

As Fast As Lightning Strikes . . .

Automotive Technology Changes . . .



F.E.R.F.

**FORD ELECTRONIC
RETURNLESS FUEL**

LBT-86

WE ENCOURAGE
PROFESSIONALISM



THROUGH TECHNICIAN
CERTIFICATION

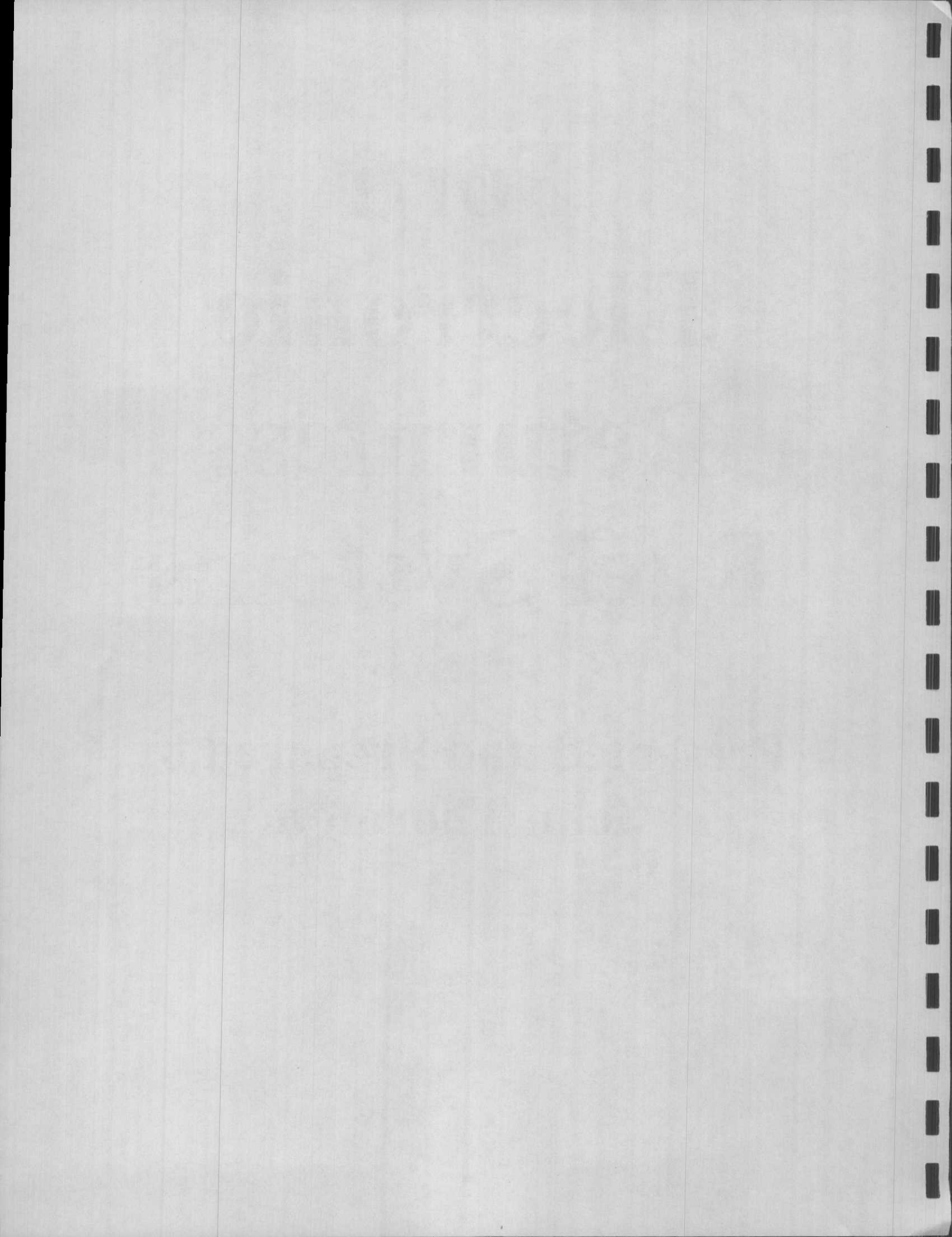
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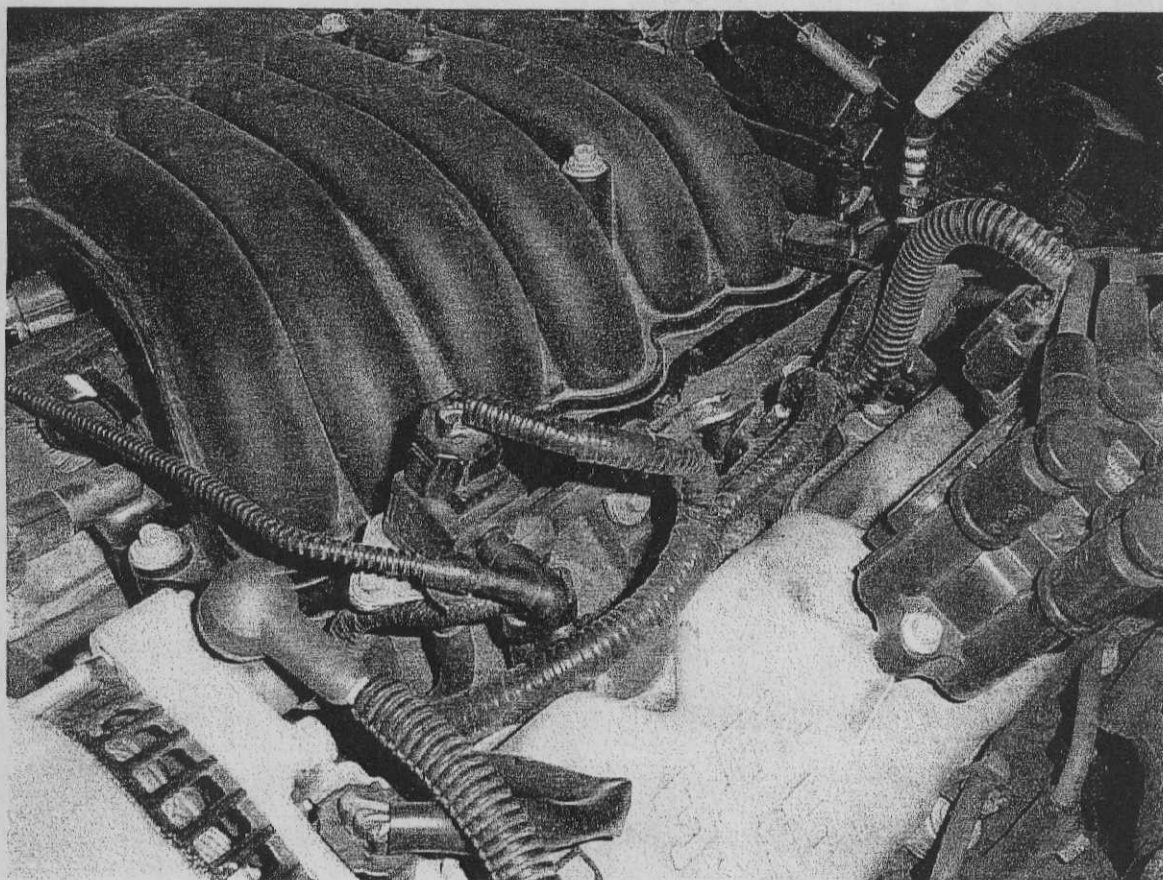
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**Ford
Electronic
Returnless
Fuel Systems**

