Palestine Polytechnic University

College of Engineering and Technology

Mechanical Engineering department

Graduation Project:

"Design of Onboard Engine Brake Power Tester"

Project Team

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“Design of onboard engine Brake Power Tester”

Project Teem

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According to the directions of the project supervisor and by the agreement of all examination committee members, this project is presented to the department of mechanical engineering at college of engineering and technology, for partial fulfillment bachelor of engineering degree requirements.

Supervisor signature

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Committee member signature

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Department head signature

…………..........

Dedication

To whom love me ...

To my family ...

To my parents ...

To unknown love ...

To whom help me ...

To my family ...

To my parents ...

To unknown love ...

To whom respect us ...

To our family ...

To our parents ...

To our friends

To our love ...

To our supervisor Dr. Mohammad Qawasmi ...

To our Home land...

To the souls of Palestine martyrs ...

To the freedom captives ...

To whom their guidance's and supports made this work possible ...

Thabet Hashem Rjoub

Hany Mohammad Sabbar

شكر وتقدير

الشُكرُ للهْ أولاً وأخيراً، وبعد الله نتقدم بجزيل الشكر إلى مؤسستنا الرائدة جامعة بوليتكنك فلسطين وعلى رأسها كلية الهندسة والتكنولوجيا، وكذلك طاقم دائرة الهندسة الميكانيكية من ادارة ومدرسين.

ونتقدم بالشكرالجزيل الى الدكتور محمد غازي القواسمة مشرف المشروع . ولا ننسى الاستاذ المهندس حسين عمرو صاحب فكرة المشروع والداعم والموجه في الجانب التنفيذي للمشروع، وذوينا وزملائنا الطلبة في دائرة الهندسة الميكانيكية والى كل من ساهم في إتمام هذا العمل المتواضع بالشكل الذي هو عليه.

ونبعث بجزيل شكرنا ايضا لادارة وموظفي مركز فحص المركبات على وقوفهم ودعمهم في تطبيق المشروع عمليا.

Abstract

Society's growing demand for better, safer and economic vehicles has stimulated high interest in early fault finding especially in Engines and all associated systems which affect the performance of the engine and the power producing in it. For that we aimed in this project to build up an onboard engine brake power tester. This will give vehicle users the ability to know the level of produced power in their vehicles continuously in all operating conditions; this willhelp in early discovering faults and repair them. An electronic system designed to determine the angle of twist of driveshaft during power transmission and then computing the torque of driveshaft to convert it to power by specific equations. To build our system, we used all needed hardware components and software programs and interface them with each other, to completely achieve the system objectives in efficient way.

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1

Chapter One

Introduction

1.1. Overview.
1.2. Project Objectives and Motivation.
1.3. Approach.
1.4. Literature Review.

1.1 Overview:

Power which produced in the internal combustion engines is very important issue in automotive engineering and engine design characteristics, in vehicle advertisements, manufacturing companies never fail to mention the horsepower of the vehicle. The output power is directly proportional to heat of combustion per unit mass of fuel that pushes piston down due to high increasing in temperature and pressure inside the chamber. ***Power is defined commonly as the rate at which work is done***. In vehicles, power produced in engine represented as rotational torque which transfers by power train to driving wheels.

The proposed project "Design of onboard engine brake power tester" aims to measure and compute the power of the engine for rear wheel drive vehicles during all operating conditions, this device based on measuring the twist which occurs in the drive shaft of vehicle during engine and power transmission to drive wheels, and calculates the power to show it in a continuous manner in monitor in a dash board.

A device was built to keep the driver knowing the level of produced power from engine and to avoid sudden engine problems and be alerted about any degrading in engine operation.

1.2 Project Objectives and Motivation:

Everyday life, the technical disruption in engine occurs, when using "onboard engine brake power tester", the driver can predict engine faults soon after they occur, this operation is more convenient and more economy than discovering faults after period of time.

Main objectives of the project:

1. Measuring the toque of rotational shaft.
2. The power of the vehicle will be continuously monitored.
3. Early discovering and tracing faults which lead to power degrading.

1.3 Approach:

The Project requires extensive knowledge in torque and power measurements, especially when rotational part exists. It requires knowing the relation between transmitted torque and the angle of twist in the drive shaft during power transfer, and the relation between Torque, power and rotational speed.

According to the development in Programing and Technology, it is necessary to choose the best program which can be used to measure twist, and knowing how to interface it with Microcontroller.

A program was built to find out a relation between torque and angle of twist to find finally engines power produced. So physical quantity will be converted to signals produced by sensors to determine finally output brake power and keep it continually monitored.

1.4 Literature Review:

In general, two methods are used to measure power, both of them used the same principle by measuring the rotational shafts torque produced from engine, but advantages and disadvantages are existed. It can be divided into two methods as following:

1- Outboard method: by using Dynamometers.
2- Onboard method: by using some electronic components.

1.4.1 Outboard methods (Dynamometer system):

Dynamometers are useful in the development and refinement of modern engine technology. The concept is to use the Dynamometers to measure and compare power transfer at different points on a vehicle, thus allowing the engine or drivetrain to be modified to get more efficient power transfer.

1.4.1.1 Types of dynamometer systems:

A 'brake' dynamometer: it applies variable load on the Prime Mover (PM) and measures the PM's ability to move or hold the RPM as related to the "braking force" applied. It is usually connected to a computer that records applied braking torque and calculates engine power output as shown in figure 1.1 based on information from a "load cell" or "strain gauge" and a speed sensor.

An 'inertia' dynamometer: it provides a fixed inertial mass load, calculates the power required to accelerate that fixed and known mass, and uses a computer to record RPM and acceleration rate to calculate torque. The engine is generally tested from somewhat above idle to its maximum RPM and the output is measured and plotted on a graph.

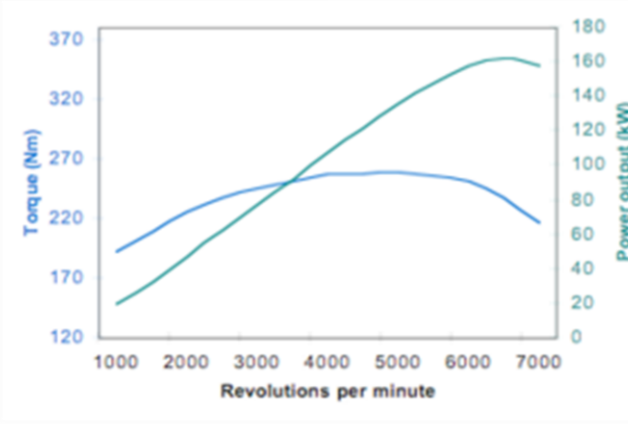

Figure 1.1 Engine performance

A 'motoring' dynamometer: it provides the features of a brake dynamometer system, but in addition, can "power" (usually with an AC or DC motor) the Prime Mover (PM) and allow testing of very small power outputs (for example, duplicating speeds and loads that are experienced when operating a vehicle traveling downhill or during on/off throttle operations).

1.4.1.2 Types of dynamometer test procedures

There are essentially 3 types of dynamometer test procedures:

1. **Steady state**: where the engine is held at a specified RPM (or series of usually sequential RPMs) for a desired amount of time by the variable brake loading as provided by the PAU (power absorber unit). These are performed with brake dynamometers.
2. **Sweep test**: the engine is tested under a load (i.e. inertia or brake loading), but allowed to "sweep" up in RPM, in a continuous fashion, from a specified lower "starting" RPM to a specified "end" RPM. These tests can be done with inertia or brake dynamometers.

3. **Transient test**: usually done with AC or DC dynamometers, the engine power and speed are varied throughout the test cycle. Different test cycles are used in different jurisdictions.

1.4.1.3 Engine dynamometer:

An engine dynamometer as shown in figure 1.2 measures power and torque directly from the engine's crankshaft (or flywheel), when the engine is removed from the vehicle. This dynamometer do not account for power losses in dynamometer do not account for the drivetrain, such as the gearbox, transmission, and differential.

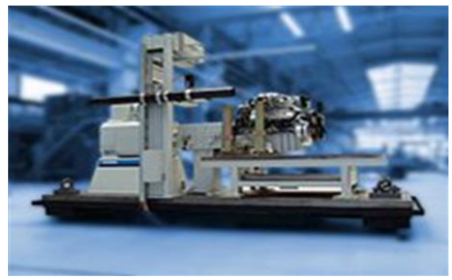

Figure 1.2: Engine dynamometer

1.4.1.4 Chassis dynamometer (rolling road):

A chassis dynamometer sometimes referred to as a rolling road, measures power delivered to the surface of the "drive roller" by the drive wheels. The vehicle is often parked on the roller or rollers, which the car then turns, and the output measured thereby.

Modern roller-type chassis dynamometer systems use the "Silverberg roller", which improves traction and repeatability, as compared to the use of smooth or knurled drive rollers. Chassis dynamometers can be fixed or portable, and can do much more than display RPM, horsepower, and torque. With modern electronics and quick reacting, low inertia dynamometer systems, it is now possible to tune to best power and the smoothest runs in real time

1.4.1.3 Disadvantages of Outboard method:

1- Dynamometers are typically very expensive pieces.

2-Normally only used in certain fields that rely on them for a particular purpose.

3-When Chassis dynamometer (rolling road) used, it measure the power which reached to wheels, without checking source of losses in engine or power train,[1].

1.4.2 Onboard methods:

They will measure the torque transmitted through the drive shaft. With this method, electrical components are being used generally, such as strain gauge, capacitive torsion bare and optical sensor which use reflectance change.

1.4.2.1 Strain gauge system:

Strain gauge circuit will measure the torque of rotational shafts by using change in the bridge circuit resistances mounted on the shaft as shown in figure 1.3. This can be accomplished using slip rings, wireless telemetry, or rotary transformers and bridge circuit. Newer types of torque transducers add conditioning electronics and an A/D converter to the rotating shaft. Stator electronics then read the digital signals and convert those signals to a high-level analog output signal, such as +/-10VDC.

Figure 1.3: strain gauge device

1.4.2.2 Capacitive torsion bare system:

Capacitive torsion bare System consists of a first and second induction member respectively mounted at the input and output end of the shaft and rotating together. The induction members are discs as shown in figure 1.4 or concentric cylindrical elements made as a conductive material. As the twist occurs at the shaft, it will change the capacitance of plates and torque can be determined.

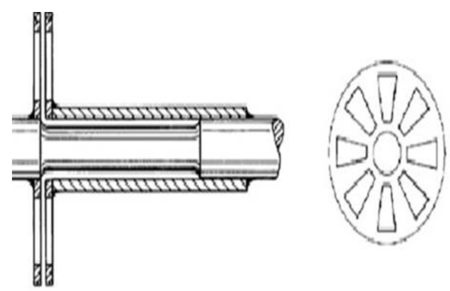

Figure 1.4: capacitive torsion bare

1.4.2.3 Optical sensor used reflectance change system:

The system includes a light source for emitting light along a light path; a reflection grating fixed to the shaft along the light path reflecting and diffracting the light as shown in figure 1.5, and the light detector having a plurality of light detecting element for receiving the reflecting and diffracted light. Torque in the shaft produces a change in the grating spacing of the grating, which in turn produces a change of diffraction angle of the reflected light, thereby causing different element of the light detector to receive the light.

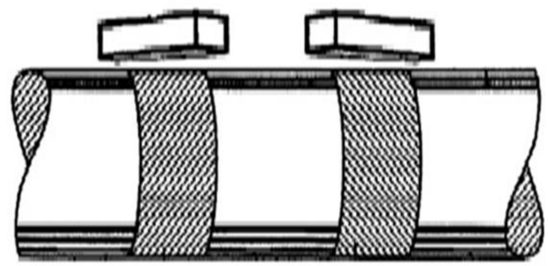

Figure 1.5: reflecting and drafting light

The microcontroller receives signals, and by calculates the difference between two signals, the twist angle will be determined and the torque can be calculated to find finally power in the shaft.

