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RPM-8000

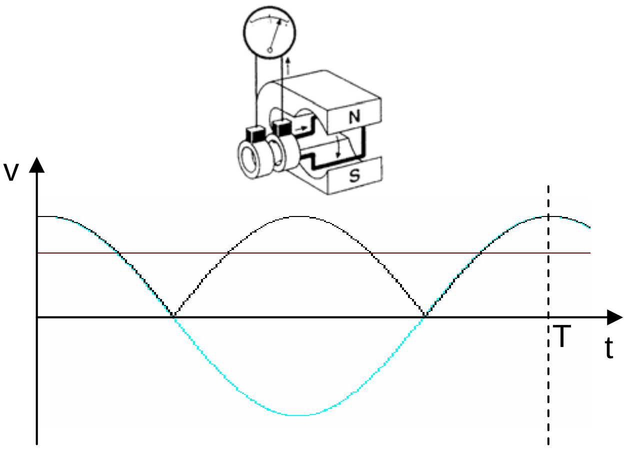
Version 4

Contact- and sensorless automotive RPM measurement

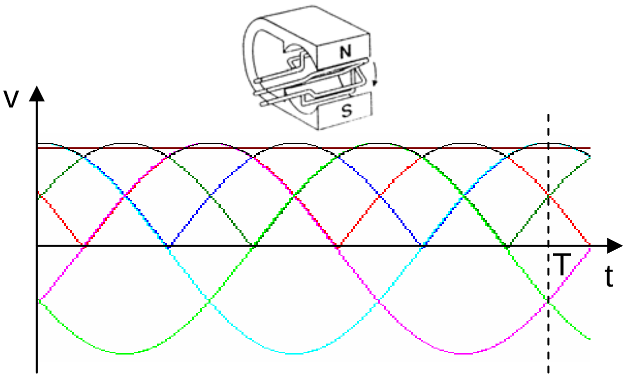
- Independent of vehicle type
- Independent of engine type
- No sensor installation / mounting
- Easy and fast RPM access
- Analog & digital output signals
- Minimal signal time delay
- Small, light, easy and handy
- For board net 12-42V

Operating principle

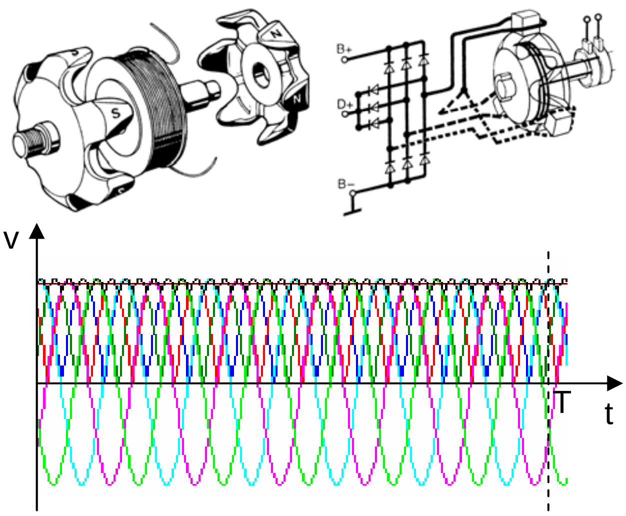
Considering the simplest physical generator with a rotating wire winding inside a magnetic field produced by two magnetic poles (one pole pair = north and south) - the output voltage is a sine wave (blue line) with one cycle per revolution. After rectification with diodes we get an alternating DC voltage with 2 pulses per revolution (black line) and a resulting average voltage (brown line).



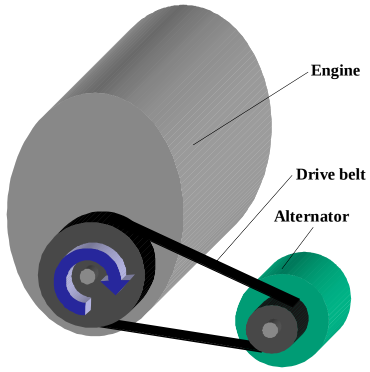
To imagine a three-phase generator we add two independent wire windings. Now we have 3 sine wave voltages which are spaced about 120° out of phase. After three-way rectification with six diodes the result is an alternating DC voltage with 6 pulses per revolution (black line) and an increased average voltage against the generator with one winding.



In practice generators for automobiles have more than two poles. In most cases here we find 12 poles (6 pole pairs) and sometimes also 16 poles (8 pole pairs). For the first one we get from every phase 6 cycles per revolution and after rectification an alternating DC voltage with 36 pulses.