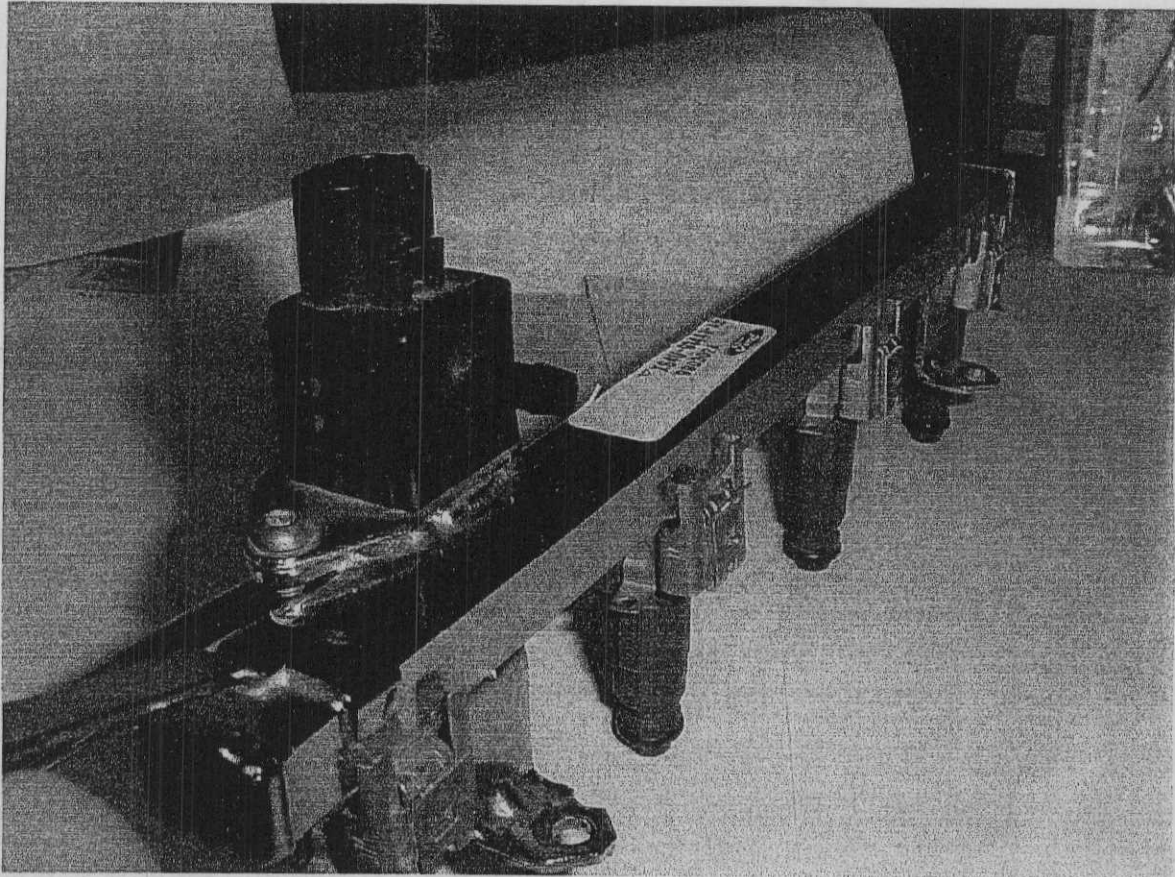
**Presented and Prepared by
John Thornton**



Ford Electronic Returnless Fuel System

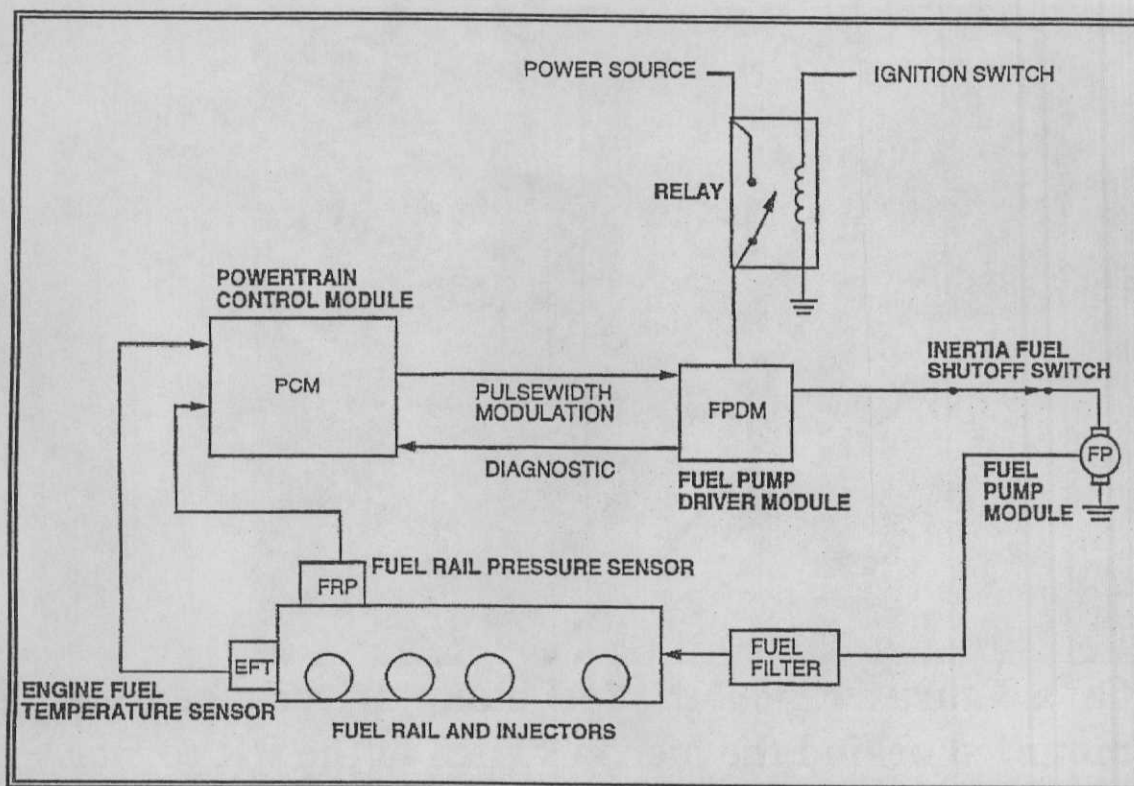


How Do We Know We Have An Electronic Returnless Fuel System?



Ford Electronic Returnless Fuel Systems can be identified by the Fuel Rail Pressure Transducer. It looks like (but isn't) a fuel pressure regulator and will have a 3 wire connector attached to it.

Ford Electronic Returnless Fuel

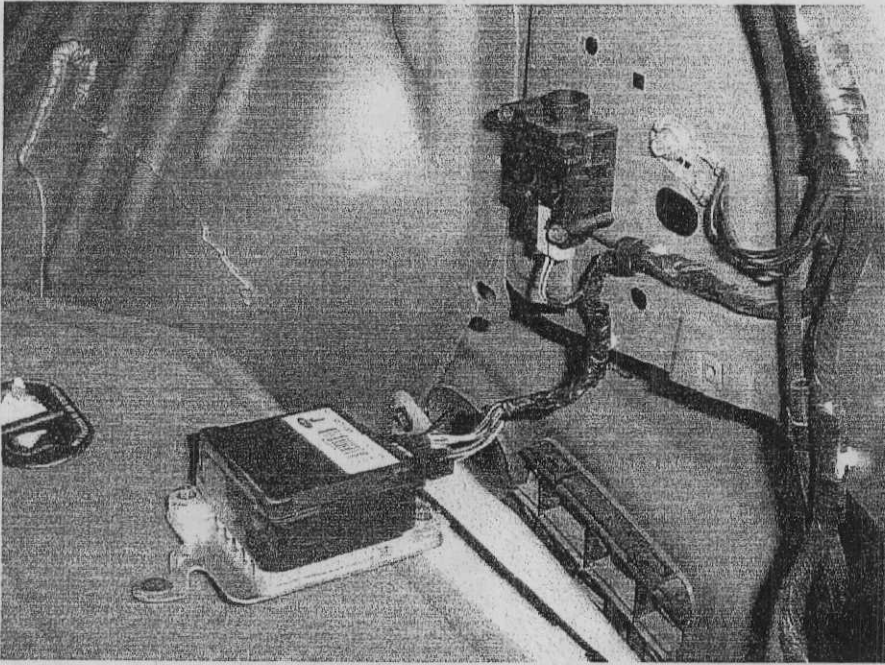


The Electronic Returnless fuel system was first introduced in 1998. By the 2002 MY, this system can be found on most Ford cars. In the 2002 MY, this system appeared in its first truck: 4.6L 4V Navigator.

Mid 1990's Lincoln Continentals had the electronic controls used by this system, but still used a fuel return line to the gas tank.

The primary input is the fuel rail pressure (FRP) sensor. An engine fuel temperature (EFT) sensor was used on the Continental until about 1998. The PCM can infer fuel rail temperature from the IAT and ECT sensors.