1.4.2.4 **Advantages of onboard method:**

1- More cheap than other methods.
2- Require few parts, as wires, strain gauge sensor and strain gauge transducer.
3- Can measure torque and power continually.

1.4.2.5 Disadvantages when using onboard method:

1. The use of strain gages and capacitive torsion bare mounted on the torque bar to measure twist angle becomes more difficult as the system rotational speed increases.
2. The slip rings or telemetry used to transfer the strain gage outputs, the wire routing.
3. Areas in terms of cost, reliability, maintenance.
4. Low accuracy,[2]**.**
5. Unable to use reflectance change when vibration exists.

2

Chapter Two

Mechanical System of onboard engine brake power tester

2.1 Introduction.
2.2 Power and Torque.
2.3 Engine power characteristics.
2.4 Transmission power.
2.5 Factors influencing output power of the engine.
2.6 Effects of engine size to power output.
2.7 How brake power will be measured in the project.

2.1 Introduction:

"Design of on board engine brake power tester" aims to measure and compute power which transmitted through power train in rear wheel drive vehicles by using two slotted discs mounted on drive shaft. A power train is a set of mechanical systems that transmit power and converted it to mechanical power, it will be transferred to the transmission, Then the transmission takes the power or *output* of the engine and through specific gear ratios, slows it and transmits it as *torque* through the driveshaft as shown in figure 2.1, the engine's torque is transmitted finally to the wheels and driving the vehicle, [3].

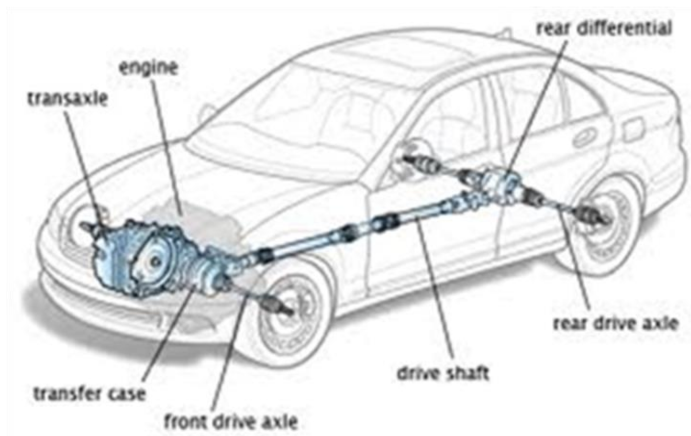

Figure 2.1: Flow of power in rear wheel drive vehicles

2.2 Power and Torque:

In vehicle, power produced in engine represented as rotational torque in drive train, when measuring torque, rotational speed must be mentioned too as shown in figure 2.2. It is essential to understand the concepts of Power and Torque because; it often seems that people are confused about the relationship between them.

$$Power = \frac{Torque\ x\ RPM}{5252} \quad \text{[horse power]} \ldots\ldots\ldots\ldots (2.1)$$

Torque: is defined as a force around a given point, applied at a radius from that point.

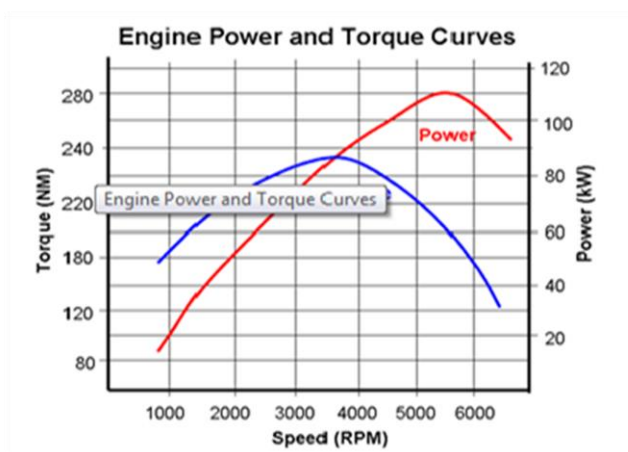

Figure 2.2 Engine power and torque curves

Power: is the measure of how much work can be done in a specified Time,[4].

2.3 Engine power characteristics:

Due to combustion of fuel inside the cylinder the temperature and pressure of gases increase to a high value. The high pressure gases push the piston down during its expansion stroke. As result of expansion of the gas, a part of the heat energy contained in the gas is converted to mechanical work and this work available on the piston. The network available on the piston can be measured by the pressure volume relation of the gas per cycle.

This work is called the indicated work of the engine. The fuel amount of work available in piston will not be available at output shaft of the engine. A part of it will be spent in overcoming mechanical losses. the mechanical losses include loss due to friction between piston rings and the cylinder, the loss due to friction on various bearing surfaces, power require to drive axillaries used as oil pump water pump, cooling fan, power to drive scavenging pump (two stroke engines) and supercharger (four stroke engines).the net power that is available at output shaft is brake power, [5].

The power engine expressed in three distinct terms:

1. Indicated power (ip).
2. Friction power (fp).
3. Brake power (bp).

2.3.1 Indicated power output:

The indicated output of an engine mainly depend on the heat of composition as the fuel put into the engine per unit time and the indicated thermal efficiency of the engine under working condition . Fuel input can be obtained if the fuel air ratio and the weight of fresh charge supplied to the engine is known. The weight of charge supplied per minute is obtained from cylinder size, rpm, inlet condition and volumetric efficiency of the engine under operating condition. Fuel air ratio at rated condition varies with the type of the engine.

Indicated thermal efficiency depends in fuel air ratio when optimum ignition timing or injection timing is used. It also changes with the cycle of operation of the engine.

Pi=ma × net work

ma   [kg/s].

Network   [kj/kg].

Pi (indicated power)   [kW].

Pi = indicated net work /cycle.

Indicated net work /cycle = *imep* × $V_{s.}$

$$\text{Pi} = \frac{\text{imep} * (\text{Ac} * \text{L}) * \text{n} * \text{N} * \text{k}}{\text{Z} * 60}$$

$$= \frac{\text{imep} * (Vc * \text{n}) * \text{N} * \text{k}}{\text{Z} * 60}$$

$$\text{So:} \quad \text{Pi} = \frac{\text{imep} * Ve * \text{N}}{\text{Z} * 60} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.2)$$

Where:

Pi = indicated power [kW].

imep = is the indicated mean effective pressure [N/m^2].

A_c = cylinder area [m^2].

L = stroke length [m].

n = number of cylinders per minute

N = engine speed [rpm].

K = number of engine cylinders.

z = 1 (for 2 stroke engines).

2 (for 4 stroke engines).

V_c = cylinder swept volume [m^3].

V_e = engine swept volume [m^3].

In order to determine the indicated output of an engine analytically the indicated thermal efficiency of the engine under operating condition must be known. The ratio of efficiency of an actual engine to that of theoretical air cycle having the same compression ratio and amount of heat added per cycle is used to evaluate the indicated thermal efficiency of the engine, [6].

2.3.2 Brake power:

The power which available at the output shaft of an engine and which can be utilized for doing external work is called the brake power of the engine. This power is less than the indicated power by the amount required overcoming all mechanical losses in the engine.

Mean effective pressure (that is the power per unit displacement volume) is commonly used to represent different forms of power of an engine. Similarly the mechanical losses of the engine can be expressed as mep_{mech}.

Brake thermal efficiency gives the degree of utilizations of heat supplied to an engine producing effective output or brake output. It is defined as the ratio of brake output per cycle to the heat energy supplied to the engine per cycle. Brake specific fuel consumption is also defined as the weight of fuel used to produce unit brake output per unit time, [7].

2.3.3 Frictional power:

Frictional Power represents the difference between the indicated power and brake power:

[Frictional power (fp) =indicated power (ip) – brake power (bp).]

The internal losses in an engine are divided to two kinds:

a. Pumping losses.
b. Frictional losses.

During the inlet and exhaust stroke the fuel pressure inside the piston is greater in its forward side (on down side during the inlet and on the upper side during the exhaust stroke), hence during both strokes the piston must be moved against a gaseous pressure this cause so called pumping losses.

The frictional loss is made because of friction between the piston and cylinder walls, piston rings and cylinder walls, in addition between the crankshaft and camshaft and their bearings, as well as by the losses incurred by driving the essential accessories, such as water pump, ignition unit system.

The designers usually aim to minimize loss of friction. Frictional power used when evaluates indicated power and mechanical efficiency,[8].

2.4 Transmission power:

Power from petrol or diesel reciprocating engine transfers in the form of torque, angular speed to the propelling wheels of the vehicle to produce motion, the object gearbox enable the engine's tuning effect and control rotational speed output to be adjusted by choosing a range of speeds under and over drive gear ratios so that the vehicle responds to the driver's requirements that related to roads situations.

Power to weight ratio:

When choosing lowest and highest gear ratio, most important factor will be considered, available engine power and weight of the vehicle.

The power developed per unit weight of laden vehicle is called "Power to weight ratio", [9]. Where:

$$\text{Power to weight ratio} = \frac{\text{brake power developed}}{\text{laden weight of vehicle}}$$

2.5 Factors influencing output power of the engine:

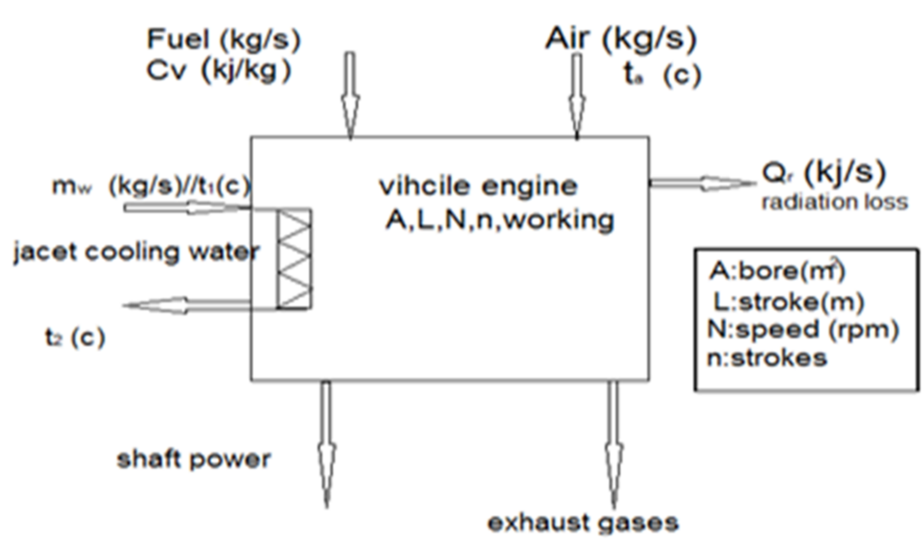

Figure 2.3 Engine diagram, [10].

2.5.1 Compression ratio:

The indicated thermal efficiency increases with increase in compression ratio .the rate of increment is influenced by the design of combustion chamber. But higher compression ratio reduces the period of ignition lag and result in smooth running of the engine with low cetane number fuel.

2.5.2 Engine design:

Engine design affects charging of the cylinder during admission, the heat loss from the combustion chamber and mechanical losses of engine. Increases size of manifold and valve and less restriction in in combustion chamber increase the volumetric efficiency of the engine. Reduce ratio of combustion chamber surface area to its volume decrease the heat loss and there for, increase the indicated thermal efficiency of the engine.

2.5.3 Fuel air ratio:

operation of petrol engine is generally stable with the rang of air coefficient within the rang 0.8 to 1.1 .the output of the engine is higher for the richer mixture range, but the indicated thermal efficiency is higher for the leaner mixture is possible only with higher value of compression ratio. When higher value of compression ratio is used with lean mixture an appreciable improvement in indicated thermal efficiency is obtained.

