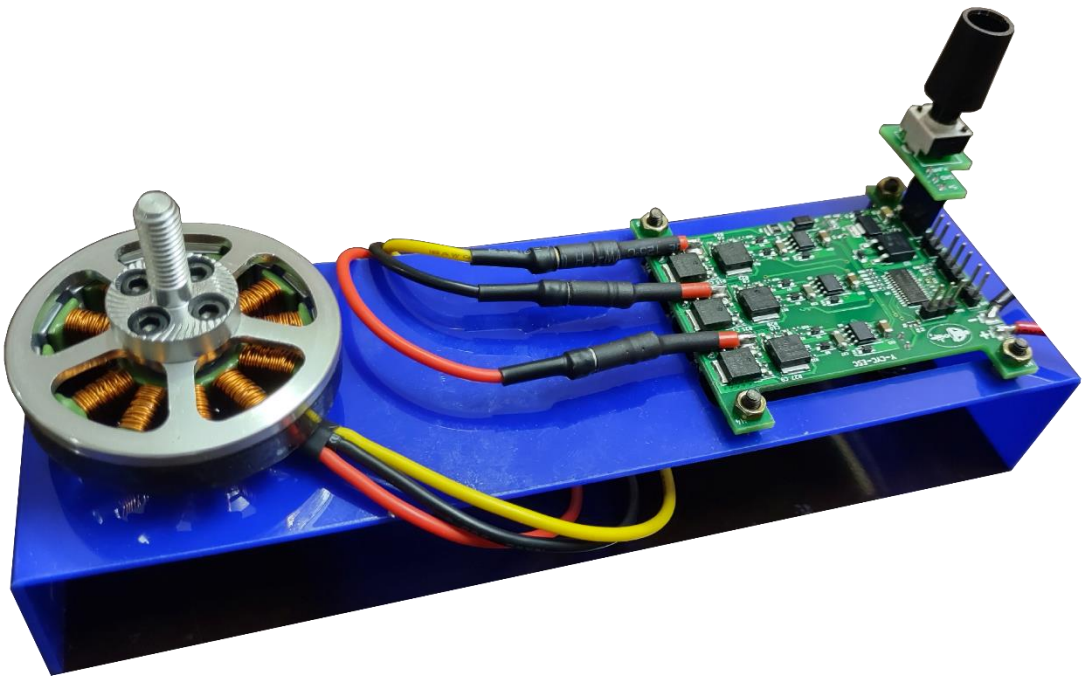

Figure 1 Y-CYC-ESC demo kit hardware

Y-CYC-ESC are adaptable to a wide range of applications. Typical applications include e-bikes, robotics, consumer electronics, drones etc.

Features:

- **Fast system identification.** Y-CYC-ESC can determine the required motor parameters within 15 seconds.
- **Simple tuning.** PID gains need not be tuned.
- **High motor speed support.** Speeds up to 140,000 eRPM can be achieved.
- **Rolling start.** This feature enables smooth startup in electric bicycles. Gently start the bicycle manually and then the controller delivers power.

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2 Technical Specifications

Voltage	**14v to 24v**
Max phase current	**50A**
BEC	**No**
Control input	**1) 0v to 5v Analog input** **2) 1000us to 2000us @ 50Hz PWM input**
PWM frequency	**21 kHz**
Max motor speed	**140,00 RPM (2 pole)**
Control Method	**Sensorless Field Oriented Control**
Control Modes	**$I_d = 0$** **1) V_q control** **2) I_q control**
Startup method	**1) Open loop I/F startup** **2) Rolling start**
Overmodulation	**Up to 92%**
Programming interface	**UART**
Dimensions (L x W x H)	**65 mm x 45 mm x 20 mm**
Weight	**30 g**

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3 Getting Started

3.1 Before you start

- Ensure you have a **suitable power supply or battery** with sufficient voltage and current requirements to run the motor.
- Y-CYC-ESC drives communicates with the GUI over UART. You need a USB-to-serial converter with appropriate drivers to communicate with the drive.
- You also need the latest dot net framework to run the GUI.

