Application Note

Using Z8 Encore! XP® MCU as a Tachometer

AN018302–1207

Abstract

This application note describes the method to use Zilog's Z8 Encore! XP® MCU as a tachometer to measure the number of revolutions of a rotating object over a specified period of time.

A locally available phototransistor is used to capture infrared light that is beamed onto a flywheel which is attached to the rotating shaft of a motor. The signals from the phototransistor are fed to the Z8 Encore! XP MCU's GPIO port. The Z8 Encore! XP on-chip timer and an interrupt vector are used to compute the revolutions per minute of the motor.

Note: *The source code associated with this application note (*`AN0183-SC01.zip`*) is available for download at* www.zilog.com.

Family Overview

Z8 Encore! XP Flash Microcontrollers

Z8 Encore! XP products are based on Zilog's new eZ8 CPU and introduce Flash memory to Zilog's extensive line of 8-bit microcontrollers. Flash memory in-circuit programming capability allows faster development time and program changes in the field. The high-performance register-to-register based architecture of the eZ8 core maintains backward compatibility with Zilog's popular Z8® MCU.

Z8 Encore! XP MCUs combine a 20 MHz core with Flash memory, linear-register SRAM, and an extensive array of on-chip peripherals. These peripherals make Z8 Encore! XP MCU suitable for various applications including motor control, security systems, home appliances, personal electronic devices, and sensors.

Discussion

A tachometer is a device that measures the rotational speed of motors, wheels, or engines. The signal received by the tachometer is directly proportional to the rotational speed of the motor, wheel, or engine. Tachometers are widely used to measure and monitor the rotational speed of engines found in cars and airplanes.

A number of techniques are used to measure the rotational speed of a motor. One method is to measure the time taken by a motor to generate high and low pulses. Another method is to measure rotational speeds without direct contact with the device being measured. Light sensors are placed beside the motor and the rotational speed is measured by the reflection of light transmitted to the wheel.

The Z8 Encore! XP MCU-based tachometer employs the method where a light-emitting device coupled with a phototransistor is used to capture reflected light from a flywheel attached to the rotating shaft of a motor.

Photoreflective Sensor

Photoreflective sensors combine a photoemitting device with a phototransistor. The phototransistor converts the reflected light beams (obtained as input) into signals for processing. A locally available infrared-emitting diode and a phototransistor are used to form the photoreflective sensor for the Z8 Encore! XP MCU based tachometer described in this application note.

Note: *Any photoemitter and phototransistor unit can be used.*

Appendix B—Alexan IR Emitting Diode on page 8 and Appendix C—Alexan WPT- 440F IR Photo Transistor on page 10 provide data sheets for IR Emitting Diode (Module No: IE-0575HLG) and the phototransistor (Module No: WPT-440F), respectively. Figure 1 displays the circuitry for the photoreflective sensor using these devices.

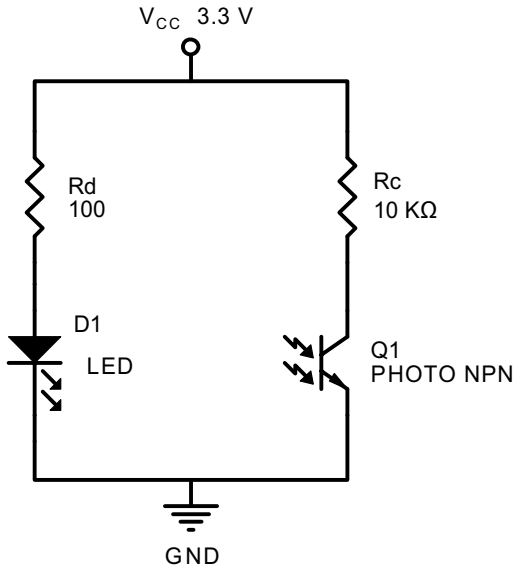


Figure 1. Circuitry for Photoreflective Sensor

Developing Z8 Encore! XP® Tachometer

The Z8 Encore! XP MCU based tachometer uses a flywheel encoder, attached to the rotating shaft of a motor. The flywheel is divided into 20 parts that are alternately black and white. This configuration is used to drive a phototransistor to saturation and cut-off alternately. The output of the phototransistor is fed to bit 2 of Port D on the Z8 Encore! XP MCU. Figure 2 and Figure 3 are snapshots of the flywheel encoder, the photoreflective sensor circuit board, and Z8 Encore! XP Development Board.