The indicated thermal efficiency of diesel engine increase with increase in air coefficient within the range 1.4 to 3.5 .in divided combustion chamber engine there some pressure less due to resistance to flow from one part of chamber to the other and high rate of heat loss at the connecting passage. This engine can work satisfactorily with low air coefficient (due to better fuel air mixing) and, therefore the losses are reduced to some extents,[10].

2.5.4 Speed:

In general, higher speed means more number of working cycle and there for, more power of the engine. With increase in speed, the intensity of turbulence increase in engine. If optimum ignition advance is selected for each speed the main phase of combustion is unaffected. At the same time at a higher speed, the heat loss per cycle is reduced due to less time being available for heat transfer and, there for, the indicated thermal efficiency increase near the higher limit of speed range commonly used (1500 – 4500 rpm). There is very little change in indicated thermal efficiency due to the influence of last phase of combustion.

Increase in speed in diesel engine will increase intensity of air motion, the effect of that is better atomization of fuel and produce higher temperature of charge at the time of injection. There for increasing in indicated thermal efficiency with speed.

2.5.5 Supercharger:

Supercharger increases the density of the charge at inlet and results in increase power output of the engine.

2.5.6 Heat transfer:

Heat loss from engine cylinder through the cooling medium as shown in figure 2.3 depends on several factors. The most important factor is temperature difference between the working fluid and the surface inclosing the fluid. The power output of the engine increase when decreasing heat losses. If the process of increase in cooling medium temperature is continued, the power output first increases, reaches maximum value and then start decreasing, [11].

In addition, there are some Defects causes a drop in power output in the vehicle, such as:

1- Disruption in piston rings and input, output valves.
2- Slipping occur from clutch in normal transmission system.
3- Slip occurs in automatic transmission clutches for automatic transmission system.
4- Drop in torque converter’s oil pump from automatic transmission system.
5- Degrading in oil pressure from automatic transmission.
6- In spark ignition system, Defects in spark plug that affected combustion process.

2.6 Effects of engine size to power output:

The engine size depends on bore (D) and stroke (L)

1- The piston Area:

If the cylinder bore is doubled, the piston area become four times. If mean effective pressure and engine speed are unchanged, the power output increases four times.

2- If the stroke length of an engine is doubled, keeping the engine bore unchanged, the power output is doubled.
3- The piston speed of an engine is doubled if the piston stroke is doubled, keeping the crankshaft speed constant. Therefore, for a given speed, the crankshaft speed can be halved by doubling the stroke.
4- Torque is equal to the product of piston thrust and crank-throw. By doubling cylinder diameter, piston thrust multiplies four times. The crank-throw doubles by doubling stroke. The torque would increase 8*(4*2) times if both cylinder diameter and piston stroke are doubled, [12].

2.7 How brake power will be measured in this project:

Indicated power is based on indicated network and is thus a measure of the force developed within the cylinder by combustion process. More practical interest is the rotational force available at the delivery point, at the engine crankshaft, and the power corresponding to it. This power is interchangeably referred as brake power. Brake power is the only term will be used in the project to indicate the power actually delivered by the engine.

Usually, the brake power measured by attaching a power absorption device to the drive shaft of the engine. Such a device sets up measurable force counteracting the force delivered by the engine, and the determined value of these absorption device measured indicative force of the forces being delivered.

2.7.1 Measuring torque under dynamic condition:

Measurement of torque under dynamic Condition, require measuring the quantity of twist angle on the drive shaft and then the parameters of the calculation for torque will be known from the drive shaft. It Require some mechanism attached to the shaft which activates an external electronic system of sensors to provide measurement of angle of twist produced in the drive shaft.

The device supported by two optical sensors, each sensor contain light source and light detector, either two slotted disks are disposed on a drive shaft with a known distance between the two disks, by measuring the relative position of the slots on the two disks with the detected light from the light source, an indication of the twist in the shaft can be obtained.

2.7.2 Physical analyses:

The amount of twist in the rotational shaft is directly proportional to the quantity of torque and to the shaft length. Thus:

$$\theta \propto T$$

$$\theta \propto L$$

Where: T: torque in the shaft (N.m).

θ: twist angle.

L: length of the shaft.

$$\theta = \frac{T*L}{J*G}$$

$$\text{So: } T = \frac{(\theta*J*G)}{L} \qquad \text{… ……………. …….} \quad (2.3)$$

Where: T: Torque applied.

L: Length of the shaft through which measure will be made.

J: Polar moment of inertia (constant for given shaft configuration).

$= \frac{\pi*c\hat{}4}{2}$ c: diameter of the shaft.

G: Torsional module (constant for a given homogenous material).

θ: Total angle of twist.

The sensors system measure θ as shown in chapter three, so the torque output become known

And:

$$P = T*\omega$$

Where: p: power output (w).

ω: angular velocity.

$\omega = \frac{2*\pi*N}{60}$ Where N: rpm for the drive shaft.

So, the Power Output becomes:

$$P = \frac{2*\pi*N*T}{60*1000} \quad (kW) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.4)$$

3

Chapter Three

Electronic System of onboard engine brake power tester

3.1 Introduction.
3.2 Electronics in vehicles.
3.3 Sensors.
3.4 Microcontroller.
3.5 Output screen.
3.6 How angle of twist will be measured by the proposed device.

3.1 Introductions:

In this chapter, electronic components used in the project will be described, and how each element will be employed in order to accomplish its aims. The circuit will be built to measure and compute the angle of twist which occurs in the drive shaft that lead finally to measure the brake power produced by engine.

3.2 Electronics in vehicles:

The electronic systems in modern cars and trucks under new scrutiny as regulators continue to raise daily, It would be easy to say the modern car is a computer on wheels, Even basic vehicles have at least 30 of these microprocessor-controlled devices, known as electronic control units, and some luxury cars have as many as 100.

These electronic brains control dozens of functions, including brake and cruise control and entertainment systems. Software in each unit is also made to work with others, and these systems are engineered to protect against the kind of false signals or electronic interference,[13].

1.5 Sensors:

A **sensor** is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument, it receives and responds to a signal when touched. *A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes,*[14].

3.3.1 Main Properties of sensors:

Three main properties of sensing systems needed to be known:

1- **Sensitivity:** how much the sensor's output changes when the measured quantity changes.

2- **Resolution:** The resolution of a sensor is *the smallest change it can detect in the quantity that it is measuring*. Often in a digital display, the least significant digit will fluctuate, indicating that changes of that magnitude are only just resolved. The resolution is related to the precision with which the measurement is made.

3- **Response Time:** This is the time the sensing system takes to display a change in the physical property it is measuring. It is often difficult to measure,[15].

1.5.2 Types of sensors used to measure rotational speed:

Many types of sensors can be used to measure the rotational speed for rotational shafts and the angle of twist for the shafts. All of them have advantages and disadvantage as follows:

3.3.2.1 Magneto-resistive sensor:

Rotational speed measurement using magneto-resistive sensors (MR-sensors) is achieved by counting ferromagnetic marks, such as teeth of a passive gear wheel or the number of magnetic elements of magneti-sedring. Beside magneto-resistive sensors also the inductive sensors and Hall-Effect sensors can be used for this task. However, the magneto-resistive effect offers some essential advantages which should be mentioned briefly.

First, the output signal level of a MR sensor does not vary with rotation speed, as it is the case in inductive sensor systems. Inductive sensors show a direct relation between the rotational speed and the output amplitude and therefore require sophisticated electronics to evaluate the large signal voltage range, especially in applications requiring low jitters.

MR-sensors, in contrast, are characterized by the fact that the sensor is static and the output signal is generated by the bending of magnetic field lines according to the position of the target wheel.

1.5.2.4.1 Advantages of Magneto-resistive sensor:

1. Low coast.
2. Small size

1.5.2.4.2 Disadvantages of Magneto-resistive sensor:

1. Self-heating
2. The output signal is sin-wave signal

1.5.2.5 Hall-effect sensors:

Hall-effect sensors offer a mix of features that make them the preferred solution to many speed-sensing problems. They operate over wide temperature ranges, are largely immune to dirt and contamination, and provide consistent performance over a variety of speeds, ranging from essentially zero to thousands of target features per second. Because their transducer elements can be integrated on the same silicon as the associated signal-processing circuitry, Hall-effect sensors can also be made for very low cost, and can be made highly resistant to electromagnetic interference.

The three major applications for Hall-effect speed sensing are magnet detection, vane sensing, and gear tooth sensing. Magnet detection is usually the simplest scheme to implement, and involves attaching a magnet to the rotating member. While it is possible to accomplish this with a single magnet, usually several magnets are employed in even pairs to present alternating north and south poles to the sensor. Another approach is to use a ring magnet that has a pattern of numerous north-south pole pairs magnetized into it.

Because magnet material is relatively expensive, another commonly used approach is vane sensing. In a vane sensor, a series of steel flags (the vanes) passes between a magnet and the Hall-sensor element, interrupting the sensed magnetic field. The use of a stamped target allows for great flexibility in mechanical mounting. In addition, vane sensors provide good timing accuracy and allow for meeting special timing requirements by using variously sized vanes on the target.

3.3.2.2.1 Advantages of using Hall-effect

1. Their flexibility in sensing a wide variety of targets.
2. Used for wide temperature range.

3.3.2.2.2 Disadvantages of using Hall-effect

1. Relatively high coast
2. Relatively require bigger size.

3.3.2.3 Optical sensor:

An optical sensor is a device that converts light rays into electronic signals. It measures the physical quantity of light and translates it into a form read by the instrument. Usually, the optical sensor is part of a larger system integrating a measuring device, a source of light and the sensor itself. This is generally connected to an electrical trigger, which reacts to a change in the signal within the light sensor.

When a phase change occurs, the light sensor acts as a photoelectric trigger, either increasing or decreasing the electrical output, depending on the type of sensor. The major importance to the proper use of an optical sensor is that it retains certain facets of measured properties. It must always remain sensitive to the property. To the same point, it must be insensitive to any other property. In addition, it cannot influence what measurement is normally being made. That is, it cannot alter the amount of light impacting the photoelectric property.

3.3.2.3.1 Operation:

An opt coupler contains a source (emitter) of light, almost always a near infrared light-emitting diode (LED), that converts electrical input signal into light, a closed optical channel (also called dialectical channel[7]), and a photo sensor, which detects incoming light and either generates electric energy directly, or modulates electric current flowing from an external power supply. The sensor can be a photo resistor, a photodiode, a phototransistor, a silicon-controlled rectifier (SCR) or a triac.

Because LEDs can sense light in addition to emitting it, construction of symmetrical, bidirectional opt coupler is possible. An optical solid state relay contains a photodiode opt coupler which drives a power switch, usually a complementary pair of MOSFETs. A slotted optical switch contains a source of light and a sensor, but its optical channel is open, allowing modulation of light by external objects obstructing the path of light or reflecting light into the sensor.

In the project an optical sensor as shown in figure 3.1 will be used because its reliability and its performance and resolution relating to its cost.

Figure 3.1: GP1A57HRJOOF

3.3.3 Advantages of sensors that used to measure rotational speed:

- It can accommodate new devices at any time.
- Very accurate.
- Small size.

3.3.4 Disadvantages of sensors that used to measure rotational speed:

- It can easily be set off and cause problem.
- Self -Heating.
- Expensive, [16].

3.4 Microcontrollers:

A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals, it designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, and it have many types in several shapes that get it the main part in electronic applications.

3.4.1 Programming a microcontroller:

Programming a microcontroller means to transfer the program from the compiler to the memory of the microcontroller, a compiler is software which provides an environment to write, test and debug a program for the microcontroller, the program for a microcontroller is generally written in C or assembly language. Finally the compiler generates a hex file which contains the machine language instruction understandable by a microcontroller, it is the content of this hex file which is transferred to the memory of the microcontroller, once a program is transferred or written in the memory of the microcontroller, it then works in accordance with the program.