Ford Electronic Returnless Fuel

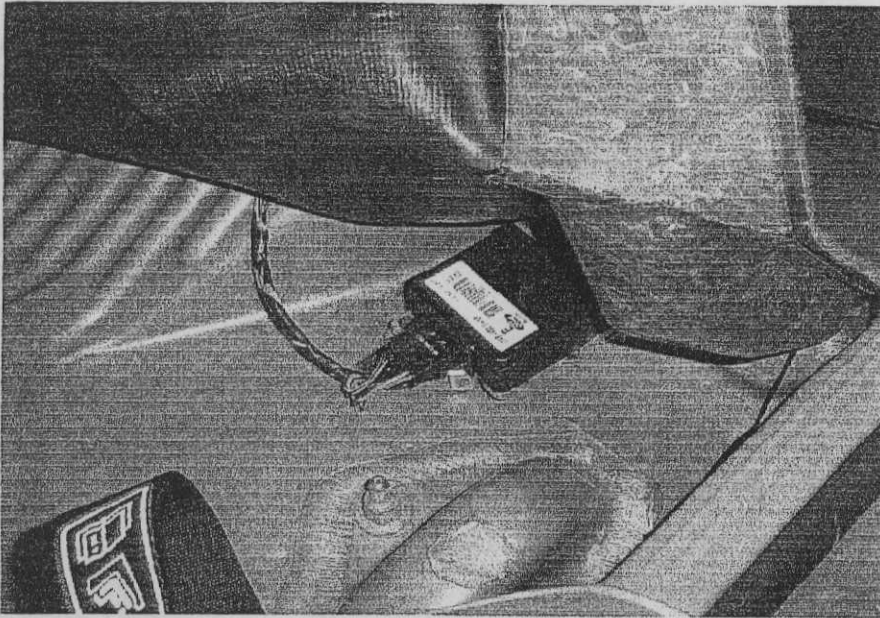


On a Taurus wagon, the fuel pump driver module is mounted behind the inertia switch in the RR corner.

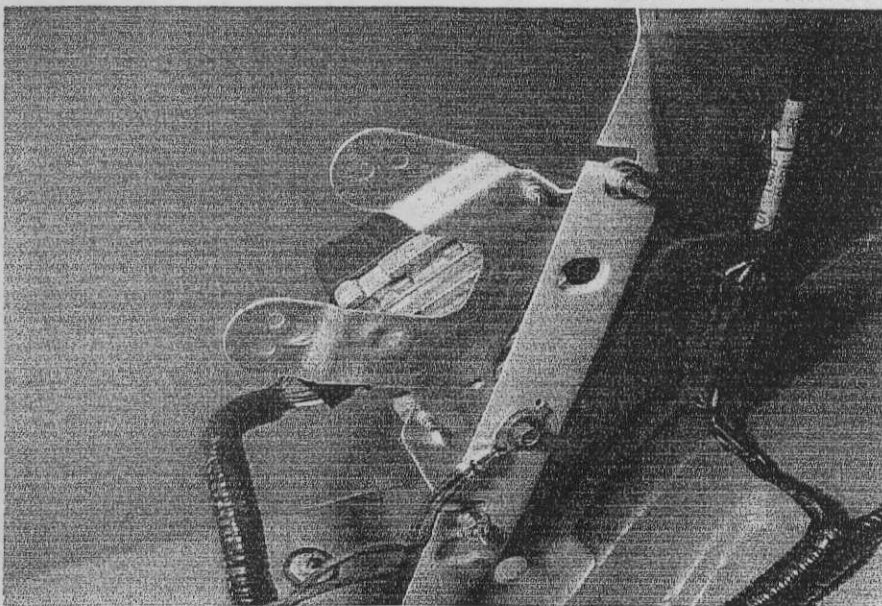


On a Taurus/Sable sedan, the fuel pump driver module is mounted behind the "C" pillar.

Ford Electronic Returnless Fuel

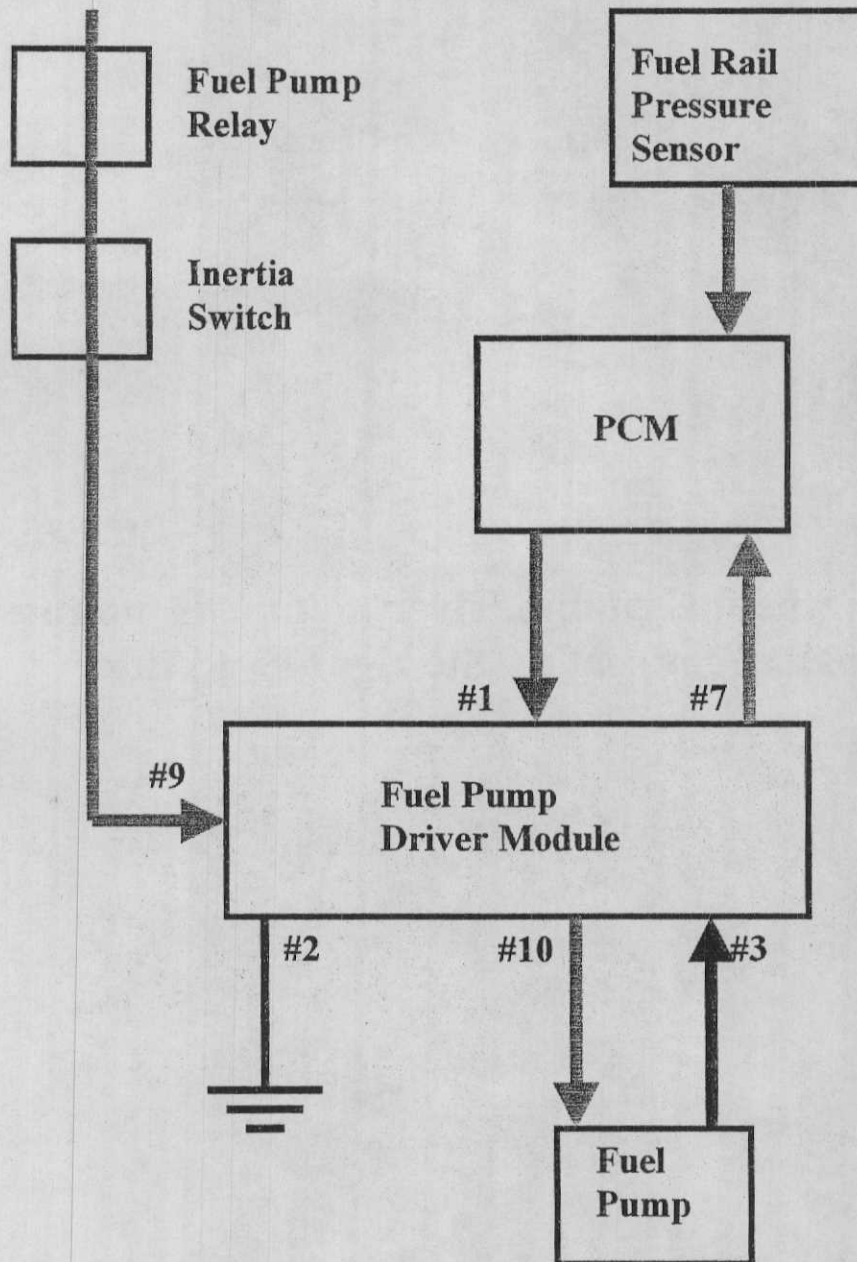


On a Focus, the fuel pump driver module is mounted under the passenger seat on the right hand side.



On a 3.8L Mustang, the fuel pump driver module is mounted in the trunk on the left hand side behind the trim panel.

