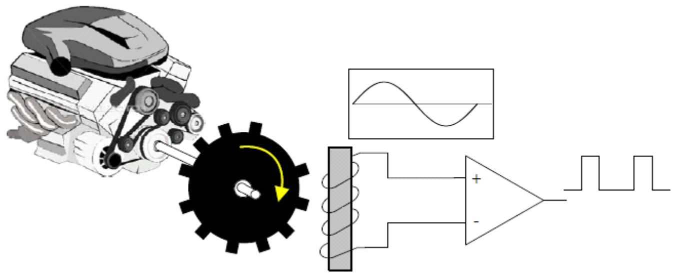
VRS automatic mode setting

Featuring the MC33813/33814 IC



1 Introduction

This application note examines fundamentals of variable reluctance sensor (VRS) systems, as well as how to correctly determine the VRS automatic mode parameters through a single bench measurement.

The MC33813 and 33814 are engine control analog power ICs intended for one and two cylinder motorcycle and other small engine control applications. The MC33813 and 33814 offers an innovating VRS automatic mode.

NXP analog ICs are manufactured using the SMARTMOS process, a combinational BiCMOS manufacturing flow, integrating precision analog, power functions, and dense CMOS logic together on a single cost-effective die.

Contents

2 Description of the VRS system

The MC33813 and 33814 contain a VRS comparator circuit with multiple thresholds, programmed via the SPI, allowing the system to handle different sensors and the wide dynamic range of the VRS outputs at engine speeds from crank to running. The output of this circuit is provided on the VRSOUT pin to the MCU.

As specified in the datasheet, two sets of parameters (Input comparator threshold and Blanking time) could be specified for engine cranking and engine running conditions. Consider "thresholds" can be manually set with SPI writes using values from Table 1.

In typical operation, a low value threshold ~100 mV is used for cranking while a higher threshold is used when the engine is running. Alternatively, an innovative Automatic mode can be used to improve noise immunity at low engine speeds and cranking without compromising performance at normal engine speeds. The following sections explain some theory of operation and how to correctly set the Automatic Mode.

2.1 Theory points

A single tooth system is used to illustrate that only a single measurement is necessary to define the key system characteristic Volt-Time Constant (VTC).

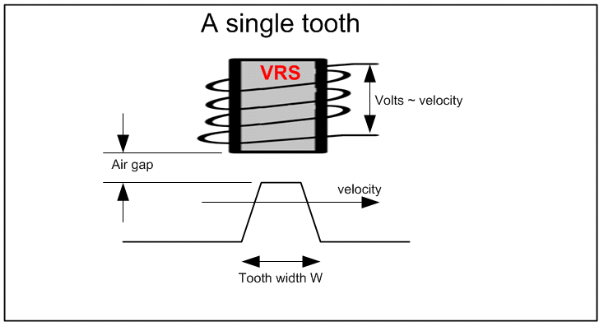


Figure 1. Single tooth system

2.1.1 Predictive curve

The VRS sensor operates by generating a voltage (e.m.f.), based on the change in magnetic flux through the sensor.

For a single tooth running at a velocity # 1, the generated signal has an amplitude V_1, and a period t_1.

For velocity #2, which is double the velocity #1, the generated signal has a amplitude V_2 and a period t_2.

As illustrated in Figure 2, t_2 is one half the t_1 period, when V_2 is double the amplitude V_1.