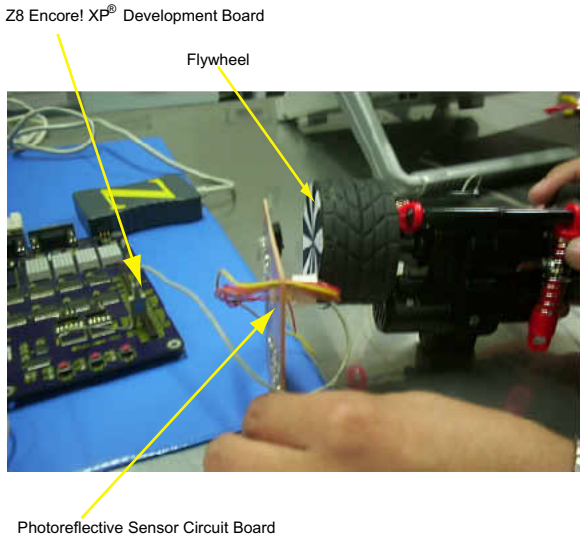


Figure 2. Z8 Encore! XP MCU-based Tachometer Setup

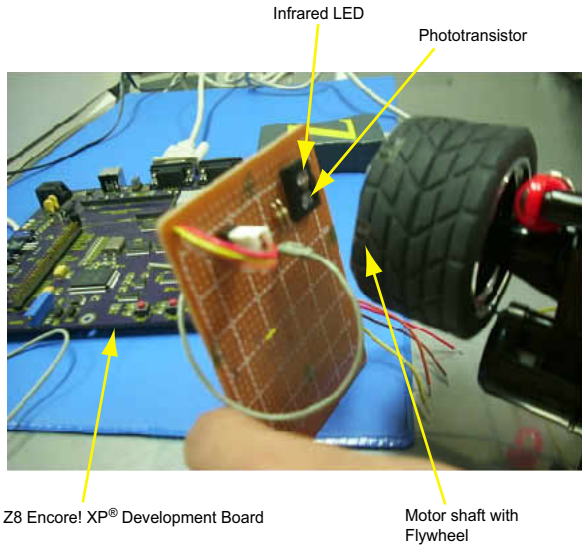


Figure 3. Photoreflective Sensor Circuit Board Details

Hardware Architecture

This application uses a photoreflective sensor which contains a phototransistor (Module no: WPT-440F) and an infrared emitting diode

(Module no: IE-0575HLG). The photoreflective sensor detects the infrared light reflected by the wheel encoder. Figure 4 displays the hardware block diagram for the Z8 Encore! XP® tachometer.

Note: *Any general-purpose phototransistor and infrared light-emitting diode can be used for the tachometer application (for data sheets of these devices, see References on page 5).*

The flywheel mounted on the motor shaft reflects infrared light on the phototransistor. The emitted infrared light does not fall directly on the phototransistor due to the acceptance angle of the phototransistor.

The infrared light that bounces off the flywheel causes the phototransistor to switch ON and OFF. This switching sends pulses to the Z8 Encore! XP MCU through Port D bit 2 (PD2). For each falling-edge signal encountered at PD2, an interrupt is generated. Infrared light is reflected only when it strikes the white portion of the flywheel. The circuit is mounted away from the center of the flywheel so that the waveform has sufficient spacing to ensure proper triggering of the phototransistor.

Software Implementation

Z8 Encore! XP Flash microcontrollers feature four built-in timers that can be used as interrupt sources or event counters, or to generate pulse-width modulation (PWM). Using these timers, the Z8 Encore! XP MCU is used to measure rotational speed, which is the basic function of a tachometer. Z8 Encore! XP microcontrollers feature both internal and external interrupt sources. The interrupts are of the following types:

- Communications peripheral interrupts
- Timer interrupt
- External-edge-triggered interrupts.

In this application, the software uses one internal (Timer0) and one external (Port D) interrupt source. Timer0 is configured to generate an interrupt every 100 ms. Port D is configured to generate an interrupt every time it encounters a rising edge from its input pin. With this configuration, a counter is incremented every time it enters the interrupt service routine (ISR) for Port D. The counter increments until Timer0 generates an interrupt. When Timer0 generates an interrupt, it calls functions which convert the counter value and display the result on the 5x7 LED Matrix display of the Z8 Encore! XP Development Board.