Ford Electronic Returnless Fuel

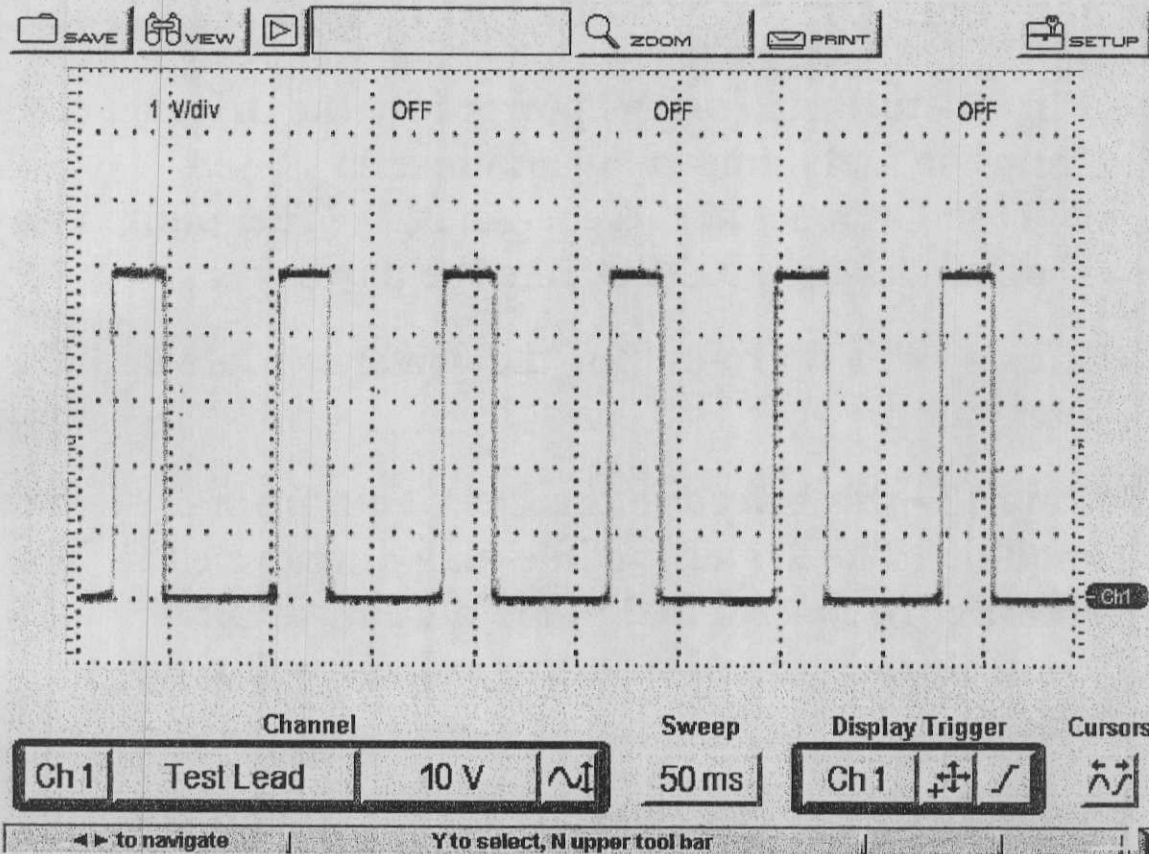


Ford Electronic Returnless Fuel

Fuel Pump Driver Module Pin Information

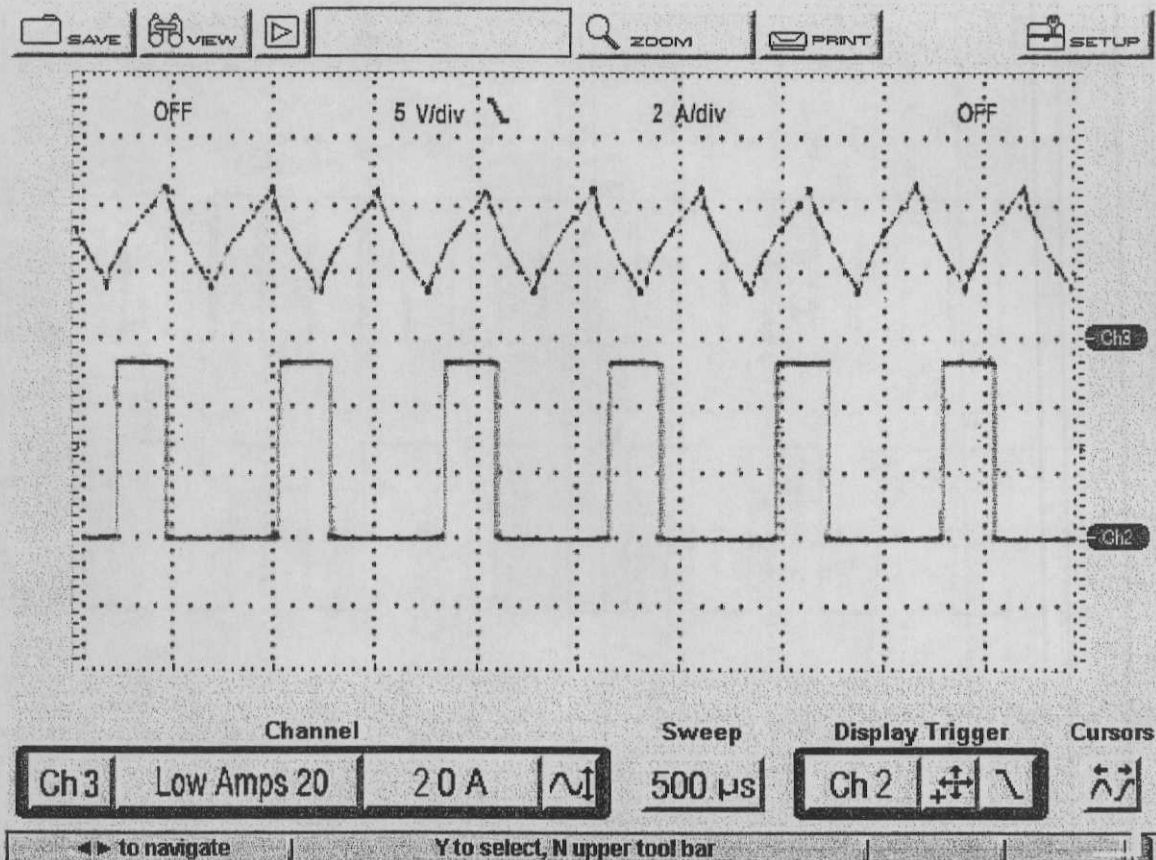
- Pin #9 - this wire brings power into the driver module from the fuel pump relay and inertia switch.
NOTE: On most of these engines, the fuel pump relay is on all the time KOEO, like the power relay.
- Pin #2 - this is ground for the driver module and the fuel pump.
- Pin #10 - this is feed to the fuel pump from the driver module. The driver module may duty cycle this line in order to control fuel pump output. If pin #3 controls the ground side, this voltage will remain steady.
- Pin #3 - this is the ground to the fuel pump from the driver module. The driver module may duty cycle this line in order to control fuel pump output. If pin #10 controls the feed side, this line will remain at ground voltage.
- Pin #1 - this is the command line from the PCM to the driver module. On this line we can see what duty cycle control the PCM is requesting. This duty cycle command can be seen on the scan tool.
- Pin #7 - this is the feedback line from the driver module to the PCM. This signal will tell the PCM if there are any faults with the fuel pump driver module.

Ford Electronic Returnless Fuel



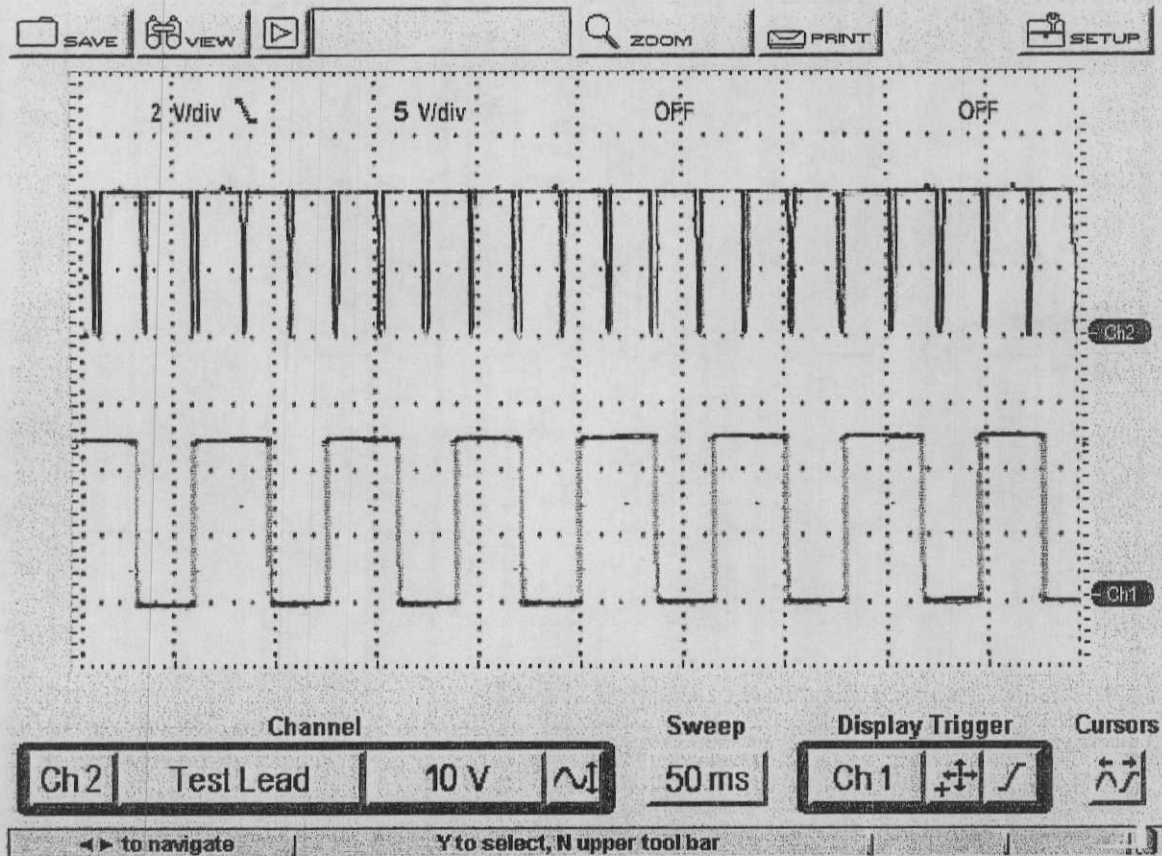
This pattern shows the fuel pump control duty cycle command from the PCM to the fuel pump driver module. The 5 volts is produced by the fuel pump driver module, and the PCM will toggle it low to produce the command. This is the command that can be seen on the scan tool.