In order to program a microcontroller we need a device called burner programmer, a programmer is a hardware device with dedicated software which reads the content of the hex file stored on the PC or the laptop and transfers it to the microcontroller to be burned, it reads the data of the hex file by connecting itself to the PC via a serial or USB cable and transfers the data to the memory of the microcontroller to be programmed in accordance with the protocols as described by the manufacturer in the datasheet.

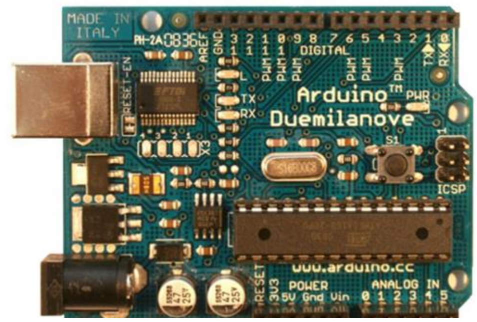

Figure 3.2: Arduiono microcontroller

2.4.2 Types of microcontrollers:

Two main types of microcontroller are being used in modern applications: pic and Arduino microcontroller.

3.4.2.1 Arduino microcontroller:

Arduino as shown in figure 3.2 is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.

Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can be communicating with software running on your computer. The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free. The Arduino programming language is an implementation of Wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment.

3.4.2.1.1 Hardware:

An Arduino board consists of an Atmel 8-bit AVR microcontroller with complementary components to facilitate programming and incorporation into other circuits. An important aspect of the Arduino is the standard way that connectors are exposed, allowing the CPU board to be connected to a variety of interchangeable add-on modules known as shields.

Some shields communicate with the Arduino board directly over various pins, but many shields are individually addressable via an I²C serial bus, allowing many shields to be stacked and used in parallel. Official Arduinos have used the megaAVR series of chips, specifically the ATmega8, ATmega168, ATmega328, ATmega1280, and ATmega2560. A handful of other processors have been used by Arduino compatibles. Most boards include a 5 volt linear regulator and a 16 MHz crystal oscillator (or ceramic resonator in some variants), although some designs such as the LilyPad run at 8 MHz and dispense with the onboard voltage regulator due to specific form-factor restrictions. An Arduino's microcontroller is also pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory, compared with other devices that typically need an external programmer.

3.4.2.1.2 Advantages of arduino:

- High accuracy.
- Require low Knowledge than other microcontroller

3.4.2.1.3 Disadvantages of arduino:

- Relatively expensive in our country.

3.4.2.2 The PIC chip microcontroller:

Microchip’s microcontrollers are commonly called PIC chips. Microchip uses PIC to describe its series of PIC microcontrollers. Although it is not specifically defined, the word PIC is generally assumed to mean programmable interface controller.

3.4.2.2.1 Why PIC chip better than other stamps:

1-Faster speed: the programed PIC chip will run 20 to 100 times faster, depending upon instructions used than the basic stamps runs.

2-Lower cost: using the PIC chips directly will save you 75 percent of the cost of comparable basic stamps, and also smaller than others.

In the project, pic 18f4550 as shown in figure 3.3 will be used, because its availability and its cost in addition it accomplish the desired work,[17].

Figure 3.3: Pic 18f4550

3.4.2.2.2 PIC programing overview:

Programing PIC microcontroller is a simple three-step process:

1- Write the code.
2- Compile the code.
3- Upload the code into microcontroller. [18]

3.4.3 Advantages of Microcontrollers:

1. Cheap in manufacture.
2. Small size.
3. Used widely in electrical applications.

3.4.4 Disadvantages of microcontrollers:

1. Speed: If a response needed to an input in less than a few microseconds, then hardware is pretty much the only way to go.
2. Complex.
3. Heat will be dissipated, [18].

3.5 Output screen:

An output screen is a device used to display output. This could be a separate monitor or other display device used only to display the output being received from the computer or other device,[18].

3.6 How angle of twist will be measured by the proposed device:

In the project, two optical sensors which have light source and light detector and two discs which fixed on a drive shaft will be used. Slots will be designed in the periphery of the discs at the same number and the same line, which mounted at the shaft with a known distance between them, and the sensors will be mounted stationary with respect to the shaft and proximate the periphery of the disc by using a preferred link that they fixed on it.

When such slot passes approximate the source and detector in disc 1, a signal will be generated, the same will occur in the second disc. The two signals will be entered to a pic microcontroller, by calculating phase shift between two phases outputs from sensors as shown in figure 3.4, the angle of twist shown in figure 3.5 will be found by the relation:

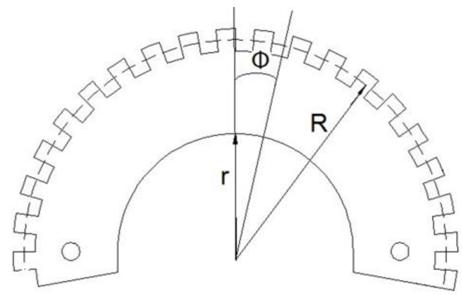

Figure 3.4: Disc designation

$$\text{Phase shift} = R * \Phi.$$

So: $$\Phi = \frac{\text{"phase shift"}}{R}$$

And $$X = \Phi * r$$

$$\theta = \frac{x}{l} = \frac{\Phi * r}{l}$$

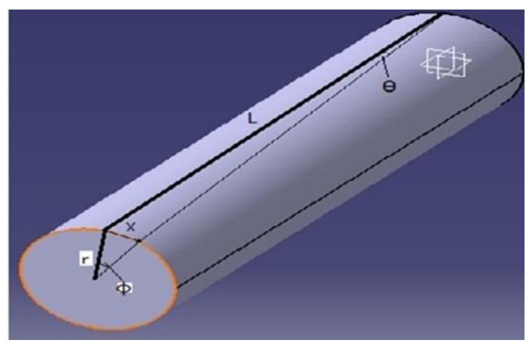

Figure 3.5: Representation of phase shift in drive shaft

Where:

θ: twist angle formed from distance between two discs.

R: radius of disc without gap. (Gap is the distance between sensor light point and tangent of disc)

X: shift distance formed at radius R.

r: radius of drive shaft.

Φ: phase angle.

L: distance between two discs.

So: the angle of twist becomes known.

And From chapter 2. Equation (2.3):

$$\theta = \frac{T*L}{J*G}$$

$$\text{So: } T = \frac{(\theta*J*G)}{L}$$

To find the rotational speed of the drive shaft, it must know the number of slots, then:

$$rpm = \frac{\text{nomber of slots passes at a minut}}{\text{nomber of slots formed at a disc}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.1)}$$

And for equ (2.4): P = T*ω

$$\omega = \frac{2*\pi*\text{rpm}}{60} \quad .$$

$$P = \frac{2*\pi*\text{rpm}*T}{60*1000} \quad \text{(kW)}$$

$$P = \frac{p\ (kw)}{746} \quad \text{(horse power)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots \text{(3.2)}$$

This brake power will be represented finally onboard by a monitor in the dashboard which receives its data from microcontroller. When fault occur in engine or in any sub system in engine, the output brake power will be gradually reduced and the driver will discover the fault and will heat it.

4

Chapter Four

Testing, Implementation and programing

4.1 Introduction.
4.2 Implementation.
4.3 Procedures for testing power when the project has been implemented on vehicle.
4.4 Operational steps.
4.5 Physical analyses of the project.
4.6 Programing pic 18f4550 microcontroller.

4.1 Introduction:

This chapter is about how the proposed system will be incorporated to the vehicle drive line. The drive shaft and sensors are being prepared, and discs were designed.

4.2 Implementation:

Design of on-board engine brake power tester which compute power transmitted through a drive shaft consist of two slotted discs mounted at each ends of the shaft and rotating for with. The slots are equal, each disc have outer diameter of 100 mm and inner diameter of 53 mm consist of (36) slot for each one. Each slot is at the same line to a slot in the other disc as shown in figure 4.1, a light emitter and receiver sensors are mounted stationary to the periphery of the disc.

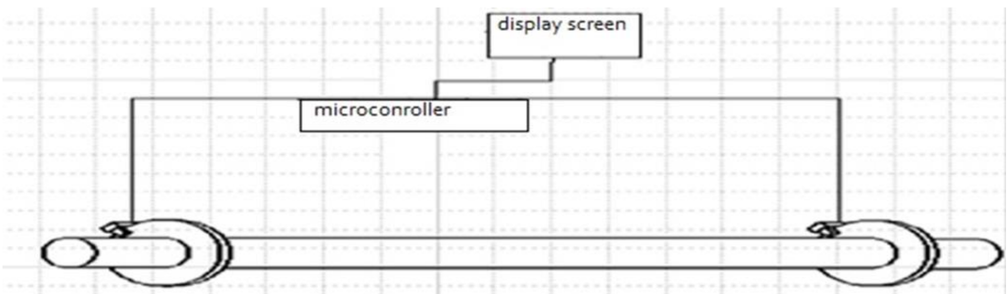

Figure 4.1: Simple design for the project

When the slot passes proximate the sensor on the disc, a signal will be generated. Two signals generated by the sensors describe the situation of the sensors.

When a twist occurs in the drive shaft, the time deviation between the pulses will be measure and the angular deviation between discs can be calculated. Measurements of the deviation time and rotational speed determine the amount of twist on the drive shaft that produced between the discs; after that torque can be calculated using equation (2.3):

$$T = \frac{(\theta * J * G)}{L}$$

Where:

$$J = \frac{\pi * (0.0508)^4}{2} - \frac{\pi * (0.046)^4}{2} = 3.43 * 10^{-6}\ mm^4.$$

G: will be assumed as a steel shaft and equal 75 Gpa (because it is unknown).

L = 56 cm (the distance between two discs with constant diameter of the shaft).

To find brake power of the engine, the rotational speed for the shaft will be measured by one of the two sensors, and by using equation (2.4):

$$P = \frac{2*\pi*N*T}{60*1000} \quad (kW)$$

$$P = \frac{p\ (kw)}{746} \quad \text{(horse power) .... (3.2)}$$

4.3 Procedures for testing power when the project has been implemented on vehicle:

The project has been implemented on an engine mounted on a bench, but when it is applied actually on a vehicle, it should be offer some important procedure for the driver when testing engine power to ensure that operational engine conditions are right.

1- Ensure that there is a fuel in the tank.
2- Ensure that the system button switch is on.
3- For normal transmission, choose the first gear ratio, this needed to get maximum torque of engine.
4- For automatic transmission, choose first gear to get maximum torque.
5- It is preferable to choose some rode grade to keep minimum speed with maximum torque produced.
6- Ensure that air-conditioning pump and power steering pump in off condition.
7- For full accelerator pedal, recognize the reading of the power screen.

The driver will see that the output power is constant at all operating conditions when accelerator pedal is full and when the engine operation is right. If power tested daily, the drive can predict his vehicle's power, as the fault occur in engine, the power of a vehicle will be degrading and the drive can predict this fault early before sudden problem done.

4.4 Operational steps:

As mentioned before, The project has been implemented on an engine mounted on a bench, the engine operates without gear box, in the other side we use a hydraulic dynamometer to make load instead of wheels and surface conditions and to find out an actual torque that produced by the engine with variable speeds.

4.4.1 First running test:

For the first test of operation, the drive shaft connected to the flywheel by a Flange with four screws and four screws flange to the dynamometer. The connecting flanges placed at the center of flywheel and dynamometer as shown in figure 4.2, but when the engine running, huge amount of vibration are being produced at idle speed and decreases when increasing the speed of engine because of centrifugal force with unbalance rotating shaft.

Figure 4.2: Connection of drive shaft in each side

After stopping engine, the connecting screws were noted untightened. The first decision is that because of clearance between the heads outer diameter of the shaft and inner diameter of the flanges, so; by using Turning process, clearance being removed by turning a steel ring between outer surface of heads and inner flange surface.