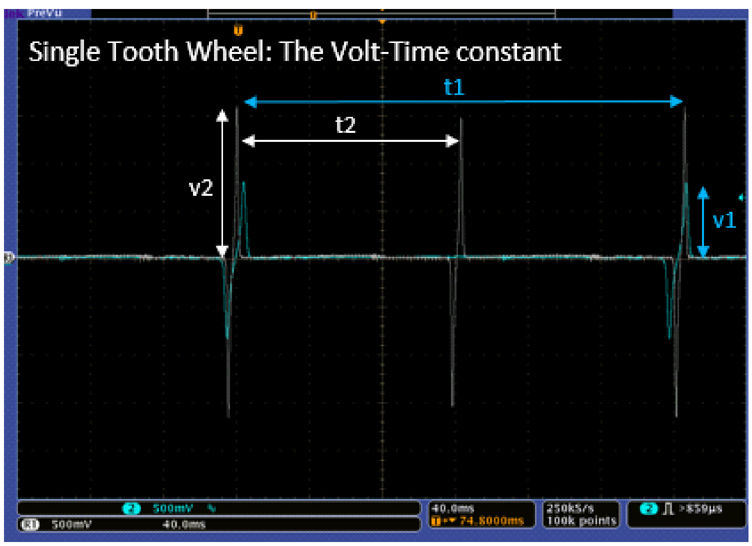


Figure 2. Input signals at two different velocities

In conclusion: $t_2 = ½ t_1$, and $V_2 = 2V_1$

→ V_2 X t_2 = 2V1 x (1/ 2)x t1

→ $\mathbf{V_2 \times t_2 = V_1 \times t_1}$

A linear relation exists between the VRS amplitude and velocity. This predictive curve could be generated based on only one measurement. As the velocity is proportional to RPM (revolutions per minute), this predictive curve is also valid for the RPM cutoff.

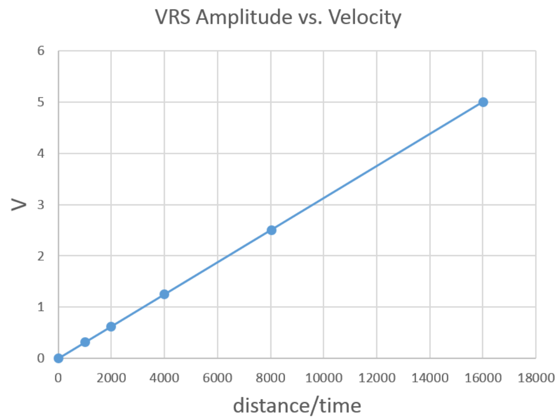
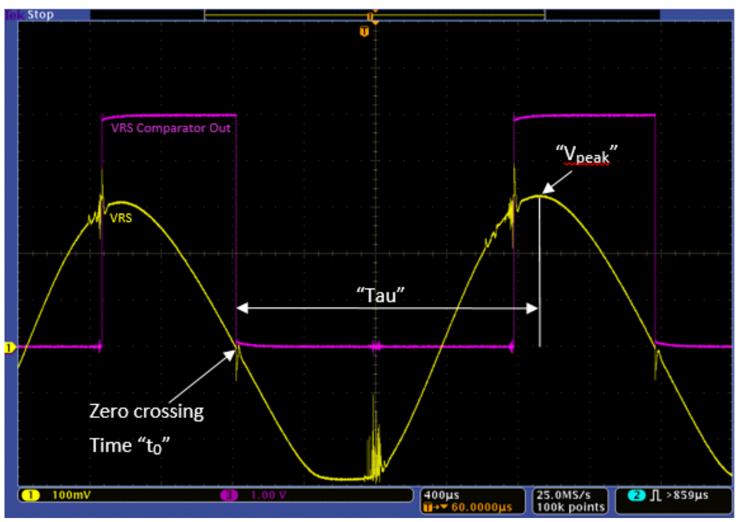


Figure 3. Predictive curve

2.1.2 Zero crossing and peak voltage

To generate the predictive curve, the volt-time constant (VTC) of the system requires two data points:

- Voltage: V_{PEAK} is the absolute voltage of the peak signal
- Time: Tau is the timing between the zero crossing and V_{PEAK} (not between two voltage peaks)



Yellow: VRS Input.
Pink: VRS Output

Figure 4. Tau & V_{PEAK} illustration

The data pair of V and T allows the user to determine the VTC, and therefore the VRS amplitude vs. Engine Speed Curve