3.2 Connections

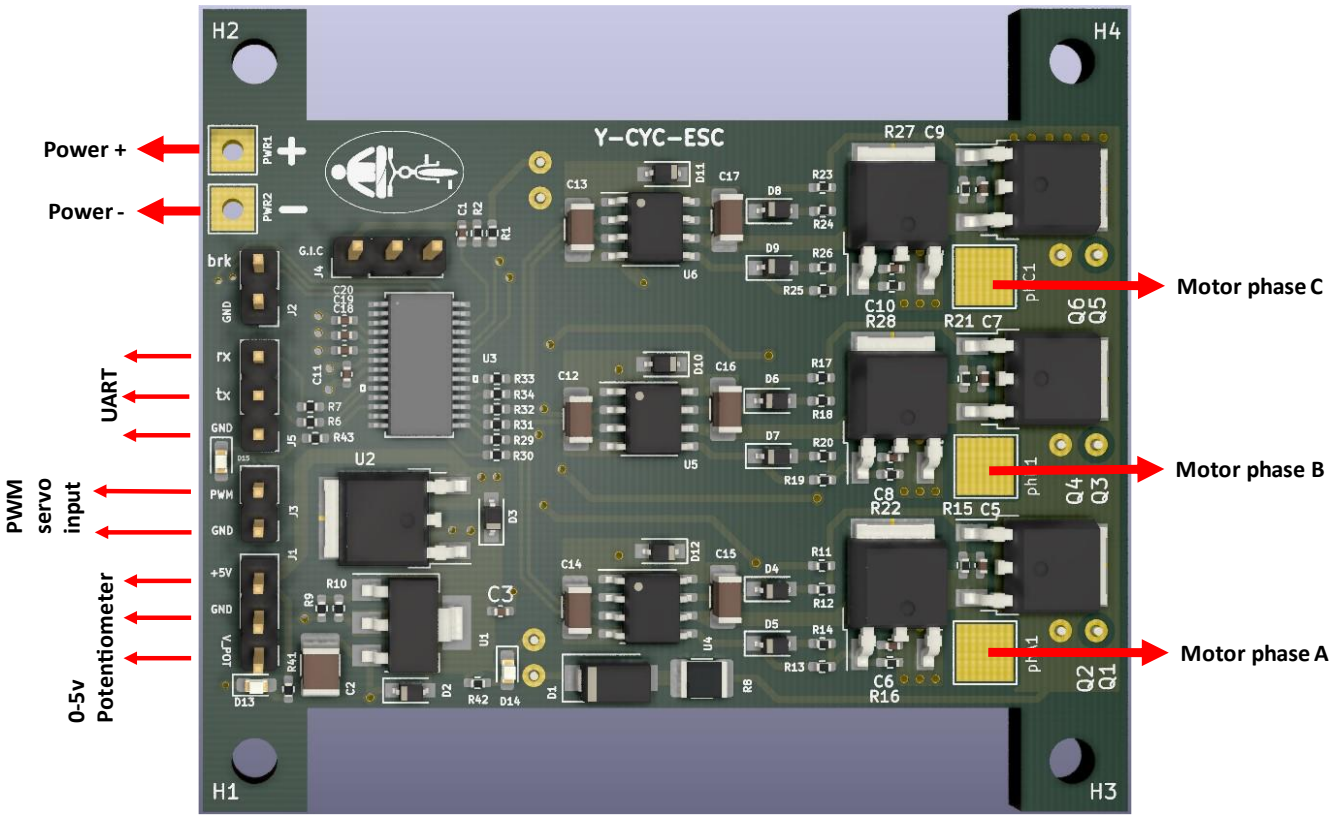

Figure 2 Connection diagram

Power

Positive and negative terminals are marked. Ensure you connect the power as indicated.

Motor phase

Motor phase A, Motor phase B, Motor phase C connections are marked in figure 2. If you need to reverse the rotation of the motor, swap the connection of any ***TWO*** phases.

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Do not connect/disconnect the motor phases when the drive is active. The active state is indicated by the blinking LED.

Potentiometer

The potentiometer port is used to provide the control input to Y-CYC-ESC. The +5V, GND, and V_Pot are marked on the board. Pin **V_Pot** can vary between **0-5V**.

PWM servo input

PWM signals can also be used as input to the controller. The PWM signal should switch between 0-5V.

UART programmer

Y-CYC-ESC uses the UART interface to update the drive parameters. A USB-to-serial converter is needed to update the drive parameters through the desktop GUI.

Ensure **converter rx -> Y-CYC-ESC tx and converter tx -> Y-CYC-ESC rx.** The ports accept up to **5V**.

3.3 Run your motor

This section will guide you to setup Y-CYC-ESC for your application.