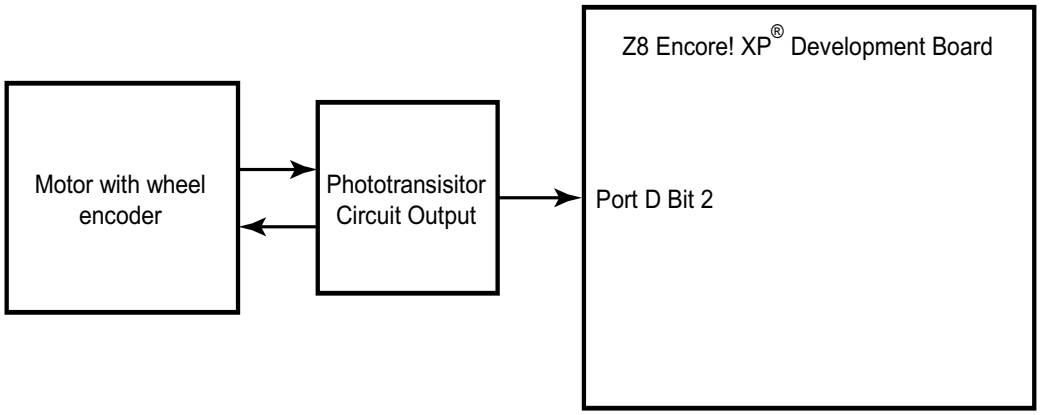


Figure 4. Hardware Block Diagram for Z8 Encore! XP Tachometer

Figure 5 on page 6 displays the flowchart of main routine of the tachometer program. The main routine initializes Port E and Port G, which are used by the 5x7 LED matrix display. It also initializes and enables the interrupts Timer0 and Port D. The program enters a continuous loop where its function is to display the value measured.

Figure 6 on page 7 displays the ISR of the rising edge interrupt on Port D. Its main function is to increment a counter whenever a rising edge is encountered.

Figure 7 on page 7 displays the ISR of Timer0. It computes and updates the value to be displayed on the 5x7 LED matrix display. The Timer0 ISR also resets the value of the counter to reinitialize its count.

Testing

This section provides details for testing the functionality of the Z8 Encore! XP MCU based tachometer. Figure 4 on page 3 displays the setup diagram. For schematics and more details on the Z8 Encore! XP Development Board, refer to *Z8 Encore! Flash Microcontroller Development Kit User Manual (UM0146)*. The compiled code, available in `AN0183-SC01.zip` file (available for download at www.zilog.com), is downloaded to Z8 Encore! XP MCU Flash memory using the ZDS II IDE for Z8 Encore! v4.8.0[1]

Equipment Used

The following equipments are used:

- Z8 Encore! XP Development Kit which includes:
  - Z8 Encore! XP Development Board
  - Z8 Encore! XP MCU (Z8F642x)
  - LED array with four 5x7 LED matrices
  - Smart Cable to connect a PC to Z8 Encore! XP Development Board
  - Universal 5 V DC Power Supply
  - ZDS II–Z8 Encore!
- Photoreflective Sensor Circuit Board
- DC Motor with a flywheel encoder attached to its shaft

Procedure

Follow the steps below to use Z8 Encore! XP MCU based tachometer:

1. Connect the Z8 Encore! XP-based tachometer circuitry (see Figure 1 on page 2 and Figure 4 on page 3).
2. Launch ZDS II and open the `tachometer.pro` program. Download this program to the Z8 Encore! XP Development Board and reset the Board.
3. Start DC motor and observe the displayed value on the 5x7 LED matrix display.

Results

The measured revolutions per minute is displayed on the Z8 Encore! XP Development Board's 5x7 LED matrix display.

The displayed value is provided below:

- LED1—Thousands Value
- LED2—Hundreds Value
- LED3—Tens Value
- LED4—Ones Value

For example, if the display reads 2000, the actual value is 2000 revolutions per minute (2000RPM). Actual values were verified using simple calculations to convert cycles per second to revolutions per minute. Table 1 provides an example of the displayed and actual values for motor speeds obtained during testing.

1.For details on how to download the code to the Flash memory on the Z8 Encore! XP MCU, refer to the Zilog Developer Studio II–Z8 Encore! User Manual (UM0130).

