Application

Vehicle detection by means of inductive loops in the pavement is not new. This technique has been used for many years and is still in use today.

Many intersections have inductive loops buried in the concrete or asphalt that sense the presence of vehicles and initiate a signal light change. Perhaps you have seen the cut-outs in the pavement that have been filled with tar. In the case of an advanced left turn arrow, they may be set back from the intersection by several car lengths. If you know what to look for, you can stop on one of these loops and force the left turn arrow even if you are alone in the lane.

Loops are also used in counting vehicular traffic to determine pavement wear and tear and when painting of white lines is warranted. In this case, a loop is buried in the pavement for each lane of a highway. The leads are brought to the side of the road where a junction box is installed. A counter connects to the loops at the measurement site and monitors vehicular traffic. Each time a vehicle goes over a loop, a count is registered. The accumulated count for each lane is saved to memory periodically and the counts are zeroed. A typical interval may be 15 minutes but other intervals could be chosen. The surveys are conducted over several hours and the data is analyzed by custom software back at the office.

Other uses for inductive loop sensing might include garage door openers, and security alarms.

Method

A loop consisting of 2 to 3 turns of copper wire is imbedded into the pavement. A more complete explanation of site preparation can be found at:

http://www.nzta.govt.nz/resources/maint-installation-inductive-loops-traffic-monitoring-sites/docs/maint-installation-inductive-loops-traffic-monitoring-sites.pdf

Also at:

https://en.wikipedia.org/wiki/Induction_loop

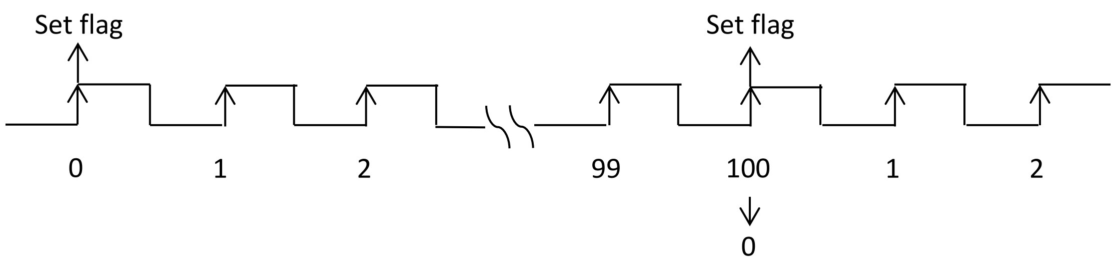
Electronics

The loop leads are connected to an oscillator so that the inductance of the loop forms part of the tuned circuit. A wide variety of inductances needs to be automatically accepted in order to provide the greatest flexibility for the end user. Typically, loop inductances between 40 μH and 400 μH should be accommodated.

The loop oscillator output is squared up by a Schmitt Trigger and presented to the microcontroller GPIO pin which has interrupt capability. This small signal conditioning is all that is required from external circuits. Taking advantage of the microcontroller speed and internal circuits minimizes the number of external components necessary.

Software

The GPIO pin is set to interrupt the processor on positive going edges of the signal. In order to get a longer sampling time of the loop oscillator frequency, the interrupt routine counts 100 pulses before setting a flag.



Dwell time in the interrupt routine is kept to a minimum. Computation occurs in the background after the processor returns from the interrupt.

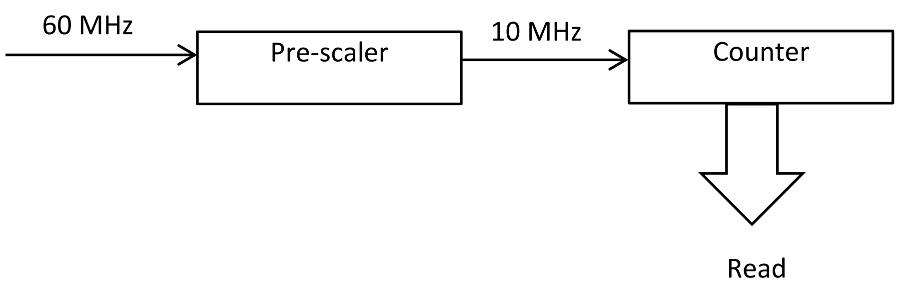
The flag is checked each time through the "main" loop of the code. If the flag is set, a computation is performed to determine if the loop oscillator frequency has changed sufficiently to declare that a vehicle is over the loop coil.

The microcontroller hardware is summoned to assist in this computation. An internal timer (Timer6 in this case) is set in the following manner.

1. The pre-scaler is set to produce a frequency of 10 MHz.
2. The timer 16-bit counter is set to free-run with this clock input.
3. No interrupts from the timer are enabled and it has no external pins.
4. The accumulated count can be read out by the processor at any time.

The system clock in this case is 120 MHz which is divided by 2 to feed the internal peripheral circuits including Timer6. This results in a 60 MHz input clock. The pre-scaler is set to 5 in order to divide the input clock by 6 (TIM6_PSC + 1). The pre-scaler output drives the timer counter at 10 MHz.

Timer6



When the background routine sees the flag set, it reads the timer counter into New-Value variable. Then, Old-Value is subtracted from New-Value and the difference is put into a 4-value buffer so that it overwrites the oldest entry. The 4 most recent entries are added and divided by 4 to obtain an average. This action tends to smooth out small variations and makes the result more stable. Old-Value is replaced by New-Value in preparation for the next reading and calculation. This calculation works even though the 16-bit counter eventually overflows and starts counting again from 0.

The presence of a metal object over the loop coil results in a shift of the oscillator frequency upward (the frequency increases slightly). Therefore, it takes a little less time to count the 100 oscillator pulses by the interrupt routine. Timer6 has less time to accumulate the 10 MHz pulses resulting in a lower difference value being computed. The current average value is compared to a threshold value (Low-Threshold) and if it is lower than this value, the code has determined that a vehicle is present over the loop. When the vehicle leaves the loop area, the loop oscillator frequency returns to its original value. A small hysteresis (High-Threshold) is used to prevent counting the vehicle more than once.

A state machine is used to set the initial thresholds and re-evaluate them from time-to-time. The threshold amount is determined by the definitions of UPPER and LOWER values. These can be adjusted to set the sensitivity of the detection hardware/software. A compromise exists between sensitivity and false detection events and may differ depending on detector usage.

This example uses a simplistic state machine to set up and monitor detector operation. This is where more intelligent software can be implemented. A flow-chart of event possibilities and their resolution (error handling) can be implemented to make the whole product more robust. All it needs is imagination.

Testing

Although small variations will exist from one board to the next, these are typical observed data for one circuit board.

Coil Number	Inductance of Loop Coil	Loop Oscillator Frequency	Accumulated Count	Time Available to Accumulate
1	35.9 µH	85258.76 Hz	11726	1.1726 ms
2	212 µH	45685.05 Hz	21889	2.1889 ms
3	328 µH	41118.42 Hz	24322	2.4322 ms

The maximum range for a 16-bit counter driven by a 10 MHz clock is:

$2^{16} * 10^{-7} = 6.5536 \times 10^{-3}$ seconds or 6.5536 ms and therefore, the 3 samples fall comfortably within this range.

If the average length of a car is 174 inches or 14.5 feet,

At 60 mph a car is traveling 88 feet/second,

Time to traverse the loop is 14.5 / 88 = 164.7 ms,

With a typical loop coil the time to accumulate is approximately 2 ms,

Therefore, the number of samples that can be taken is 164.7 / 2 ≈ 82.