1. Ensure board is powered **OFF**.
2. Connect the power, motor phase, potentiometer, and UART programmer as described in the previous section.
3. Set the potentiometer and PWM input to ZERO.
4. Power **ON** the board through the power source.
5. Start the Y-CYC-ESC GUI app.
6. Click *"connect"*. The STATUS window will be updated to "Connected" along with the COM port number to which Y-CYC-ESC is connected to the computer.
7. If you already have a configuration file for your motor and application, you can click *"Load configuration file"* button and select the ".y" file. Otherwise, go to the *"Motor Parameters"* tab.
8. Click the *"System ID"* button to measure the motor parameters. At this point, Y-CYC-ESC will inject test signals into the motor for measuring motor parameters. The text box will automatically be populated with the estimated motor parameters.
   If you already know the motor parameters, you can enter these values directly in to the box.
9. Go to *"gain tuning"* tab. Enter the gains as per your application requirements (refer to **Gain Tuning**). Default gains are:
   a. BEMF filter bandwidth (Hz) = 600
   b. Angle filter bandwidth (Hz) = 60
   c. Current control bandwidth (Hz) = 100
10. Go to *"Application settings"* tab.
    a. First, select the control mode based on your application (refer to **Control Modes**).
       i. Mode 0, I/F startup and Vq control
       ii. Mode 1, I/F startup and Iq control

iii. Mode 2, rolling start and Iq control

b. Next, select the Control input signal (refer to **Control Inputs**).
c. Then set the nominal DC voltage (if Mode 0 is selected), or max phase current in the motor (if Mode 1 or Mode 2 is selected)
d. If you select control mode 0 or control mode 1, configure the startup ramp (refer **I/F startup**)
e. After confirming the application settings, click *"update application settings".*

11. Go to the Update tab. The *"parameter summary"* tab lists the motor parameters and the drive parameters that were just set. This can be saved by clicking "*save to file*".
12. Click *"Load parameters to drive"*. The GUI will upload the parameters to the drive.
13. Set the potentiometer to ZERO. Click *"reset and start"*

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4 Gain Tuning

Y-cyc-esc requires 3 gains as part of the setup. This section highlights some guidelines to set the gains appropriately for your application.

- BEMF filter bandwidth:
  - The BEMF filter has a role of filtering the estimated back-emf from the motor. This parameter can be set between 50 Hz – 2100 Hz.
  - Lower values are used when more filtering is required for low-speed operation. Higher values are used when fast transients need to tracked (like sudden speed changes).
  - The default value of 600 Hz is a tradeoff between transient tracking and low speed operation.
- Angle Filter bandwidth:
  - The Angle Filter helps to filter and reject the noises in angle estimation from BEMF estimations. This parameter is usually set 1/5 to 1/10 of BEMF filter bandwidth.
  - For example, if the BEMF filter bandwidth is set to 600 Hz, the Angle filter bandwidth is set to about 60 Hz.
- Current control bandwidth:
  - The current controller bandwidth is set close to or lower than the RL circuit bandwidth of the motor winding.
  - Higher bandwidth setting leads to quicker response but high control effort. Lower bandwidth settings provide smoother but slower response.

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5 Control Modes

Y-CYC-ESC supports 2 types of startup methods (I/F and rolling start) and 2 types of control variables (Vq and Iq). Together, 3 control modes of operation are possible.

5.1 I/F startup

The purpose of this startup routine is to spin the rotor to sufficient speed in *open loop*, i.e, without any feedback.

For the purpose of the startup routine, the frequency is not represented as Hertz, but as eRPM (electrical RPMs). For example, if you have a 14-pole motor and you want to reach 100 RPM by the end of the startup routine, you need to enter the speed as 700 RPM. (eRPM = Mechanical RPM x $\frac{No\ of\ poles}{2}$ *)*

Voltage represents the line-to-neutral voltage applied to the motor

After the rotor reaches a certain speed, the back emf generated can be estimated accurately. At this point, the drive can estimate the rotor position and begin the field-oriented control.

I/F startup is configured by 3 parameters (see Figure 3):

1. Speed final (eRPM): The speed of the motor at the end of open-loop run. Typically, this value is 5% of the max speed of the motor. Note that the speed is entered as *electrical RPM* and **NOT** mechanical RPM.
2. Startup Iq current (mA): The phase current that is required during the open loop run.
3. Speed ramp time (ms): The time taken to accelerate the motor to reach the speed final eRPM.