Ford Electronic Returnless Fuel



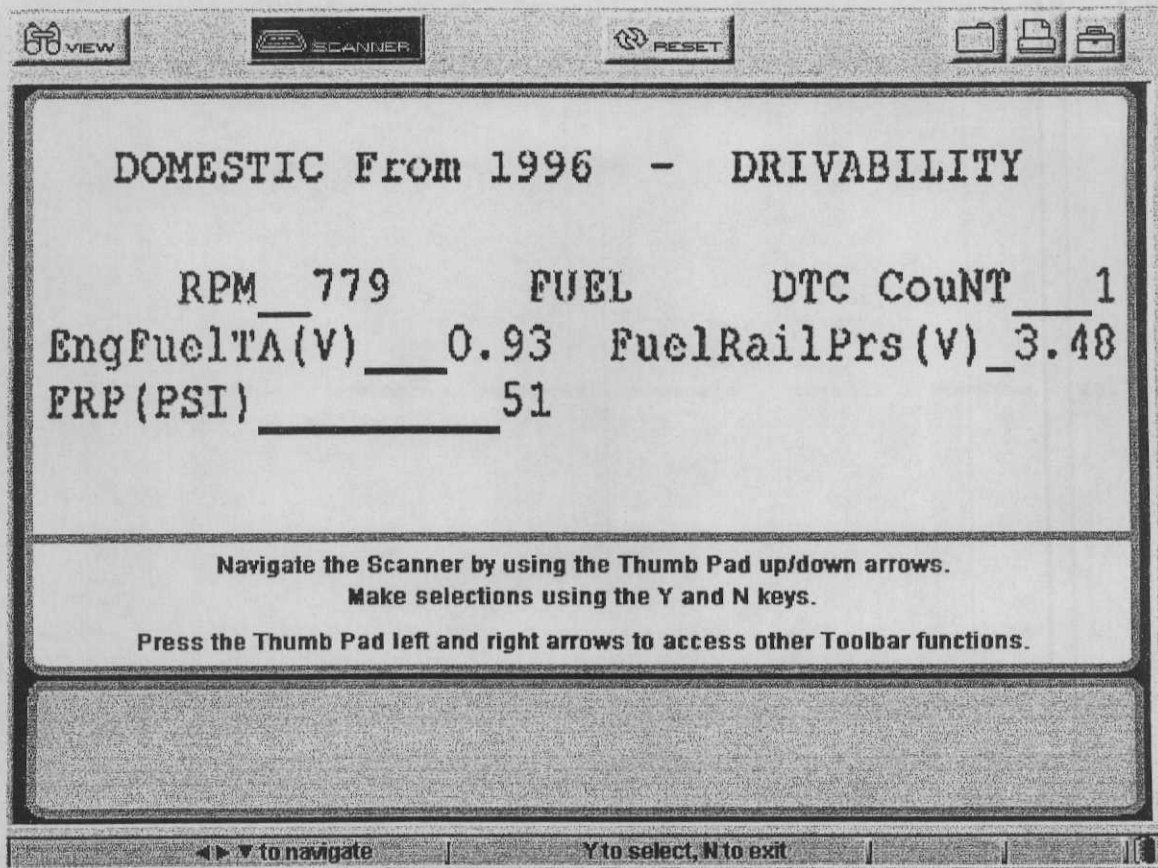
Notice the comparison between Channel 1 and Channel 2. This setting on the labscope can be used to verify the relationship between supply voltage and current draw.

Ford Electronic Returnless Fuel



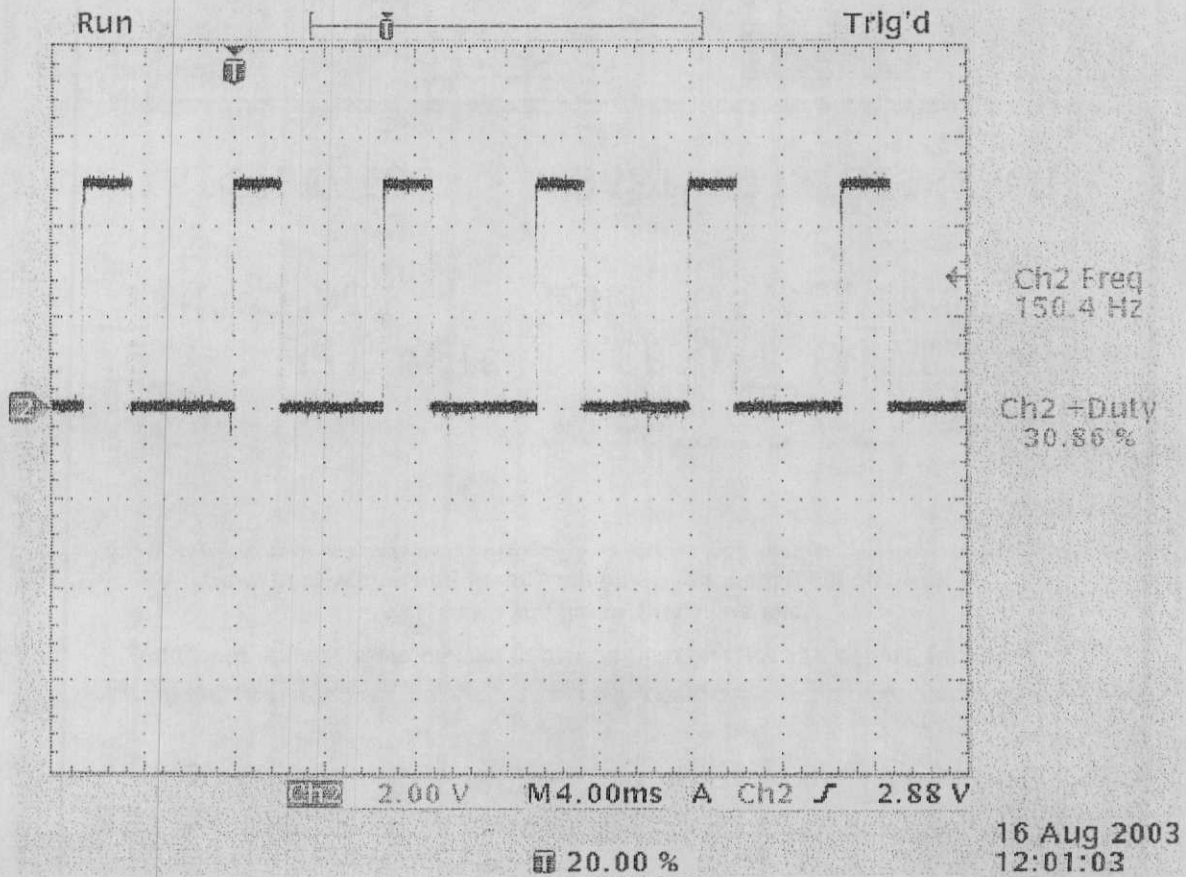
In this labscope example, fuel pump duty cycle command and the fuel pump control line can be compared for the 2 to 1 ratio.