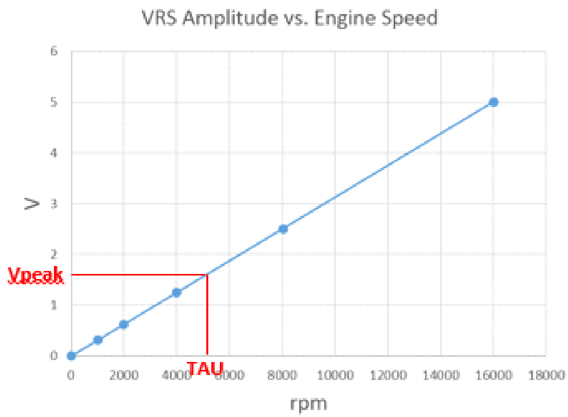


Figure 5. Predictive curve

2.2 Automatic mode circuitry

2.2.1 Automatic mode circuitry principle

The purpose of the automatic mode is to get a VRS system less sensitive to the noise in the cranking area and to reduce software overhead.

In automatic mode, as soon the VRS Input signal crosses zero, the VRS system selects the highest input comparator threshold (VT_{MAX} typically, 1.715 V) and decays as 1/t. To accommodate a wide variety of trigger wheels and sensors, the decay rate is programmable via the SPI VRS Automatic Parameters Configuration register.

The oscilloscope plot in Figure 6 illustrates the V_{PEAK} detection and the Decay circuitry. The VRSP input signal is in blue, the VRS_{OUT} signal is in yellow, and an internal signal is in pink (accessible only in test mode) reflects the input comparator threshold value (V_T).

When V_{SRP} reaches the V_T selected, the VRS_{OUT} signal is set to a high level. At this point, the V_{PEAK} detection circuit starts to determine the magnitude of the positive peak and digitizes it according to SPI VRS Status register definition. When the V_{RSP} signal crosses zero, the decay circuitry sets the V_T threshold to the maximum level, and decays to the V_T selected in the appropriate timing. In this way, the threshold tracks the input signal, allowing to the system to be less sensitive to noise than manual mode with a fixed V_T threshold.

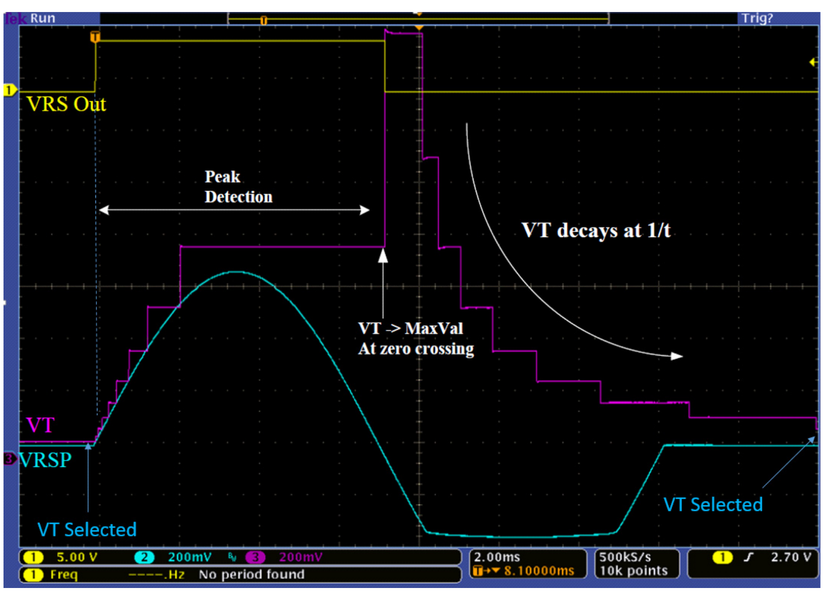


Figure 6. Peak detection and decay system illustration

2.2.2 Mathematica formula

Mantissa and exponent parameters defined in the VRS Automatic mode parameters register set the decay time of the system from the VT_{MAX} to $VT_{SELECTED}$.