The shaft is being connected again and the engine running, but vibration still the same until the flywheel screws being damaged and the drive shaft end with dynamometer side being damaged too as shown in figure 4.3, because of centrifugal force produced by high speed rotation with unbalance shaft.

Figure 4.3: Damaged drive shaft ends and flywheel screws

The drive shaft, like any other rigid tube, has a natural vibration frequency. This means that if one end of the tube were held tightly, the tube would vibrate at its own frequency when it rotates. It reaches this natural frequency at its critical speed. The critical speed of a drive shaft depends on the diameter of the tube and the length of the drive shaft. Drive shaft diameters are as large as possible and shafts as short as possible to keep the critical speed frequency above the normal driving range.

Causes of vibration may be due to:

1. A drive shaft that used has only one universal joint.
2. No sliding joint exist.
3. The engine and dynamometer are not at the same line.

4.4.1.1 Sliding yoke joint:

Drive shafts use a slip (sliding) joint at one end of the drive shaft, which allows it to lengthen or shorten. The purpose of the slip joint is similar to the plunging CV joint used in FWD cars. The slip yoke as shown in figure 4.4 is positioned at the center of two-piece designs or at end of the drive shaft, but is typically fitted to the front U-joint.

Figure 4.4: Yoke sliding joint

4.4.1.2 Single Universal joint:

The single Universal joint as shown in figure 4.5 primary purpose is to connect the two yokes that are attached directly to the drive shaft. The joint assembly forms a cross, with four machined points equally spaced around the center of the axis. Needle bearings used to reduce friction and provide smoother operation are set into bearing cups.

Figure 4.5: Single universal joints

Unfortunately; another drive shaft must be used and a new flanges with different dimensions two.

4.4.2 Second running test:

In second running test, drive shaft consisting two parts with sliding yoke joint between them and three universal joints exist. To connect shaft to flywheel side, flange as shown in figure 4.6 has been designed, and flange as shown in figure 4.7 has been designed to connect the other shaft to hydraulic dynamometer.

Figure 4.6: Flange to connect the shaft to flywheel

The drive shaft consists of mounting bearing joint that joints the drive shaft bearing to the body of the vehicle. In the project the mounting joint has been fixed to the bench that mounts the engine.

Figure 4.7: Flange to connect the shaft to dynamometer

After the shafts have been connected again, the engine has been running, and with variable speeds of engine without load in dynamometer, we made sure that there is no vibration occurs in the shaft. The slotted discs have been fixed to each ends of the longer drive shaft, and the PM-T54 optical sensors fixed to the body of the bench approximated to the slots of the discs. A thin layer of rubber has been used between the discs and drive shaft to reduce slip between them as possible.

4.4.3 Third running test:

Third running test has been implemented after the discs fixed on the drive shaft, and the sensors fixed a proximate to the discs, while the sensors are being connected to the pic circuit. In this test a PM-T54 optical sensor with 1KHZ has been used.

This test aims to check if the sensor has the ability to read the drive's shaft signals when it rotates at 2500 rpm, but when operating the engine and when the shaft rotates with approximately 2500 rpm, the sensor could not read this frequency, because the frequency of the sensor is less than the frequency of the shaft at 2500 rpm. So, sensor with higher frequency must be used.

4.4.3.1 Finding the frequency of the shaft at 2500 rpm:

As mentioned before, the discs have 36 slots, this mean 36 periods for one revolution. To find the frequency of the shaft at 2500 rpm, it require firstly finding number of revolution per second.

@ 2500 rpm

Number of revolution per second= $\frac{2500 \text{ rpm}}{60 \text{ s}}$ = 41.666 rps.

Each revolution has 36 periods. So:

Number of periods per second= 41.666 * 36

= 1500 period/second.

To find the time require for one period to pass through the sensor:

Time for one period= $\frac{1}{1500}$

= $0.66 * 10^{-3}$ s.

= 0.66 ms.

Now, the frequency of the shaft @2500 rpm= $\frac{1}{0.66*10^{-3}}$

= 1500 Hz

= 1.5 KHz

This is the frequency of the drive shaft when it rotates at 2500 rpm. And the frequency of the PM-T54 optical sensor is **1KHZ** from its data sheet. So, another optical sensor with higher frequency must be used.

In the project, to ensure that the sensor has the ability to read the signal with high resolution, an optical sensor with a frequency of ten times the frequency of the drive shaft when it rotate at

2500 rpm should be used, so a GP1A57HRJOOF optical sensor will be used for a frequency of 0.3 MHz.

4.5 Physical analyses of the project:

As mention before the principle of finding the twist angle in the drive shaft is firstly finding the phase shift between two discs. Each signal measured by sensors has been entered to the microcontroller as a squared wave signal as shown in figure 4.8, and it's represented as time of each slot in microcontroller. When the shaft rotates without load, the waves entered to the micro controller are the same without shift as shown in figure 4.9.

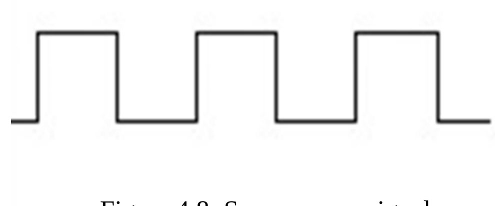

Figure 4.8: Square wave signal.

As a twist angle occur, phase shift between two signals being occur as shown in figure 4.10. And by finding deviation time between two signals; we find the phase shift as a time shift between two discs.

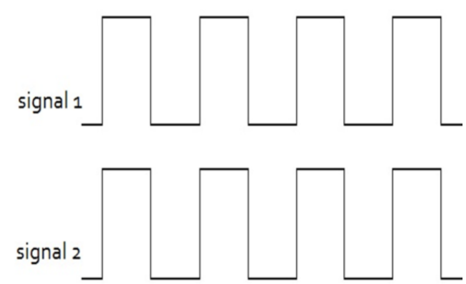

Figure 4.9: Signals of sensors without shift.

But, the phase shift must be phase distance between two discs, so by the equation:

$$speed\left(\frac{m}{s}\right) = \frac{\text{distance(m)}}{\text{time(s)}}$$

So: distance= speed*time

And:

$$\text{Phase shift (distance)} = \frac{2*\pi*\text{rpm}}{60*1000} * phasetime(s)$$

$$\text{"Phase shift"}=R*\phi$$

$$\Phi= \frac{\text{"}2\pi*rpm*phase\ time\text{"}}{R*60*1000}$$

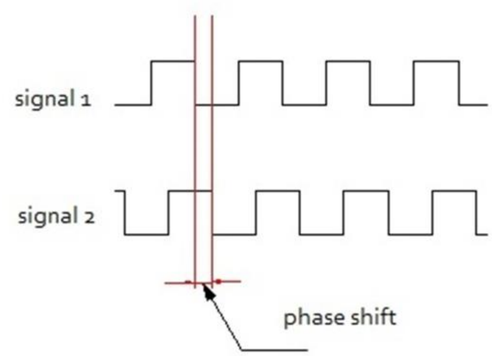

Figure 4.10: Signals of sensors with shift

And: $X = \Phi * r = \frac{2\pi * rpm * phase\ time * r}{R*60*1000}$

Then: $\theta = \frac{x}{l} = \frac{2\pi * rpm * phase\ time * r}{l*R*60*1000}$

By substituting values of R, r and L:

$\theta = 0.000099 * phase\ time * rpm$

And: phase time and the rotational speed (n) are measured by sensors, so the value of θ becomes known.

Now: $T = \frac{(\theta * J * G)}{L} = \frac{0.000099*3.43*10^{-6}*75*10^{9}*phase\ time*rpm}{56*10^{-2}}$

$= 0.0004547 * phase\ time(s) * rpm$

Then: Power = $T*\omega = 0.0004547*phase\ time\ (s) * rpm * \frac{2*\pi*rpm}{60*1000}$

$= 4.7591 * 10^{-8} * rpm^{2} * phase\ time\ \ (kw).$

$$Power\ (horse\ power) = \frac{4.7591 * 10^{-8} * rpm^{2} * phase\ time\ \ (kw)}{746}$$

4.6 Programing pic 18f4550 microcontroller:

To determine the angle of twist that occurs between slotted discs, the program has been built to find firstly the duration time required for each slot. So, each signal interference on a timer inside pic microcontroller. As a twist occurs, there is a difference in time duration for two signals in the final slot. To find this time the program built as shown below:

```
unsigned time_1;

unsigned time1;
```

```
unsigned time_2;
unsigned time2;
char txt_time1[11];
char txt_time2[11];
void showdata()
{
LongWordToStrWithZeros(time1, txt_time1);
LongWordToStrWithZeros(time2, txt_time2);
Lcd_Out(1,1,txt_time1);          // Write text in first row
Lcd_Out(2,1,txt_time2);
}
void main()
{
OSCCON=0x72;
trisb=0;
trisc=255;
trisa=255;
trisd=255;
porta=0;
portb=0;
portd=0;
portc=0;
delay_ms(100);
Lcd_Init();                // Initialize LCD
Lcd_Cmd(_LCD_CLEAR);           // Clear display
Lcd_Cmd(_LCD_CURSOR_OFF);        // Cursor off
```

```
while(1)

{

if(rd0_bit==0){time_1++;delay_us(1);}

else{time1=time_1;time_1=0;}

if(rd1_bit==0){time_2++;delay_us(1);}

else{time2=time_2;time_2=0;}

showdata();

}

}
```

After determining the duration time between two output sensors, the program has been continued to calculate the power produced in engine as shown below:

```
phase=time_1-time_2;

rpm1=(time_1*36)/60;

POWER=0.00297319 *phase* rpm1 * rpm1 ;
```

The program did not test because the GP1A57HRJOOF optical sensor did not exist in Palestine and for some obstacles we cannot test and operating our project to get real results.

4.7 Conclusion:

Power which produced in the internal combustion engines is very important issue in automotive engineering and engine design characteristics. The proposed project “Design of onboard engine brake power tester” aims to measure and compute the power of the engine for rear wheel drive vehicles during all operating conditions.

This device based on measuring the twist which occurs in the drive shaft of vehicle during engine and power transmission to drive wheels, and calculates the power to show it in a continuous manner in a monitor in a dash board.

The project has been implemented on an engine mounted on a bench. The mechanical system consists of a drive shaft which connected between diesel engine and hydraulic dynamometer, and a slotted discs which mounted on a shaft is already done taking into account the disposal of vibrations in the drive shaft.

An electronic circuit consisting of pic microcontroller has been built with appropriate program to measure and calculate the twist angle to find finally the brake power of engine, but the program did not tested because of some obstacles that will be mention below.

While we got the last stage of operating the device, we faced several obstacles in the operation of the project in its final form. An optical sensor with high frequency is not available in Palestine, so we looked for it in neighboring countries but after several delays by electronic companies through where we tried to purchase the needed sensor, they told us that it’s impossible to find this type of sensor as soon as needed.

So, unfortunately; the device has not been operated or tested, but in the future we hope that this project can be finished and operated by other mechanical engineering students in Palestine polytechnic university.