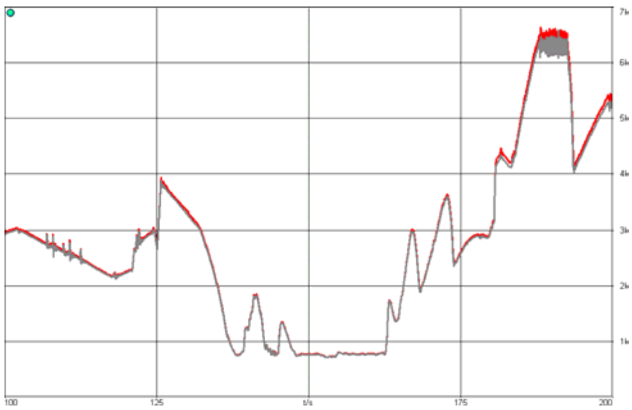
The board net voltage ripple frequency can simply calculated by multiplying the alternator RPM with the number of poles (e.g. 12) and the number of phases (3).



By connecting to an automotive cigarette lighter socket the measurement unit RPM-8000 senses the small AC ripple of the vehicle board net DC supply voltage and generates on its outputs both a TTL digital pulse train and an analog voltage signal. These signals are "per design" linear to the alternator RPM and by the linear drive belt relationship also to the engine RPM. The scaling factor can determined by the relation between the effective diameters of the engine and the alternator pulleys.

Accuracy

Next diagram shows a part of a test measurement of a famous German automobile manufacturer. The RPM reference signal was obtained from the car internal CAN bus, which will also used for the electronically engine management. To verify the dynamical performance, the RPM signal was provide with an additional scaling factor of 1.02 - actually both curves are congruent.



In practice the generated alternator ripple also includes electrical noise and disturbances from other electrical devices and loads connected to the vehicle supply. In petrol engine vehicles this is mainly due to the ignition system and is relatively straight-forward to eliminate. In Diesel engine vehicles however the main noise source is from the electronic injection system and, due to the spectral content of the injection signals, is very difficult to decouple from the relatively small signal of interest from the alternator. This technical background helps to explain the different accuracies of the RPM signal, which are achieved: approx. 1.5% for petrol and approx. 3% for Diesel engines. Strictly recommended is to switching on constant load accessories such as vehicles lights, windscreen heaters etc. for improving the signal to noise ratio and with it the measurement accuracy. This does not apply to non-constant load devices or electrical noise generators such as electric fan motors and newer technology gas discharge lamps!

Important notes

- The operating principle is based on the condition that the vehicle DC supply is switched stable from the lead acid battery to the alternator. Therefore RPM measurement with the RPM-8000 unit is not possible during start up operations!
- The use of cigarette-lighter sockets in the rear seating area or in the car boot in some vehicles can cause additional interference noise to be injected into the long line routes. You should therefore use only the socket on the dashboard or on the driver's console.
- A loss of synchronization may occur when the motor speed drops. In this case the vehicle electrical supply briefly switches to battery-backup mode, as the high Faraday capacity of the battery is not able to decay quickly enough. This effect will eliminate by switching on additional resistive loads (light, window heater).
- Some Diesel vehicles of upper class cars are equipped with overrunning alternators. This may cause in cases of extremely high negative accelerations a short-time rotational speed difference between engine and alternator. This is important to know, because the RPM-8000 measures indeed the revolutions per minute of the alternator.

Calibration

1. For calibrating the device with an analog reference sensor measure simultaneously the output voltage from the reference and the RPM-8000. Using the supplied screwdriver to change the gain with the potentiometer on the RPM-8000 labeled "Analog Cal." until both signals are equal.
2. For calibrating the device with a digital reference sensor simultaneously record both the reference signal and the output frequency of the RPM-8000. This signal always corresponds with the actual residual ripple frequency and is not influenced by the position of the potentiometer! Therefore determine a correction factor from the relationship between both signal values. You can integrate this factor into your digital data acquisition system as a multiplier.
3. If you calibrate with technical parameters without a reference sensor, proceed as follows:
   a) Determine the generator pole number. This is an even number that you will find in the generator data sheet or which you can obtain from the manufacturer.
   b) Determine the transmission ratio between crankshaft and generator. This ratio is obtained from the relationship of the effective diameters of both pulleys.
   c) Calculate the digital frequency correction factor or the analog output voltage to be set with the following formulas:

Digital **Analog**

$$\mathbf{n = f * \frac{60}{3 * p * g}} \qquad \mathbf{v_{Cal} = \frac{v_{Ref} * f_{Cal}}{n_{Ref} * 3 * p * g}}$$

The meaning of the symbols:

- g ... Transmission ratio between crankshaft and generator pulleys (Petrol cars 2 – 3, Diesel cars ≈ 3, Trucks ≈ 5)
- p ... Pole number of generator (usually 12, sometimes 16)
- 3 ... Factor, arising from the 3 phases of the three-phase generator
- 60 ... Conversion factor for Hz to min^{-1} (1Hz = 60min^{-1})
- f ... RPM-8000 output frequency (Hz)
- f_{Cal} ... Internally generated RPM-8000 reference frequency during calibration (4000Hz)
- n ... Motor speed (min^{-1})
- n_{Ref} ... Reference rotational speed (1000min^{-1} = 16.667Hz)
- v_{Ref} ... Reference voltage (1V)
- v_{Cal} ... Analog output voltage of RPM-8000 to be set in calibration mode

Notes: I) n_{Ref} and v_{Ref} are examples for an equivalence of 1V = 1000min^{-1}.
II) For devices with the value-8 frequency divider option the numerator of the digital formula has to be 60 * 8 = 480 instead of 60.

Example: A transmission ratio of 2.14 and a pole number of 12 gives a frequency correction factor of 0.779 (1000 Hz output frequency corresponds to a speed of 779min^{-1}) and an analog output voltage of 3.115V to be set in calibration mode (1V during measurement then corresponds to 1000min^{-1}).

   d) If the frequency output is used, the calculated correction factor must be taken into account during digital data acquisition. To adjust the RPM-8000 by analog means, switch to calibration mode by actuating the test contact "Analog Cal." on the RPM-8000 with the supplied hexagon key. Activation is signaled by the flashing green "O.K." LED. To eliminate external noise calibration should be carried out with the ignition switched on for powering and the motor switched off.
   e) In this mode the digital output generates a quartz-stable frequency of 4000Hz that also serves as input signal to the analog stage to be calibrated. Now, using the screwdriver supplied, set the calculated voltage (for example 3.115V) at the analog output at the potentiometer "Analog Cal.".
   f) Deactivate the calibration mode by pressing the "Analog Cal." pushbutton again. The green "O.K." LED must go off and the device is ready for measurement.

4. A calibration via the RPM reference in the dashboard panel will not recommended, because of the generally high inaccuracy of this instrument, especially in the higher RPM range. However, for rough measurements with easy calibration it's possible. To get acceptable results note the RPM-8000 output frequencies for different dashboard RPM's in the first half of the vehicle RPM range. Next table shows an example for a Peugeot 205 petrol car.

Specification for Peugeot 205			
Number of poles p			12
Crankshaft pulley diameter d_c			139.3mm
Alternator pulley diameter d_a			65.0mm
Diameter ratio of pulleys g = d_c / d_a			2.143
Actual scaling factor 3 * p * g			**77.148**
Measurement results			
Dashboard instrument RPM (min^{-1})	Dashboard instrument RPM (Hz)	RPM-8000 output frequency (Hz)	Scaling factor between RPM-8000 output frequency and dashboard RPM
1000	16.67	1250	75
1500	25.00	1900	76
2000	33.33	2630	78.9
2500	41.67	3300	79.2
Average scaling factor			**77.275**

In this practical example the relative error between the real and measured scaling factor is only 0.16%, but it can't guaranteed, that this accuracy will reached for all vehicles.

How to use the RPM-8000

- Start engine
- Switch on headlight and rear window heater,
  switch off air condition and blowers (recommended)
- Plug RPM-8000 adapter into cigarette lighter socket
- Wait for synchronization (approx. 1-2s)
- Measure

Application areas

Generally the RPM-8000 unit is useful in all manner of applications, where RPM measurement is required on internal combustion engines. It is equally suited in stationary as well as mobile applications and some examples are:

- Inside quality assurance in automotive production, where acoustic measurements linked to engine RPM have to be applied. With ever decreasing test time available at the end of production lines sensor installation is too time consuming and impractical.
- To record vehicle speed in standard „Pass by noise“ tests, in which a fixed and pre-selected gear is used. The calibration in this case, can be for example based on the engine RPM – Gear – Final drive – Wheel circumference ratios - to obtain vehicle speed or via an external Peiseler wheel.
- On vehicle proving grounds, where drivers are required to test a wide range of vehicles, the RPM-8000 is useful for fast and „fuss free“ installation.
- Various applications can also be found in car, truck, bus motorcycle and development.