Ford Electronic Returnless Fuel



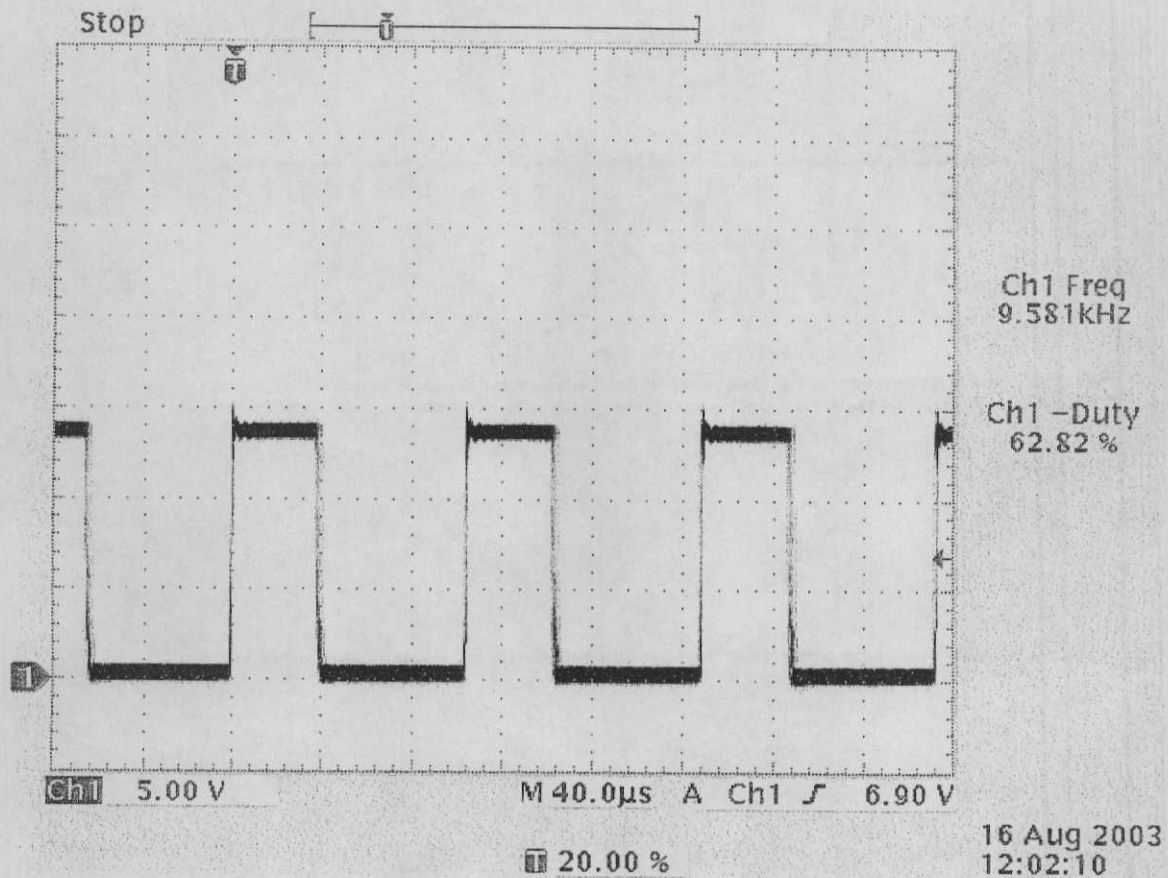
The fuel rail pressure (FRP) pid is the actual pressure across the fuel injectors (the difference between rail pressure and intake manifold pressure). It is not fuel rail pressure (which we measure with our fuel pressure gauges).

Ford Electronic Returnless Fuel



The 31% fuel pump control duty cycle command is translated to approximately 62% - 64% by the fuel pump driver module. This will be the duty cycle of the fuel pump control line.

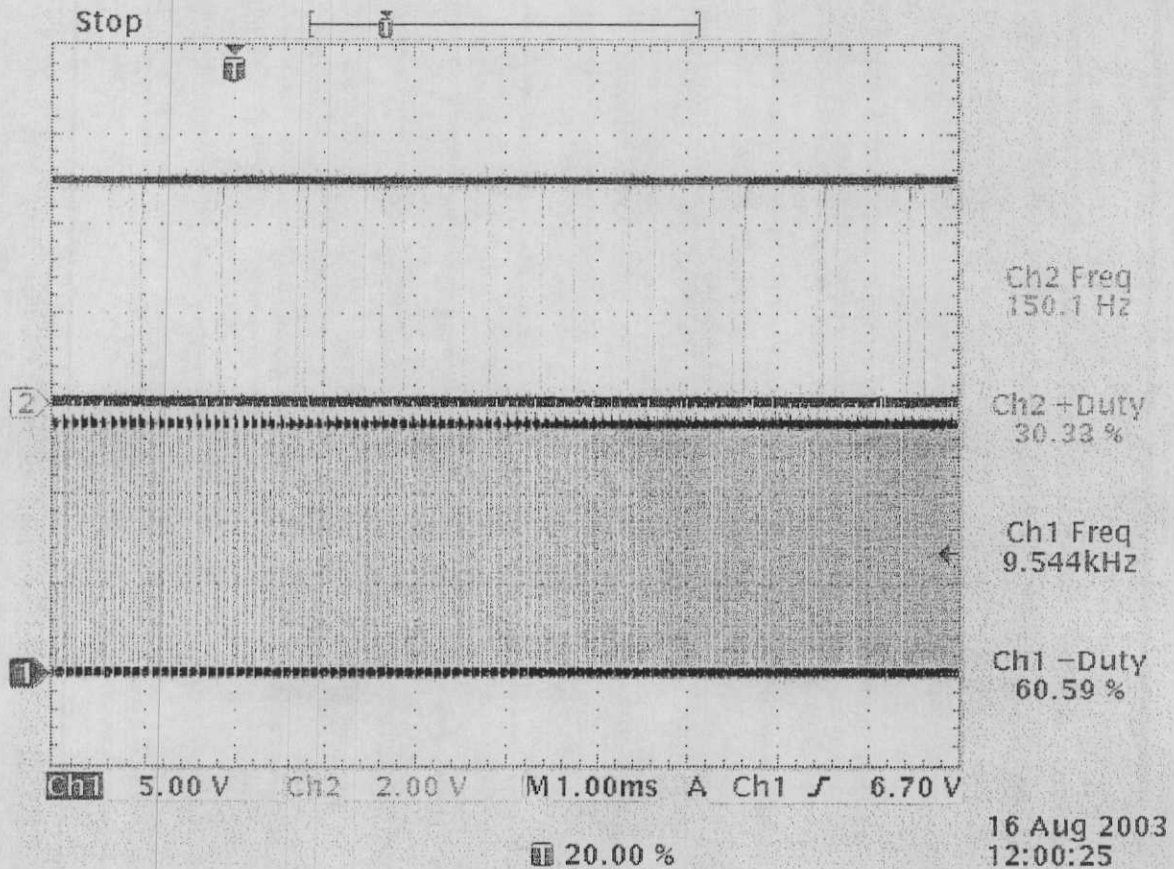
Ford Electronic Returnless Fuel



This scope pattern shows the fuel pump driver module controlling the ground side (Pin #3) of the pump.

The scope's timebase has been set to 40 microseconds/div. Check out the frequency of almost 9600 hertz! The ground side duty cycle is almost 63%.

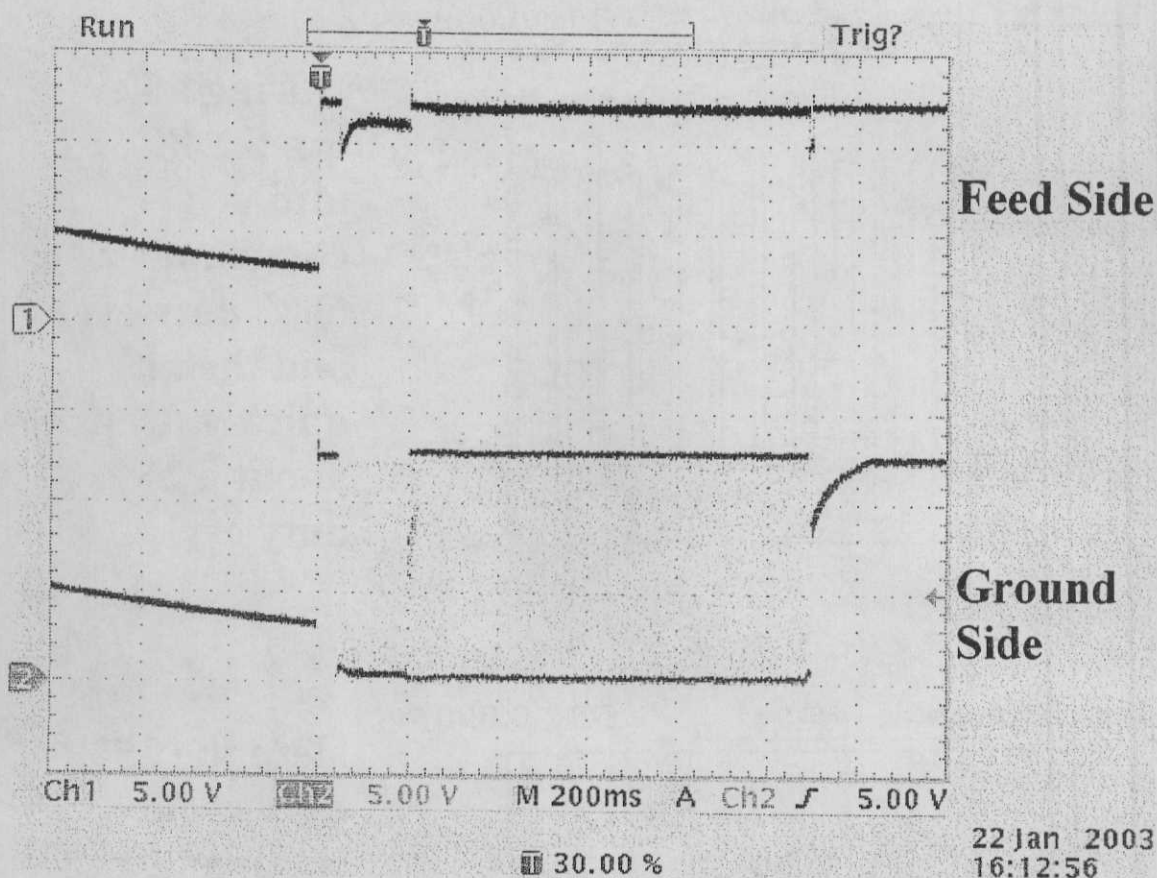
Ford Electronic Returnless Fuel



Channel 1 is connected to the fuel pump control duty cycle command line. Channel 2 is connected to the fuel pump driver module ground side control line of the fuel pump.