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Appendix

PIC18F2455/2550/4455/4550

28/40/44-Pin High-Performance, Enhanced Flash USB Microcontrollers with nanoWatt Technology

Universal Serial Bus Features:

- USB V2.0 Compliant SIE
- Low-speed (1.5 Mb/s) and full-speed (12 Mb/s)
- Supports control, interrupt, isochronous and bulk transfers
- Supports up to 32 endpoints (16 bidirectional)
- 1-Kbyte dual access RAM for USB
- On-board USB transceiver with on-chip voltage regulator
- Interface for off-chip USB transceiver
- Streaming Parallel Port (SPP) for USB streaming transfers (40/44-pin devices only)

Power Managed Modes:

- Run: CPU on, peripherals on
- Idle: CPU off, peripherals on
- Sleep: CPU off, peripherals off
- Idle mode currents down to 5.8 µA typical
- Sleep current down to 0.1 µA typical
- Timer1 oscillator: 1.1 µA typical, 32 kHz, 2V
- Watchdog Timer: 2.1 µA typical
- Two-Speed Oscillator Start-up

Flexible Oscillator Structure:

- Five Crystal modes, including High-Precision PLL for USB
- Two External RC modes, up to 4 MHz
- Two External Clock modes, up to 40 MHz
- Internal oscillator block:
  - 8 user selectable frequencies, from 31 kHz to 8 MHz
  - User tunable to compensate for frequency drift
- Secondary oscillator using Timer1 @ 32 kHz
- Fail-Safe Clock Monitor
  - Allows for safe shutdown if any clock stops

Peripheral Highlights:

- High current sink/source: 25 mA/25 mA
- Three external interrupts
- Four Timer modules (Timer0 to Timer3)
- Up to 2 Capture/Compare/PWM (CCP) modules:
  - Capture is 16-bit, max. resolution 6.25 ns (T_{CY}/16)
  - Compare is 16-bit, max. resolution 100 ns (T_{CY})
  - PWM output: PWM resolution is 1 to 10-bit
- Enhanced Capture/Compare/PWM (ECCP) module:
  - Multiple output modes
  - Selectable polarity
  - Programmable dead-time
  - Auto-Shutdown and Auto-Restart
- Addressable USART module:
  - LIN bus support
- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI™ (all 4 modes) and I²C™ Master and Slave modes
- 10-bit, up to 13-channels Analog-to-Digital Converter module (A/D) with programmable acquisition time
- Dual analog comparators with input multiplexing

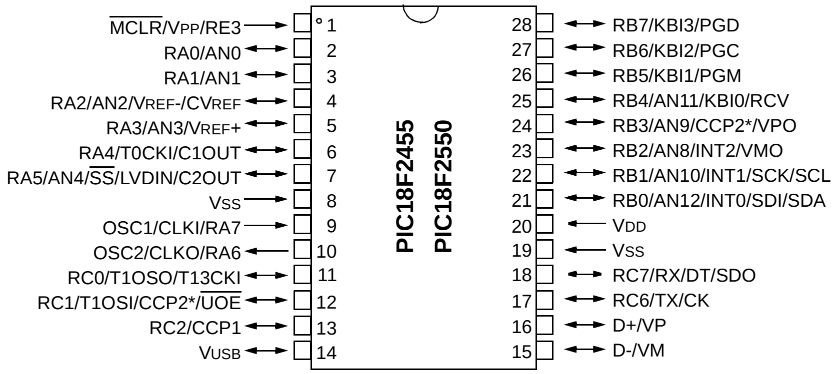
Special Microcontroller Features:

- C compiler optimized architecture with optional extended instruction set
- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle data EEPROM memory typical
- Flash/data EEPROM retention: > 40 years
- Self-programmable under software control
- Priority levels for interrupts
- 8 x 8 Single Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Programmable Code Protection
- Single-supply 5V In-Circuit Serial Programming™ (ICSP™) via two pins
- In-Circuit Debug (ICD) via two pins
- Wide operating voltage range (2.0V to 5.5V)

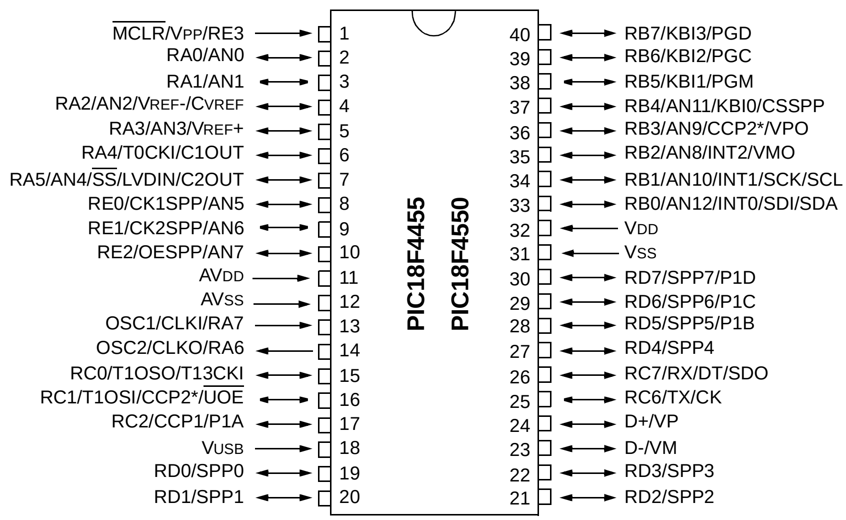
Device	Program Memory		Data Memory		I/O	10-bit A/D (ch)	CCP/ ECCP (PWM)	SPP	MSSP		EAUSART	Comparators	Timers 8/16-bit
	FLASH (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI	Master I^2C			
PIC18F2455	24K	12288	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F2550	32K	16384	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F4455	24K	12288	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3
PIC18F4550	32K	16384	2048	256	35	13	1/1	Yes	Y	Y	1	2	1/3

Pin Diagrams

28-Pin SDIP, SOIC



40-Pin PDIP

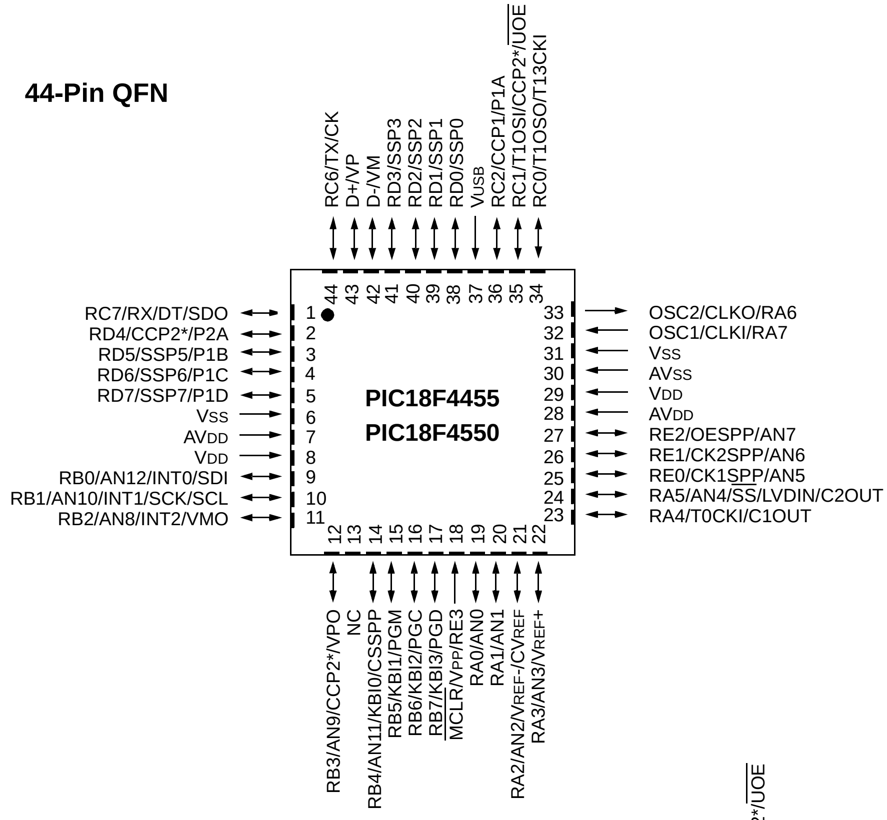


Note: Pinouts are subject to change.

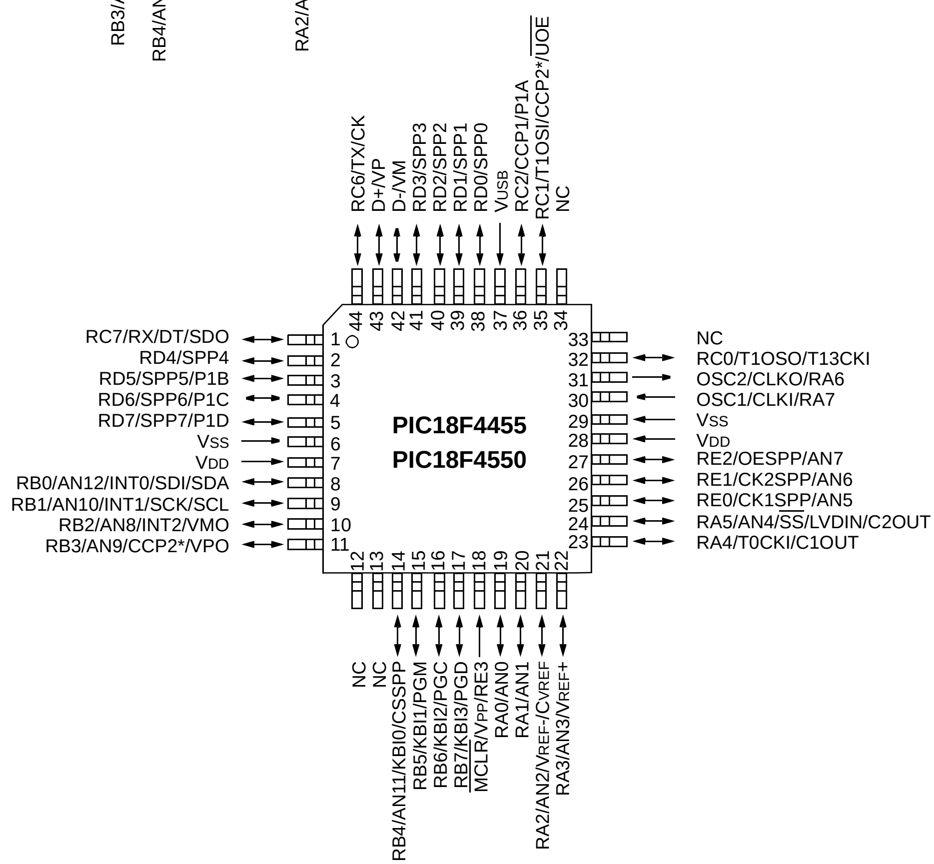
* Assignment of this feature is dependent on device configuration.

Pin Diagrams (Continued)

44-Pin QFN



44-Pin TQFP



Note: Pinouts are subject to change.

* Assignment of this feature is dependent on device configuration.

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07/28/03

GP1A57HRJ00F

Gap : 10mm, Slit : 1.8mm *OPIC Output Case package Transmissive Photointerrupter

■ Description

GP1A57HRJ00F is a standard, OPIC output, transmissive photointerrupter with opposing emitter and detector in a case, providing non-contact sensing. For this family of devices, the emitter and detector are inserted in a case, resulting in a through-hole design.

This device has a wide gap.