Table 1. Displayed and Actual Values from the Z8 Encore! XP® Tachometer

Actual Motor Speed (in RPM)	Displayed Motor Speed (in RPM)
405	0405
750	0750
2250	2250
7800	7800
9600	9600

Summary

This application note demonstrates the capability of Zilog's Z8 Encore! XP Flash microcontrollers with their built-in timers to measure the speed of a rotating body with simple programming and some discrete devices like a phototransistor and an infrared light-emitting diode.

The development of the hardware and software to implement Z8 Encore! XP MCU based tachometer is simple. The hardware uses few discrete devices, thus making it easy to design. The software utilizes simple interrupt routines, thus reducing code size and complexity. Additionally, non-contact tachometers are easy to install without requiring a change to existing motor configuration.

References

Details on Z8 Encore! XP products, ZDS II, photo transistors and light emitting diodes are available in the references listed below:

- Z8 Encore! XP MCU:
  - Z8 Encore!® Flash Microcontroller Development Kit User Manual (UM0146)
  - Z8 Encore! XP® 64K Series Flash Microcontrollers Development Kit User Manual (UM0151)
  - Z8 Encore! XP® F0822 Series Flash MCU Development Kit User Manual (UM0150)
  - Z8 Encore! XP® 64K Series Flash Microcontrollers High Performance 8-Bit MCUs Product Specification (PS0199)
- eZ8 CPU — eZ8 CPU Core User Manual (UM0128)
- ZDS II-IDE — Zilog Developer Studio II–Z8 Encore!® User Manual (UM0130)
- Photo transistor — Phototransistor S2829 data sheet available on www.hamamatsu.com.
- Infrared light-emitting diode — IR LED XTH153W850 available on www.sunled.com.

Appendix A—Flowcharts

This appendix contains flowcharts associated with Z8 Encore! XP-based tachometer application described in this document.

Figure 5 displays the flowchart for the main routine.

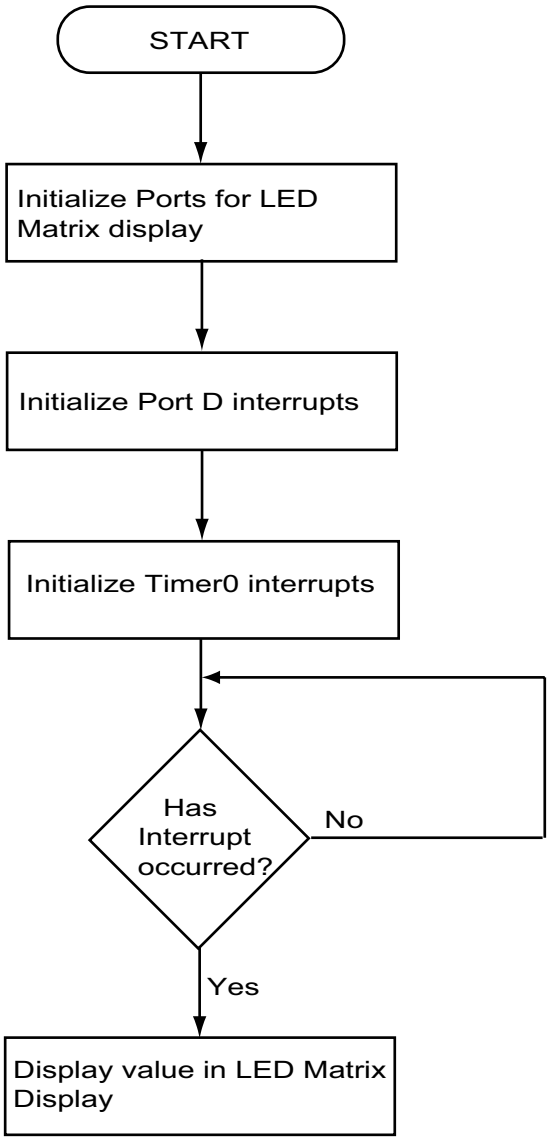


Figure 5. Main Routine

Figure 6 displays the flowchart for Port D interrupt routine.

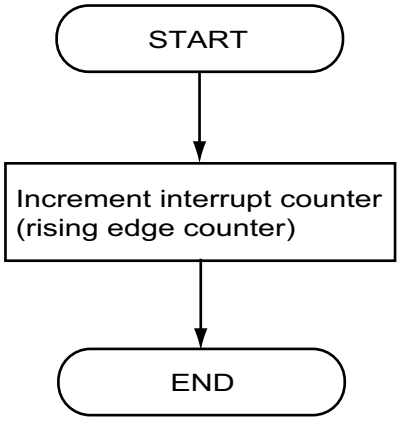


Figure 6. Port D Interrupt Routine

Figure 7 displays the flowchart for Timer0 interrupt routine.