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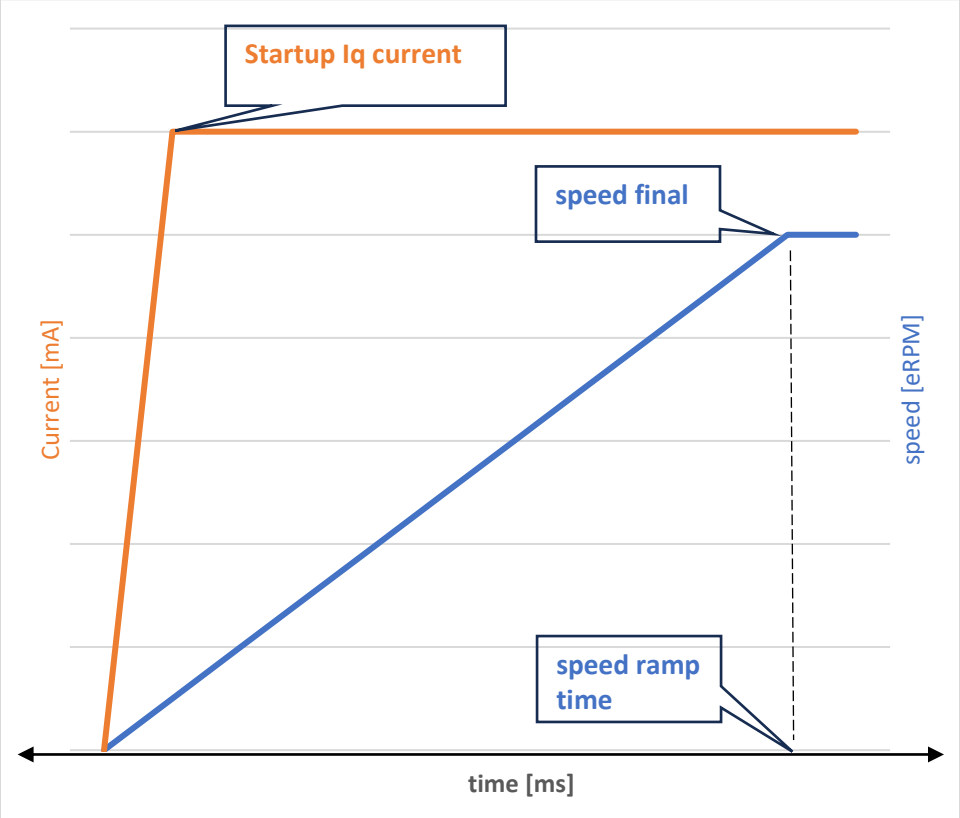

Figure 3 I/F startup parameters

5.2 Rolling start

When a I/F ramp cannot be used to start the motor, Y-CYC-ESC can use the rolling start.

The controller waits for an external force to rotate the motor and then delivers torque after the motor starts rotating.

The controller does not provide any holding torque while waiting for the motor rotation. The motor will be free to rotate.

For example, in direct-drive motors in electric bicycles, the motor is started from zero speed by gently moving the bicycle. Y-CYC-ESC delivers torque after the bicycle starts moving slowly.

5.3 Vq control

In Vq control, Y-CYC-ESC directly sets the Vq voltage. Iq is not controlled. Id is to zero.

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Vq control can cause regenerative voltage when slowing down the motor. Ensure the power-supply/battery can withstand regenerative voltage.

5.4 Iq control

This regulates the Iq to the desired setpoint, Id is set to 0. This mode is also called torque control mode because the torque generated in the motor depends directly on Iq.

Y-CYC-ESC supports three control modes based on the startup method and controlled variables.

Mode 1: I/F startup with Vq control mode

In mode 1, the motor starts up in I/F mode. You need to configure the startup ramp so that the motor reaches sufficient speed for sensorless FOC to work. After reaching sufficient speed, the motor works in Vq control.

Mode 2: I/F startup with Iq control mode

In mode 1, the motor starts up in I/F mode. You need to configure the startup ramp so that the motor reaches sufficient speed for sensorless FOC to work. After reaching sufficient speed, the motor works in Iq control.

Mode 3: Rolling start with Iq control mode

The Y-CYC-ESC waits until motor is externally rotated. After the motor starts rotating, the controller sets the Iq setpoint.

6 Control Inputs

Y-CYC-ESC supports 2 input modes: Analog voltage and PWM pulses. Only one of these inputs can be used at a time.