■ Features

1. Transmissive with OPIC output
2. Highlights :
   - Vertical Slit for alternate motion detection
   - Output Low Level at intercepting optical path
   - Wide gap width (10mm)
   - Positioning Pin to prevent misalignment
3. Key Parameters :
   - Gap Width : 10mm
   - Slit Width (detector side) : 1.8mm
   - Package : 18.6×15.2×5mm
4. Lead free and RoHS directive compliant

■ Agency approvals/Compliance

1. Compliant with RoHS directive

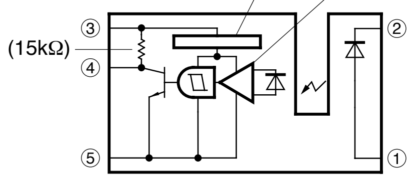
■ Applications

1. General purpose detection of object presence or motion.
2. Example : Printer, FAX, Optical storage unit

* "OPIC"(Optical IC) is a trademark of the SHARP Corporation. An OPIC consists of a light-detecting element and a signal-processing

Sheet No.: D3-A03901EN
Date Oct. 3. 2005

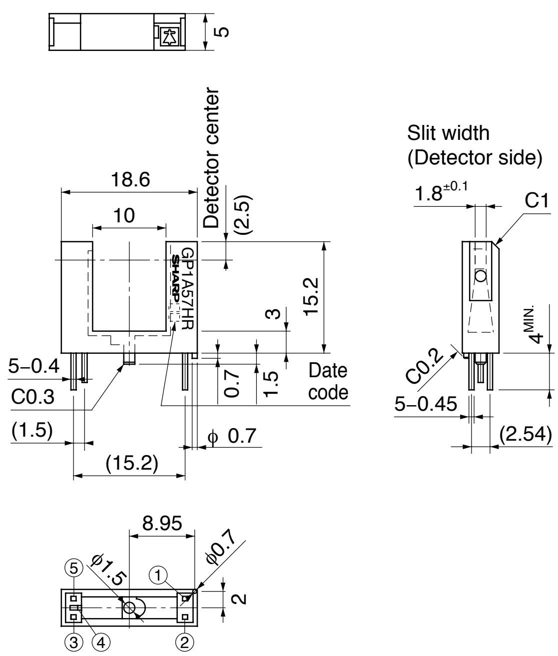
■ Internal Connection Diagram



① Anode
② Cathode
③ V_{CC}
④ V_O
⑤ GND

■ Outline Dimensions

(Unit : mm)



• Tolerance : ±0.2mm
• ( ) : Reference dimensions

Product mass : approx. 0.7g

Dip soldering material : Sn−3Ag−0.5Cu

Date code (2 digit)

1st digit		2nd digit	
Year of production		Month of production	
A.D.	Mark	Month	Mark
2000	0	1	1
2001	1	2	2
2002	2	3	3
2003	3	4	4
2004	4	5	5
2005	5	6	6
2006	6	7	7
2007	7	8	8
2008	8	9	9
2009	9	10	X
2010	0	11	Y
:	:	12	Z

repeats in a 10 year cycle

Country of origin

Japan, Indonesia or Philippines
(Indicated on the packing case)

■ Absolute Maximum Ratings

(T_a=25˚C)

Parameter		Symbol	Rating	Unit
Input	*1 Forward current	I_F	50	mA
	*1, 2 Peak forward current	I_{FM}	1	A
	Reverse voltage	V_R	6	V
	Power dissipation	P	75	mW
Output	Supply voltage	V_{CC}	–0.5 to +17	V
	Output current	I_O	50	mA
	Power dissipation	P_O	250	mW
Operating temperature		T_{opr}	–25 to +85	˚C
Storage temperature		T_{stg}	–40 to +100	˚C
*3 Soldering temperature		T_{sol}	260	˚C

*1 Refer to Fig. 1, 2, 3
*2 Pulse width ≤ 100μs, Duty ratio=0.01
*3 For 5s or less

■ Electro-optical Characteristics

(T_a=25˚C)

Parameter			Symbol	Condition	MIN.	TYP.	MAX.	Unit
Input	Forward voltage		V_F	I_F=7mA	–	1.14	1.4	V
	Reverse current		I_R	V_R=3V	–	–	10	μA
Output	Operating supply voltage		V_{CC}	–	4.5	–	17	V
	Low level output voltage		V_{OL}	V_{CC}=5V, I_{OL}=16mA, I_F=0	–	0.15	0.4	V
	High level output voltage		V_{OH}	V_{CC}=5V, I_F=7mA	4.9	–	–	V
	Low level supply current		I_{CCL}	V_{CC}=5V, I_F=0	–	1.7	3.8	mA
	High level supply current		I_{CCH}	V_{CC}=5V, I_F=7mA	–	0.7	2.2	mA
Transfer charac-teristics	*4 "Low→High" threshold input current		I_{FLH}	V_{CC}=5V	–	1	7	mA
	*5 Hysteresis		I_{FHL}/I_{FLH}	V_{CC}=5V	0.55	0.75	0.95	–
	*6 Responce time	"Low→High" Propagation delay time	t_{PLH}	V_{CC}=5V, I_F=7mA, R_L=280Ω	–	3	9	μs
		"High→Low" Propagation delay time	t_{PHL}		–	5	15	
		Rise time	t_r		–	0.1	0.5	
		Fall time	t_f		–	0.05	0.5	

*4 I_{FLH} represents forward current when output goes from "Low" to "High".
*5 I_{FHL} represents forward current when output goes from "High" to "Low".
*6 Test circuit for response time is shown in Fig.12.