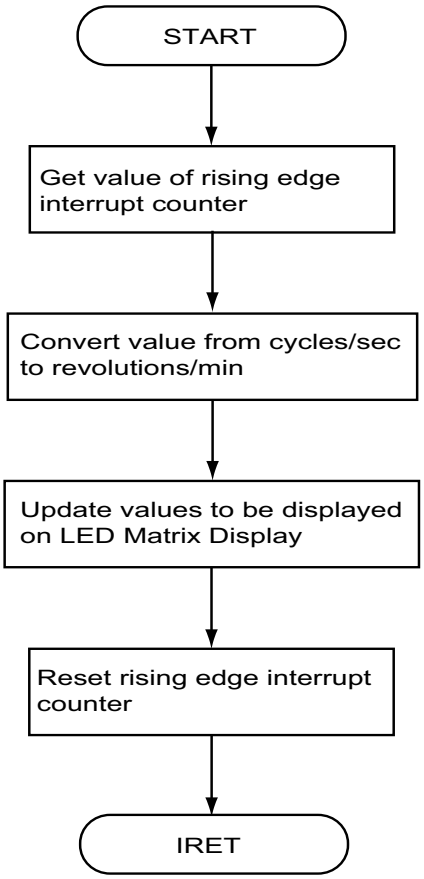


Figure 7. Timer0 Interrupt Routine

Appendix B—Alexan IR Emitting Diode

This appendix provides the data sheet for Alexan IR Emitting Diode used in Z8 Encore! XP-based tachometer application.

Infrared Emitting Diode

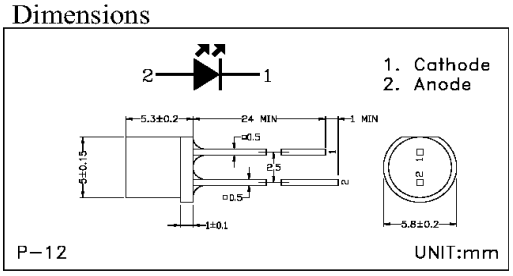
0-01-06-06

Module No.: IE-0575HLG

1. General Description:

IE-0575HLG is a high output power GaAlAs infrared light emitting diode, mounted in a clear epoxy end looking cylinder package. It emits narrow band of radiation peaking at 940nm.

Dimensions



2. Features

- Extra wide beam angle (±75°)
- Capable of pulse operation
- High output power
- ∅5mm cylinder package (Flat-head)
- Low cost

3. Absolute Maximum Ratings

(Ta=25°C)

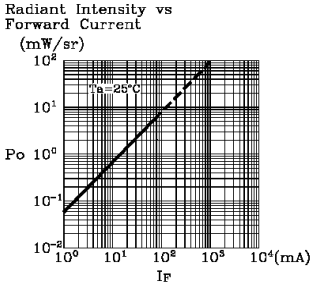
Parameter	Symbol	Ratings	Unit
Forward Current	I_F	100	mA
Pulse Forward current *1	I_{FP}	1	A
Reverse Voltage	V_R	5	V
Power Dissipation	P_D	100	mW
Operating Temperature	T_{opr}	-25 ~ +70	°C
Storage Temperature	T_{stg}	-30 ~ +80	°C
Soldering Temperature *2	T_{sol}	260	°C

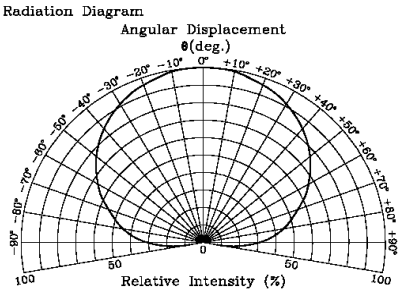
*1 Pulse width ≤ 100μsec. Time Cycle=10msec.
*2 At the position of 2mm from the bottom of the package within 5 seconds.