Multiplying the command line duty cycle of 30% times two (2) equals a pump control line duty cycle of 60%. The duty cycle ratio is 2:1.

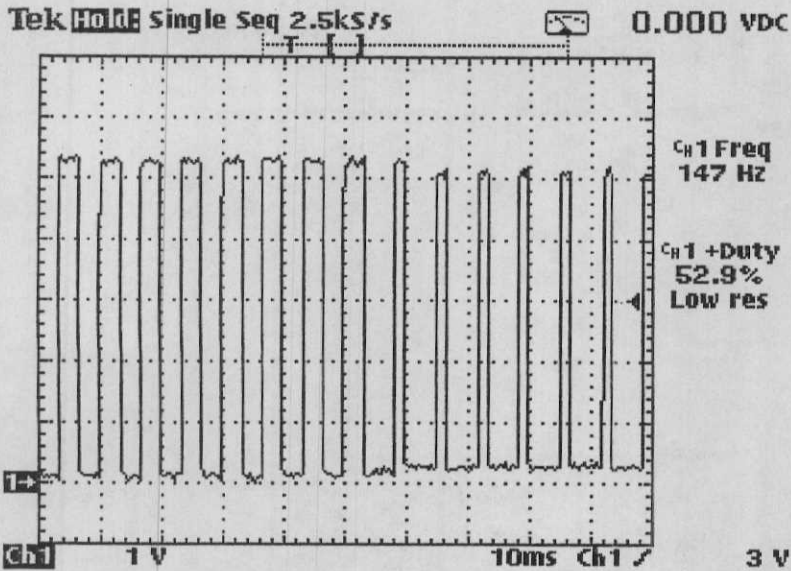
Ford Electronic Returnless Fuel



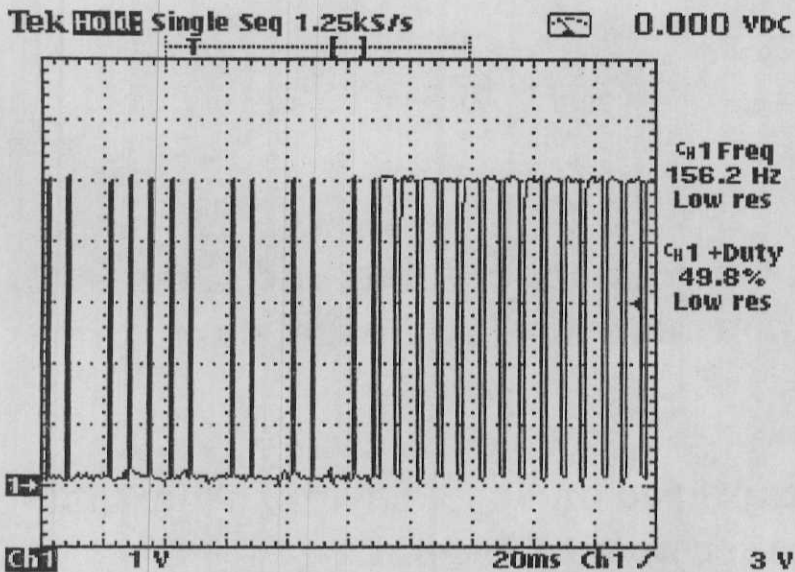
Channel 1 is on the fuel pump feed line, and Channel 2 is on the fuel pump ground line (at the fuel pump driver module).

This pattern was captured during a key up. Note that the fuel pump runs for about 1 second.

Ford Electronic Returnless Fuel




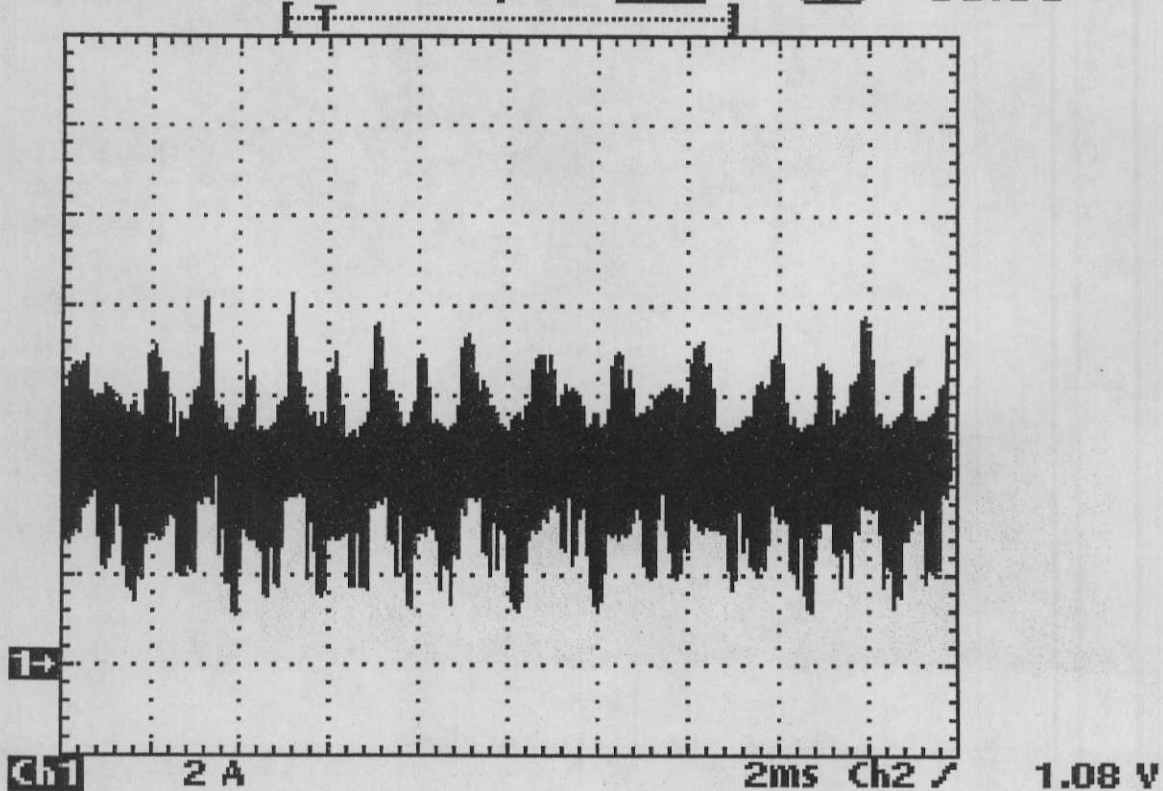
During a key up, the PCM initially commands a 50% duty cycle and then it quickly drops to about a 25% duty cycle.



Here the 25% duty cycle command is increasing to a 75% command which means pump off.