Fig.1 Forward Current vs. Ambient Temperature

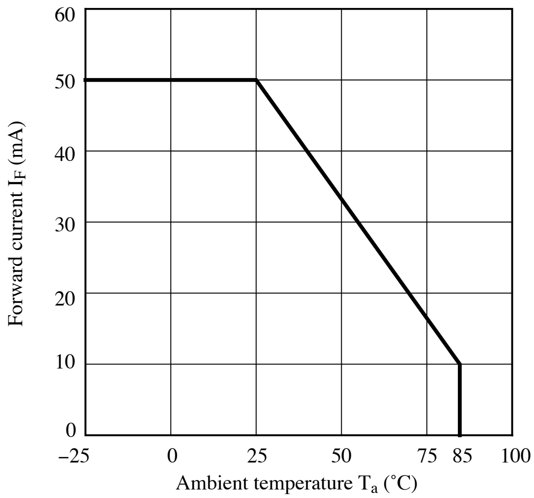


Fig.2 Output Power Dissipation vs. Ambient Temperature

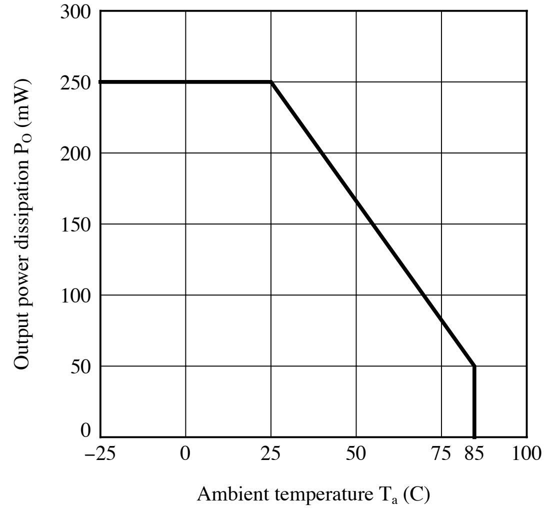


Fig.3 Low Level Output Current vs. Ambient Temperature

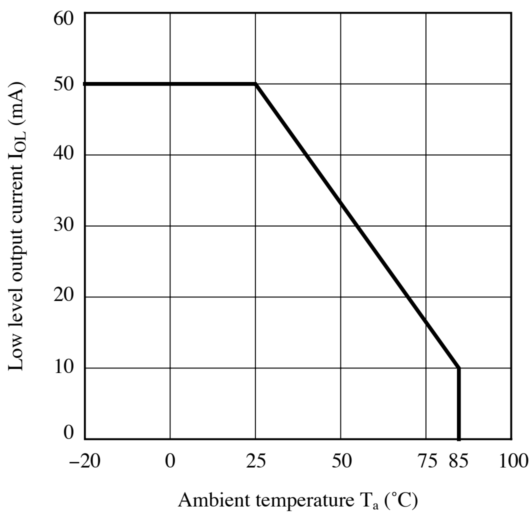


Fig.4 Forward Current vs. Forward Voltage

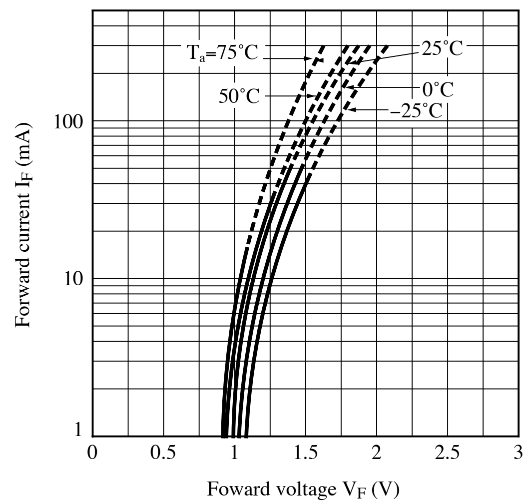


Fig.5 Relative Threshold Input Current vs. Supply Voltage

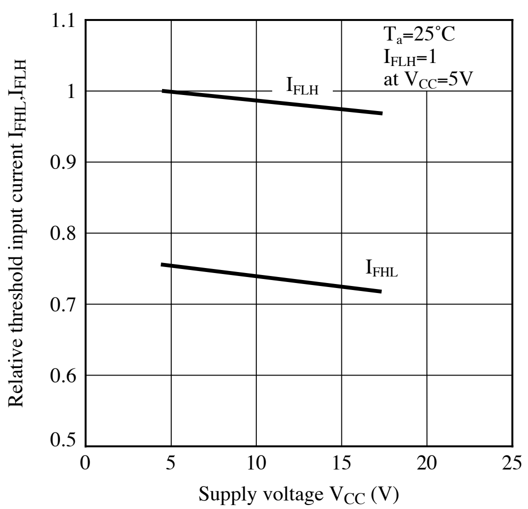


Fig.6 Relative Threshold Input Current vs. Ambient Temperature

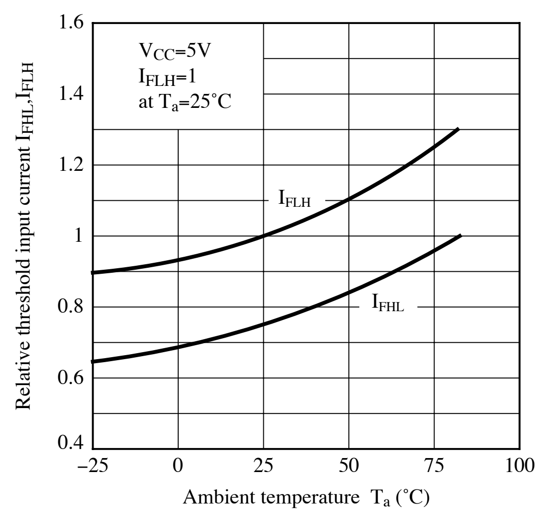


Fig.7 Low Level Output Voltage vs. Low Level Output Current

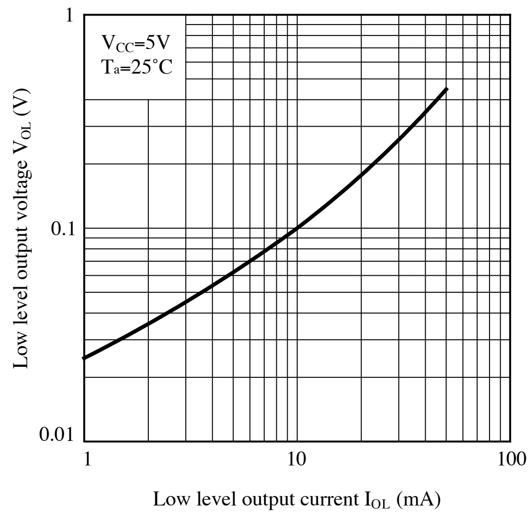


Fig.8 Low Level Output Voltage vs. Ambient Temperature

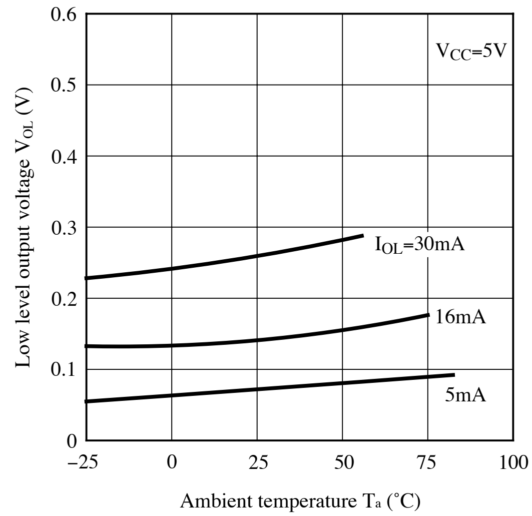


Fig.9 Supply Current vs. Ambient Temperature

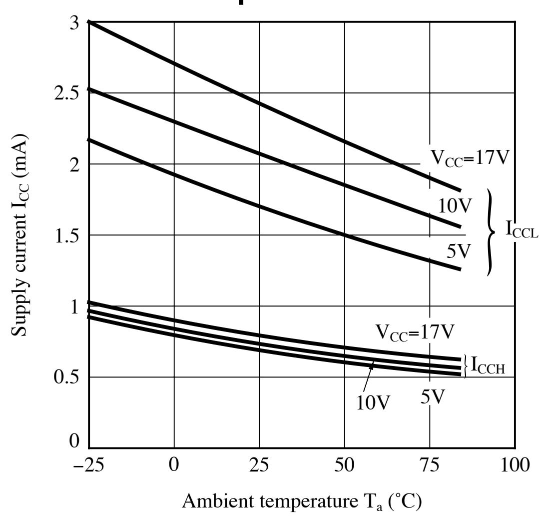


Fig.10 Propagation Delay Time vs. Forward Current

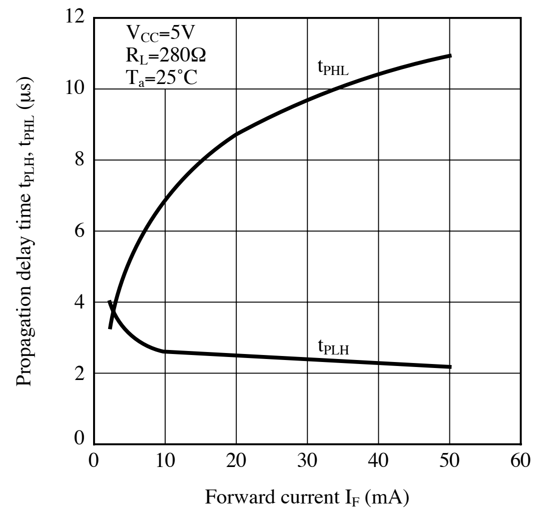


Fig.11 Rise Time,Fall Time vs. Load Resistance

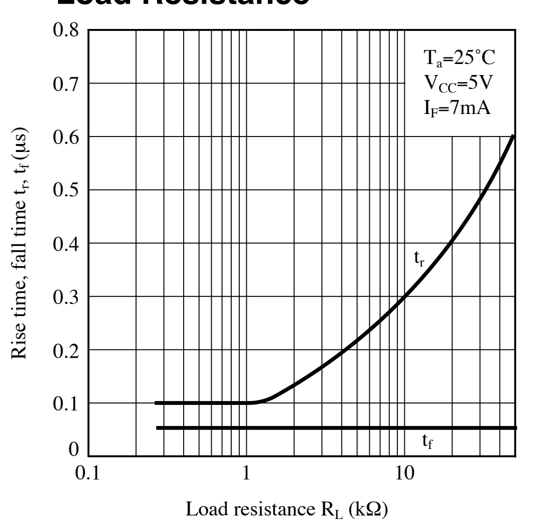
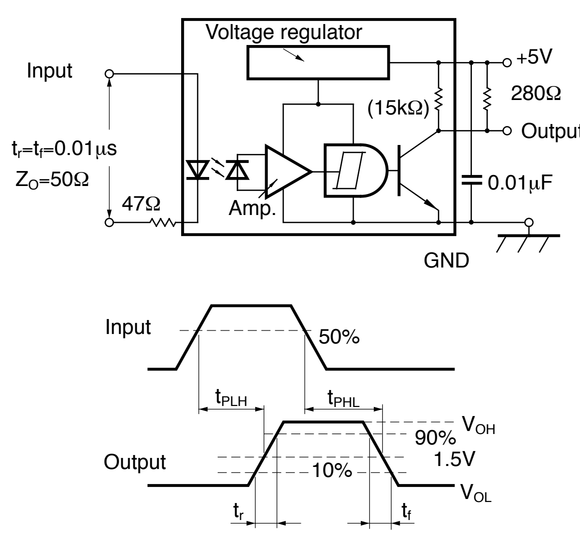


Fig.12 Test Circuit for Response Time



Remarks : Please be aware that all data in the graph are just for reference and not for guarantee.

Design Considerations

● Recommended operating conditions

Parameter	Symbol	MIN.	TYP.	MAX.	Unit
Output current	I_O	–	–	16	mA
Forward current	I_F	10	–	20	mA
Operating terperature	T_{opr}	0	–	70	˚C

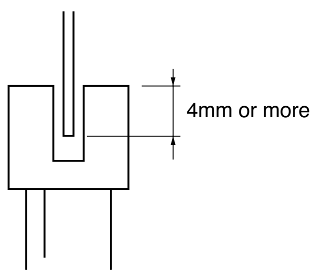
● Notes about static electricity

Transisiter of detector side in bipolar configuration may be damaged by static electricity due to its minute design.

When handing these devices, general countermeasure against static electricity should be taken to avoid breakdown of devices or degradation of characteristics.

● Design guide

1) Prevention of detection error
   To prevent photointerrupter from faulty operation caused by external light, do not set the detecting face to the external light.
2) In order to stabilize power supply line, connect a by-pass capacitor of more than 0.01μF between V_{CC} and GND near the device.
3) Position of opaque board
   Opaque board shall be installed at place 4mm or more from the top of elements.
   (Example)



This product is not designed against irradiation and incorporates non-coherent IRED.

● Degradation

In general, the emission of the IRED used in photocouplers will degrade over time.

In the case of long term operation, please take the general IRED degradation (50% degradation over 5 years) into the design consideration.

● Parts

This product is assembled using the below parts.

• Photodetector (qty. : 1) [Using a silicon photodiode as light detecting portion, and a bipolar IC as signal processing circuit]

Category	Maximum Sensitivity wavelength (nm)	Sensitivity wavelength (nm)	Response time (µs)
Photodiode	900	400 to 1 200	3

• Photo emitter (qty. : 1)

Category	Material	Maximum light emitting wavelength (nm)	I/O Frequency (MHz)
Infrared emitting diode (non-coherent)	Gallium arsenide (GaAs)	950	0.3

• Material

Case	Lead frame plating
Black NORYL resin	Solder dip. (Sn–3Ag–0.5Cu)

• Others

Laser generator is not used.

■ Manufacturing Guidelines

● Soldering Method

Flow Soldering:

Soldering should be completed below 260˚C and within 5 s.
Please take care not to let any external force exert on lead pins.
Please don't do soldering with preheating, and please don't do soldering by reflow.

Hand soldering

Hand soldering should be completed within 3 s when the point of solder iron is below 350˚C.
Please solder within one time.
Please don't touch the terminals directly by soldering iron.
Soldered product shall treat at normal temperature.

Other notice

Please test the soldering method in actual condition and make sure the soldering works fine, since the impact on the junction between the device and PCB varies depending on the cooling and soldering conditions.

Flux

Some flux, which is used in soldering, may crack the package due to synergistic effect of alcohol in flux and the rise in temperature by heat in soldering. Therefore, in using flux, please make sure that it does not have any influence on appearance and reliability of the photointerrupter.

● Cleaning instructions

Solvent cleaning :

Solvent temperature should be 45˚C or below. Immersion time should be 3 minutes or less.

Ultrasonic cleaning :

The effect to device by ultrasonic cleaning differs by cleaning bath size, ultrasonic power output, cleaning time, PCB size or device mounting condition etc.
Please test it in actual using condition and confirm that doesn't occur any defect before starting the ultrasonic cleaning.

Recommended solvent materials :

Ethyl alcohol, Methyl alcohol and Isopropyl alcohol.

● Presence of ODC

This product shall not contain the following materials.
And they are not used in the production process for this product.
Regulation substances : CFCs, Halon, Carbon tetrachloride, 1.1.1-Trichloroethane (Methylchloroform)

Specific brominated flame retardants such as the PBBOs and PBBs are not used in this product at all.

This product shall not contain the following materials banned in the RoHS Directive (2002/95/EC).

- •Lead, Mercury, Cadmium, Hexavalent chromium, Polybrominated biphenyls (PBB), Polybrominated diphenyl ethers (PBDE).

■ Package specification

● Case package

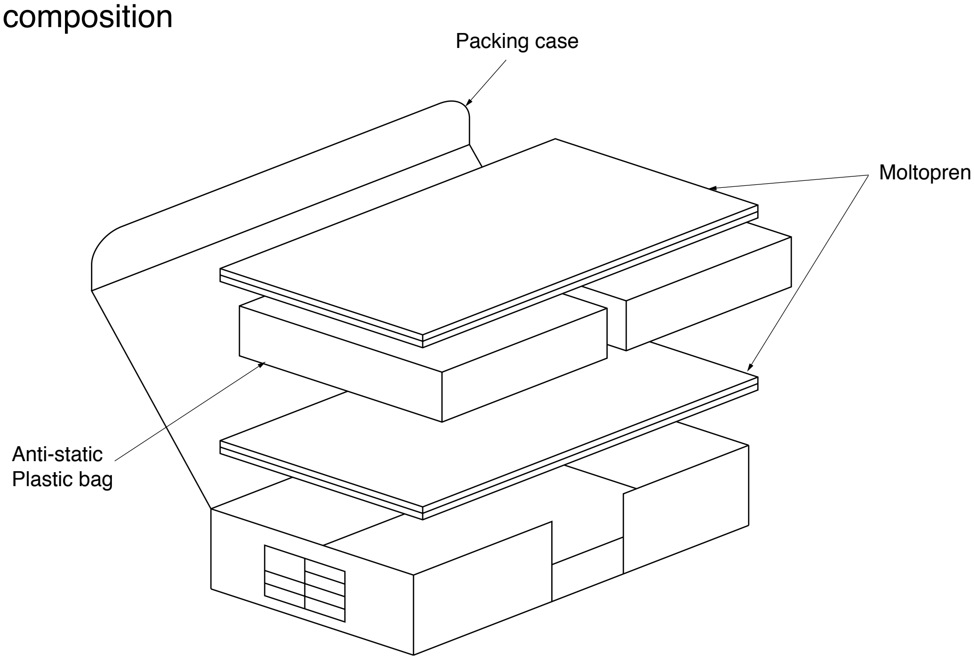
Package materials

Anti-static plastic bag : Polyethtylene
Moltopren : Urethane
Packing case : Corrugated fiberboard

Package method

50 pcs of products shall be packaged in a plastic bag, Ends shall be fixed by stoppers. The bottom ot the packing case is covered with moltopren, and 2 plastic bags shall be put int the packing case.
Moltopren should be located after all product are settled (1 packing contains 100 pcs).

Packing composition



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(i) The devices in this publication are designed for use in general electronic equipment designs such as:

--- Personal computers
--- Office automation equipment
--- Telecommunication equipment [terminal]
--- Test and measurement equipment
--- Industrial control
--- Audio visual equipment
--- Consumer electronics

(ii) Measures such as fail-safe function and redundant design should be taken to ensure reliability and safety when SHARP devices are used for or in connection with equipment that requires higher reliability such as:

--- Transportation control and safety equipment (i.e., aircraft, trains, automobiles, etc.)
--- Traffic signals
--- Gas leakage sensor breakers
--- Alarm equipment
--- Various safety devices, etc.

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--- Space applications
--- Telecommunication equipment [trunk lines]
--- Nuclear power control equipment
--- Medical and other life support equipment (e.g., scuba).

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