4. Electro-optical Characteristics

(Ta=25°C)

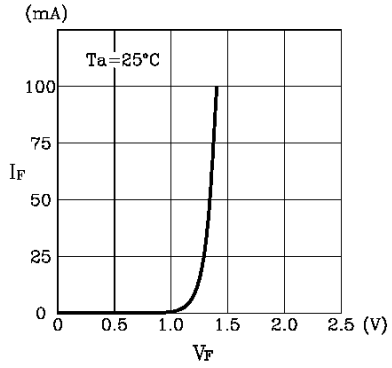
Parameter	Symbol	Testing Conditions	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F=100mA		1.4	1.7	V
Reverse Current	I_R	V_R=5V			10	μA
Radiant Intensity	Po	I_F=20mA	0.7	1.5		mW/sr
Terminal Capacitance	C_t	f=1MHz		20		pF
Half Power Beam Angle	Δθ			±75		deg.
Peak Emission Wavelength	λp	I_F=50mA		940		nm
Spectral bandwidth at 50%	Δλ	I_F=50mA		50		nm



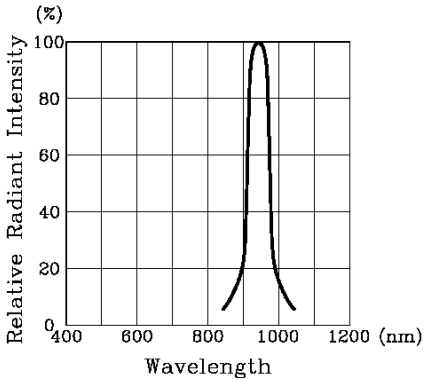


Module No.: IE-0575HLG

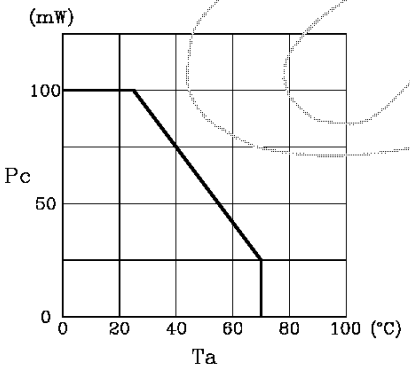
Forward Current vs
Forward Voltage



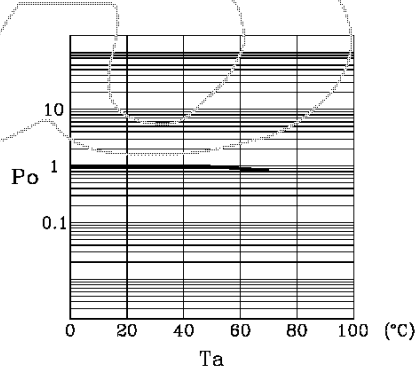
Spectral Distribution



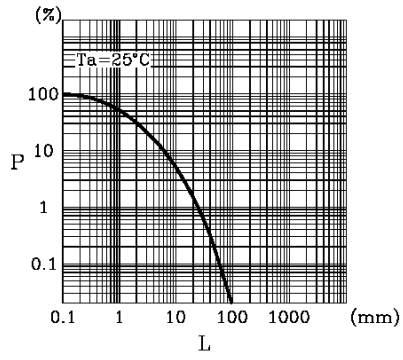
Power Dissipation vs
Ambient Temperature



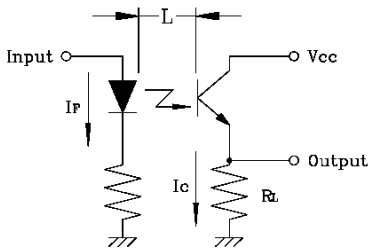
Relative Output power vs
Ambient Temperature



Relative Power vs
Distance to Detector



Distance to Detector Test Conditions



Appendix C—Alexan WPT- 440F IR Photo Transistor

This appendix provides data sheet for Alexan WPT-440F IR Photo Transistor used in Z8 Encore! XP-based tachometer application.

Photo Transistor

1-03-01-16

Module No.: WPT-440F

1. General Description:

The WPT-440F is a high sensitivity NPN silicon phototransistor mounted in a clear epoxy side looking package. It is compact, low profile and easy to mount.