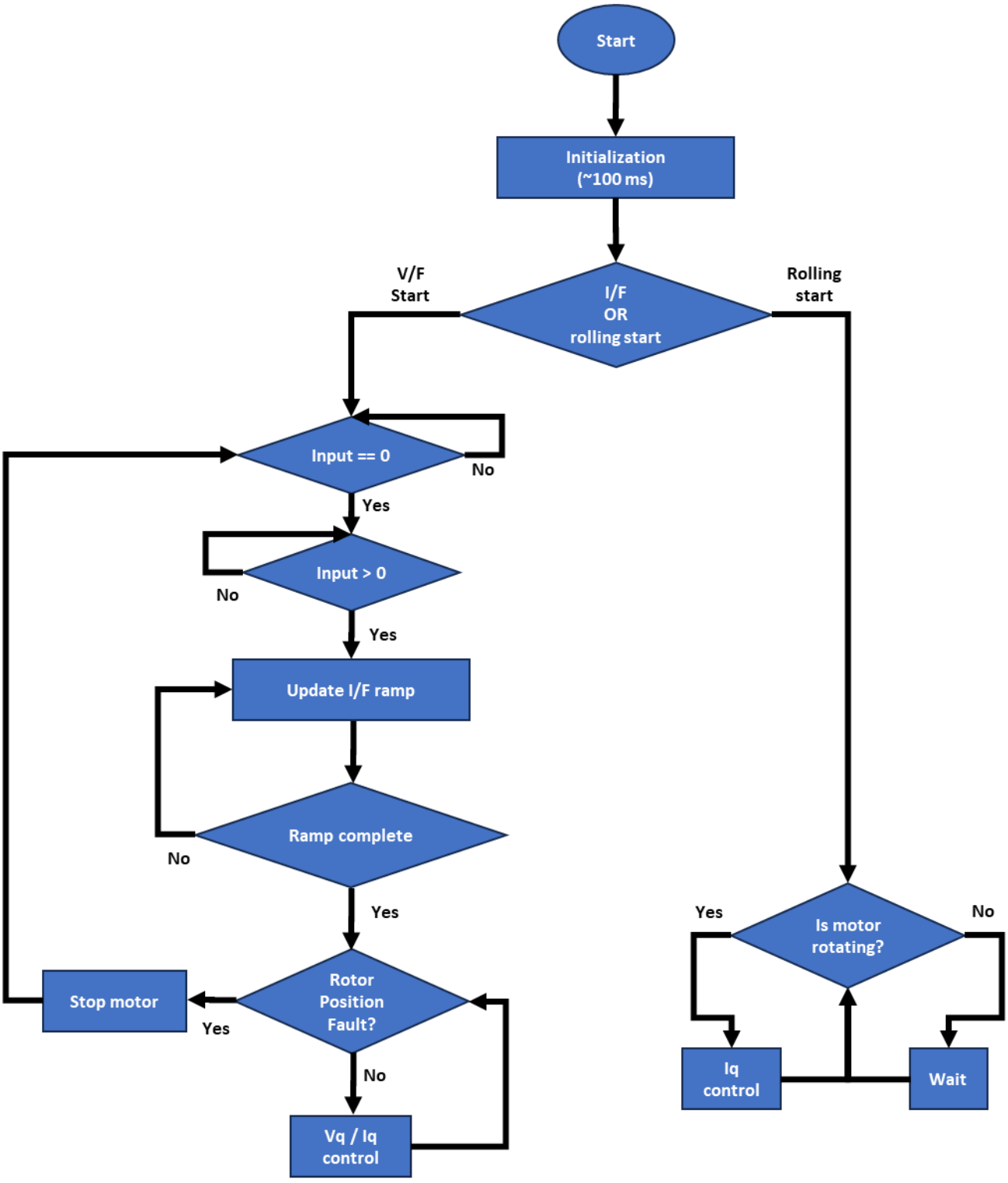
6.1 Analog voltage input

The potentiometer port accepts analog 0–5V voltage signal. A minimum voltage signal of 600mV is required below which the controller treats the signal as ZERO volts. Thus, 600mV to 5000mV is operating voltage range.

6.2 PWM Input

The PWM signal must switch between 0v and 5v at 50 Hz and operating pulse width is between 1000us to 2000us. Pulse width of less than 1000us is treated as ZERO. Pulse width of more than 2000us are treated as 2000us.

7 Operating flow chart



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