Specifications

					Input frequency				
					500Hz	1kHz	2kHz	5kHz	10kHz
Accuracy	Signal-to-noise ratio of input signal	2 (6dB)	Output frequency	Mean value [Hz]	504	1001	2003	5060	10283
				Min. value [Hz]	439	974	1972	5020	10162
				Max. value [Hz]	661	1030	2036	5102	10395
			Max. analog output ripple for 1V = 1kHz [mV]		225	120	150	170	300
			Non-linearity [%]		2.83				
		5 (14dB)	Output frequency	Mean value [Hz]	500	1000	2000	5021	10098
				Min. value [Hz]	473	982	1976	4990	10039
				Max. value [Hz]	560	1020	2024	5050	10183
			Max. analog output ripple for 1V = 1kHz [mV]		120	120	125	130	200
			Non-linearity [%]		0.98				
		10 (20dB) -> typ. practical conditions	Output frequency	Mean value [Hz]	500	1000	2000	5003	10032
				Min. value [Hz]	474	990	1980	4980	9984
				Max. value [Hz]	541	1016	2020	5030	10081
			Max. analog output ripple for 1V = 1kHz [mV]		125	105	120	130	145
			Non-linearity [%]		0.32				
		20 (26dB)	Output frequency	Mean value [Hz]	496	1000	2000	5001	10007
				Min. value [Hz]	477	988	1980	4979	9979
				Max. value [Hz]	505	1033	2020	5020	10060
			Max. analog output ripple for 1V = 1kHz [mV]		120	105	120	120	130
			Non-linearity [%]		0.8				
		50 (34dB)	Output frequency	Mean value [Hz]	495	1000	2000	5000	10002
				Min. value [Hz]	473	990	1984	4989	9961
				Max. value [Hz]	505	1028	2020	5020	10040
			Max. analog output ripple for 1V = 1kHz [mV]		110	105	105	110	130
			Non-linearity [%]		1.00				
	Jitter (max. frequency difference between two successive periods)				4.0%	1.0%	0.25%	0.1%	0.1%
	Max. digital time delay				2.0ms	1.0ms	0.5ms	0.2ms	0.1ms
	Analog time delay				20ms				
	Typ. digital output frequency drift (f = 4000Hz)				0.01Hz				
	Typ. analog output voltage drift (v = 4.000V)				40mV				
	Typ. full scale system accuracy with headlight and window heater on as well air condition and blowers off			Diesel engines	3%				
				Petrol engines	1.5%				
Outputs	Digital	Signal frequency range			500Hz – 10kHz				
		Signal level			TTL (0V, 4V)				
		Connector			BNC				
		Output impedance			130Ohm				
	Analog	Range			0.5 – 10V				
		Output impedance			2Ohm, 10mA				
		Smoothing filter			2pole, 20Hz				
		Connector			BNC				
		Minimum potentiometer adjustment range			1.0KHz = 0.25 ... 1.0V				
System parameters		Synchronization frequency range			800 - 2000Hz				
		Synchronization time (typ.)			1-2s				
Power supply		Via vehicle power supply		Unsiversal	12-42V				
Dimensions		Basic unit		Without connectors	80 x 50 x 40 mm				
				With connectors	92 x 50 x 40 mm				
		Cable length to cigarette lighter adapter		Slack	0.5m				
				Stretched	appr. 3m				
Weight		Without adapter cable			120g				
		With adapter cable			280g				
Housing material		Aluminium (annodised)							
User controls		Calibration button							
		Adjustment potentiometer							
Indicators		Power – LED							
		Synchronization– and calibration-LED							
Environmental		Operating temperature			0 – 70°C				
		Storage temperature			-20° - 80°C				
		Humidity			20 – 80% non-condensing				
		Vibration			5g Mil standard 810C, curve C				
		Shock			100g in any direction				
Reference	Environment temperature				23°C				
	Measurement equipment	Hewlett Packard Infinium Oscilloscope HP54815A							
		Hewlett Packard 15MHz Function / Arbitrary Waveform Generator HP33120A							
		Keithley 2000 Multimeter							
		Thurlby Thandar Instruments TG550 Function Generator							
		Hameg 100MHz Oscilloscope HM1005							
		Ora 50V/5A Power Supply LN505							
		H.G.L. Multimeter 3300							

Specifications are subject to change without notice!