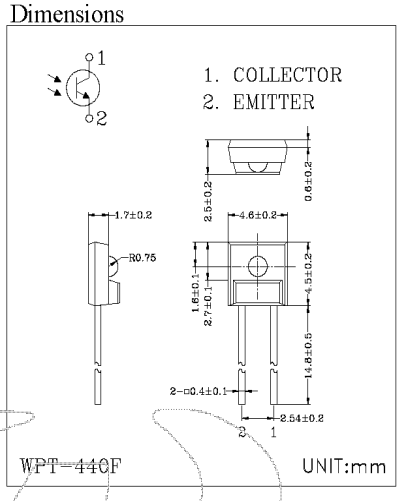
2. Features

- Compact
- Wide beam angle (±30°)
- Side looking package
- Capable of pulse operation
- Low profile
- Low cost

3. Applications

- Optical counters
- Optical detectors
- Flywheel counters

Dimensions



4. Absolute Maximum Ratings (Ta=25°C)

Parameter	Symbol	Ratings	Unit
Collector-Emitter Voltage	V_{CEO}	30	V
Emitter-Collector Voltage	V_{ECO}	5	V
Collector Current	I_C	40	mA
Collector Power Dissipation	P_D	100	mW
Operating Temperature	Topr	-20 ~ +75	°C
Storage Temperature	Tstg	-30 ~ +85	°C
Soldering Temperature *1	Tsol	240	°C

*1 At the position of 2mm from the bottom of the package within 5 seconds.

5. Electro-optical Characteristics (Ta=25°C)

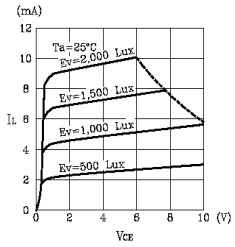
Parameter	Symbol	Testing Conditions	Min.	Typ.	Max.	Unit
Collector Light Current	Ic	V_{CE}=5V, Ev=1000Lux, (Ee=5mW/cm^2) *2	1.0	5.0	15	mA
Collector Dark Current	I_{CEO}	V_{CE}=10V, Ee=0 *2		1	100	nA
Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	Ic=0.5mA, Ev=2000Lux Ee=10mW/cm^2 *2		0.2	0.4	V
Peak Sensitivity Wavelength	λp			880		nm
Spectral Sensitivity	Δλ		500 ~ 1050			nm
Angular Response	Δθ			±30		deg.
Rising Response Time	tr	Vcc=10V, Ic=5mA, R_L=100Ω		3.2		μs
Falling Response Time	tf			4.8		μs

*2 Ev, Ee are illuminance irradiant by CIE standard light source A (tungsten lamp) at 2856K

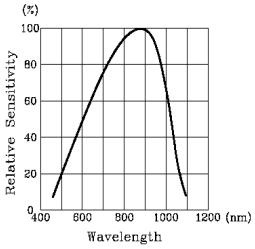
Photo Transistor

Module No.: WPT-440F

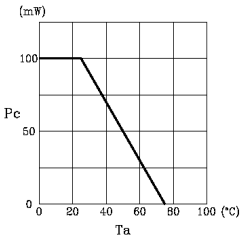
Light Current vs
Collector–Emitter Voltage



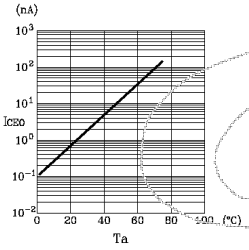
Spectral Sensitivity



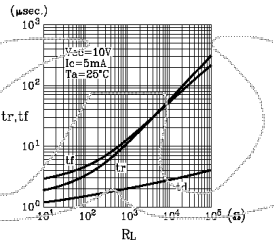
Power Dissipation vs
Ambient Temperature



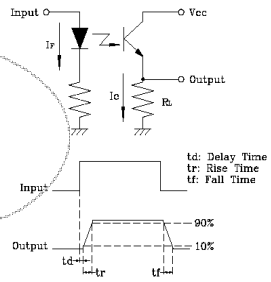
Dark Current vs
Ambient Temperature



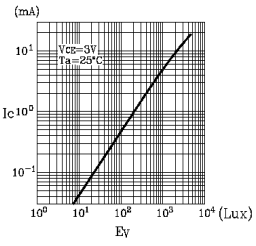
Response Time vs
Load Resistance



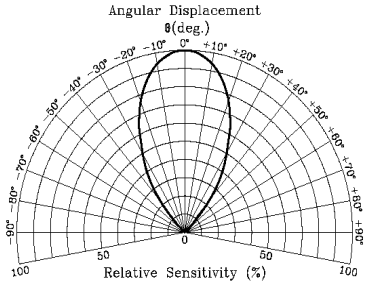
Response Time Test Conditions



Collector Current vs
Luminous Incidence



Sensitivity Diagram



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