The Mathematica formula is:

- E (Truncated) = log2 [($VT_{SELECTED}$ X Tau)/18.1] - 4
- M (Rounded to nearest integer) = {[($VT_{SELECTED}$ X Tau)/18.1] /2E} - 16

2.2.3 Measurement instructions

Only four steps are necessary to correctly set the automatic mode.

1. Measuring V_{PEAK} & Tau for the minimum RPM

   For the minimum system RPM, measure the maximum V_{PEAK} (V_{PEAK_MAX}) and Tau parameters as described in 2.1.1, Predictive curve, page 2.
2. Selecting the appropriate input comparator threshold ($VT_{SELECTED}$)

   From the SPI VRS Manual Parameters table, select the appropriate VT ($VT_{SELECTED}$) for the input comparator, to detect the V_{PEAK_MAX}.

Note: Adding some noise margin (~100 mV) could be recommended depending on the V_{PEAK_MAX} and $VT_{SELECTED}$ value. As thresholds are discrete, it could lead to select a VT corresponding to one or more lower LSBs.

Table 1. Peak detector output in the SPI VRS status register

SPI VRS Status Register Bits 7,6,5,4	Peak Values (nominal)
0000	10 mV
0001	14 mV
0010	20 mV
0011	28 mV
0100	40 mV
0101	56 mV
0110	80 mV
0111	110 mV
1000	150 mV
1001	215 mV
1010	300 mV
1011	425 mV
1100	600 mV
1101	850 mV
1110	1.210 V
1111	1.715 V

3. Mantissa and exponent calculation

   Using the Tau measured and the $VT_{SELECTED}$, customers can calculate the mantissa and exponent according to the mathematical formula.
   Note that Exponent values should be truncated, and the Mantissa value should be rounded to the nearest integer.
4. SPI register setting

   The customer should now select the automatic mode and set the three required parameters ($VT_{SELECTED}$, Mantissa and Exponent) with:

- Automatic mode in bit 7 in the SPI Miscellaneous Parameters Configuration register
- Mantissa and Exponent in bit 7-0 in the SPI VRS Automatic Parameters Configuration register
- $VT_{SELECTED}$ in bit 7-4 (as well as the Filter Time parameter) in the SPI VRS Engine Cranking Parameter Control register.

Table 2. SPI configuration register

Reg #	Hex			7	6	5	4	3	2	1	0
11	B	VRS Engine Running Parameters	R/W	Threshold 3	Threshold 2	Threshold 1	Threshold 0	Filter Time 3	Filter Time 2	Filter Time 1	Filter Time 0
			Reset	(0)	(1)	(0)	(1)	(0)	(0)	(1)	(1)
12	C	VRS Automatic Parameters	R/W	mantiss 8	mantiss 4	mantiss 2	mantiss 1	exponent 8	exponent 4	exponent 2	exponent 1
			Reset	(0)	(0)	(1)	(0)	(0)	(0)	(0)	(1)
13	D	VRS Miscellaneous Parameters	R/W	**Man.**/Auto	Disable VRS	x	**High**/Low Ref	De-glitch	Gnd VRSN	Inv Inputs	Disable 2.5 V CM
			Reset	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)

Table 3. SPI control register

Reg #	Hex			7	6	5	4	3	2	1	0
13	D	VRS Engine Cranking Parameters	R/W	Threshold 3	Threshold 2	Threshold 1	Threshold 0	Filter Time 3	Filter Time 2	Filter Time 1	Filter Time 0
			Reset	(0)	(1)	(0)	(1)	(0)	(0)	(1)	(1)

3 References

The following are URLs where you can obtain information on related NXP products and application solutions:

NXP.com Support Pages	Description	URL
MC33813	Data sheet	http://www.nxp.com/files/analog/doc/data_sheet/MC33813.pdf
MC33814	Data sheet	http://www.nxp.com/files/analog/doc/data_sheet/MC33814.pdf
Automotive Products		http://www.nxp.com/products/automotive-products
Power Management Home Page		http://www.nxp.com/products/automotive-products/power-management:POWER-MANAGEMENT-AUTO

4 Revision history

Revision	Date	Description
1.0	3/2016	• Initial release

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