Ford Electronic Returnless Fuel

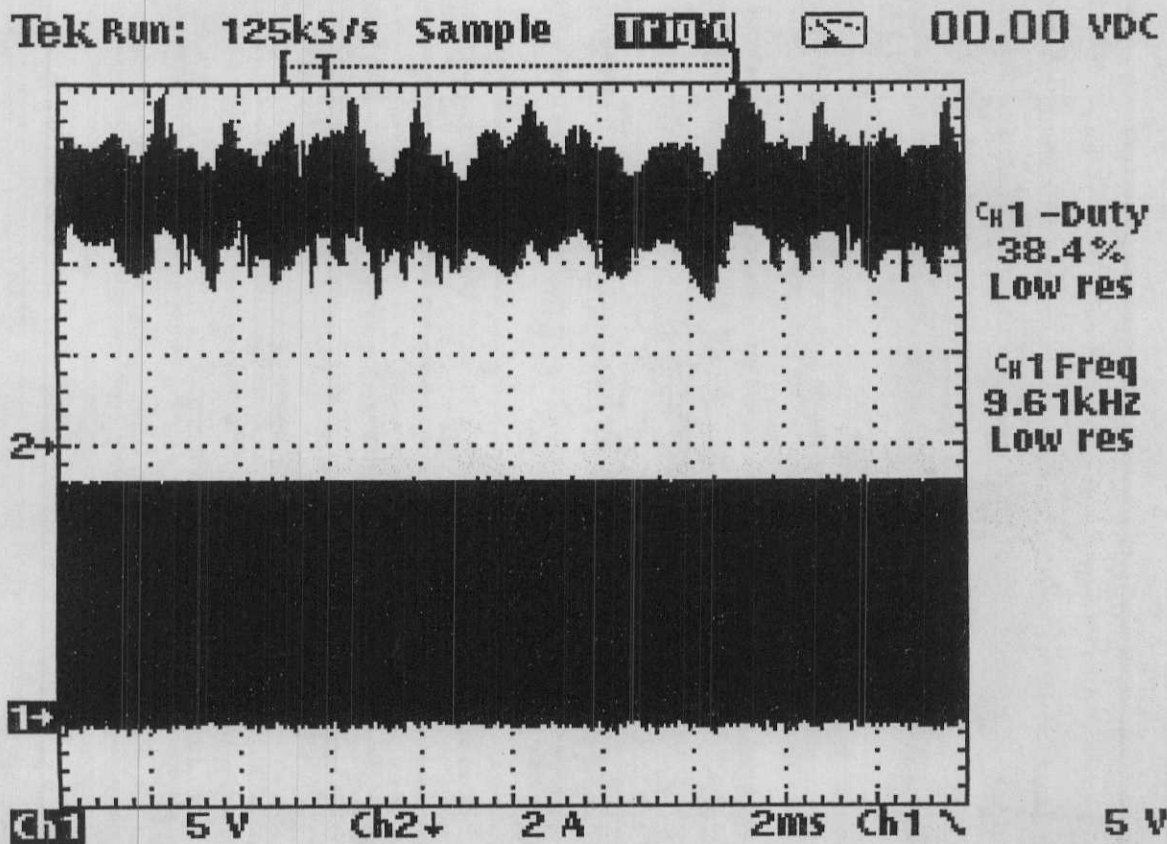
Tek Run: 125kS/s Sample AUTO  00.00 VDC



This fuel pump current pattern is from a 1999 Mustang with a 3.8L. The vertical scale (2 amps/div) and horizontal scale (2 milliseconds/div) settings chosen for this pattern are conventional when analyzing fuel pump current.

This pattern is typical of what one sees when acquiring fuel pump current between the fuel pump and the fuel pump driver module.

Ford Electronic Returnless Fuel

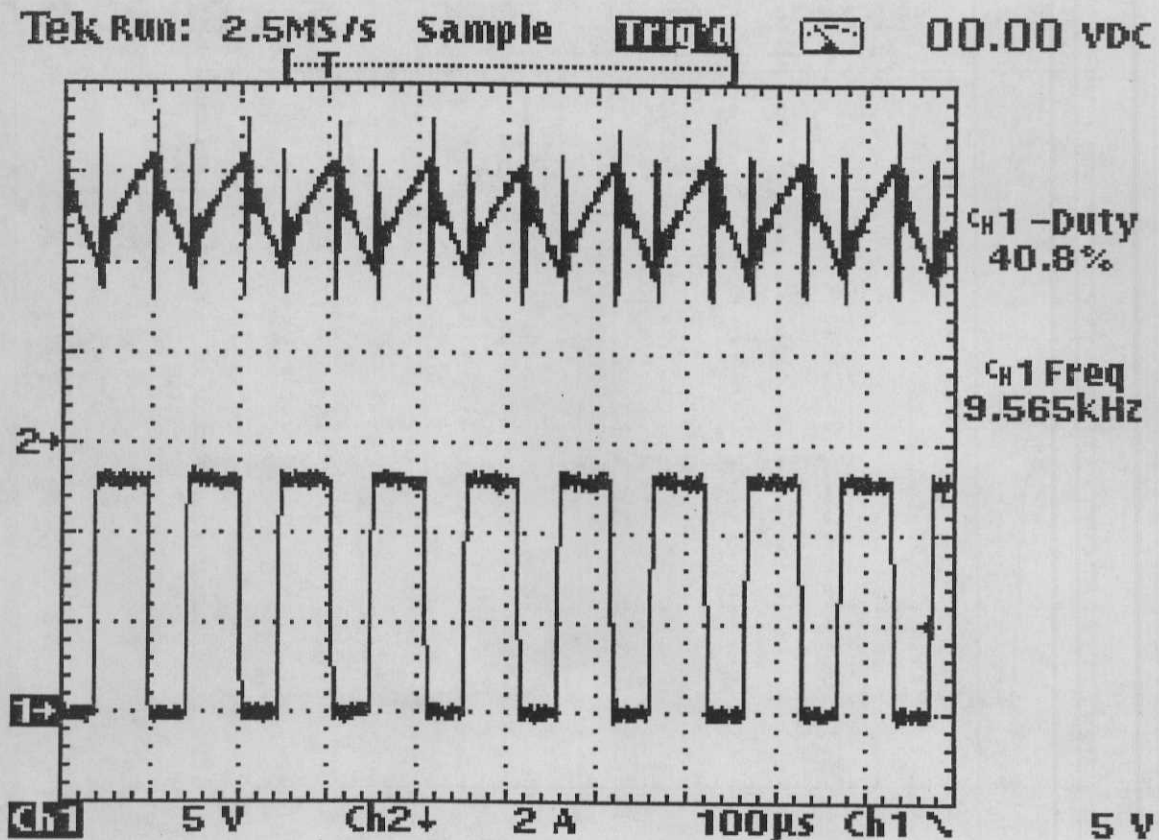


This pattern is from a 2000 Continental with a 4.6L.
This pattern will be opened up over the next 2 pages.

Channel 1 is connected to the fuel pump control line at the FPDM, and Channel 2 is connected to a current probe clamped around one of the fuel pump wires.

At this timebase, not much can be seen.

Ford Electronic Returnless Fuel

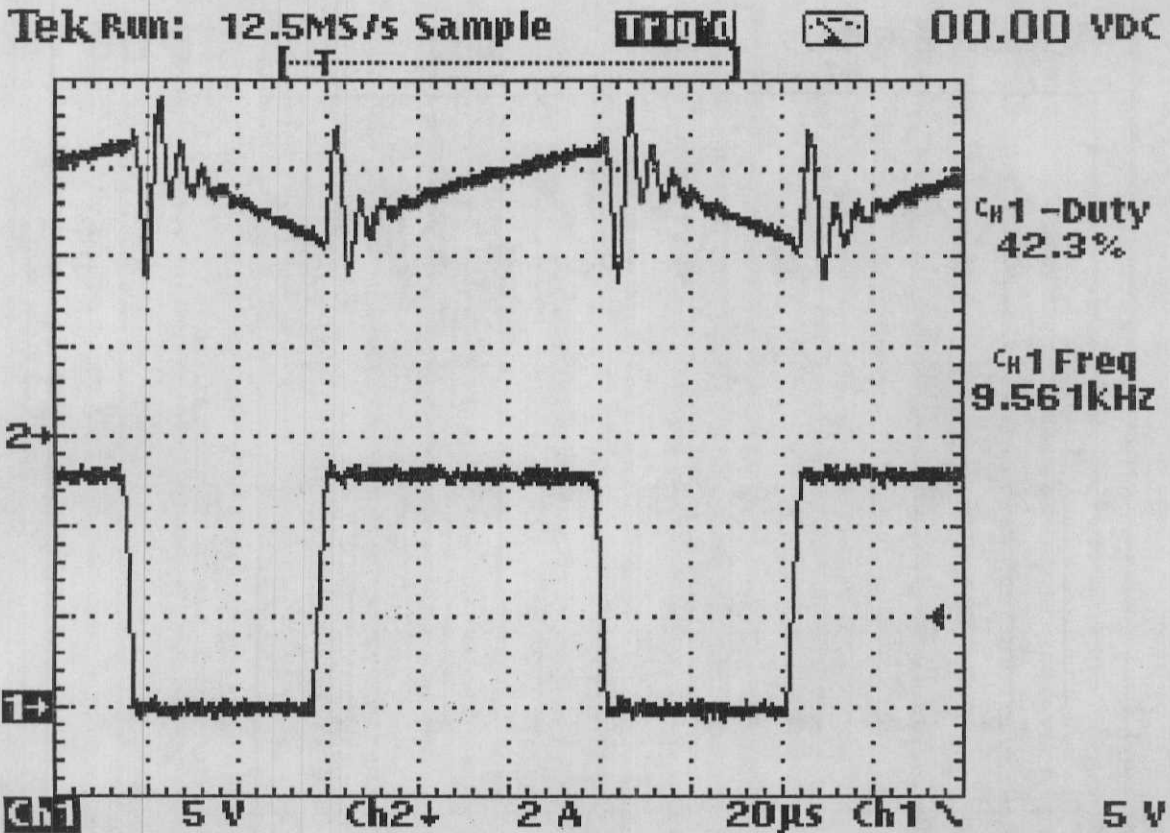


Channel 1 is connected to the fuel pump control line at the FPDM, and Channel 2 is connected to a current probe clamped around one of the fuel pump wires.

The timebase has been increased to 100 microseconds per division. The current pattern is starting to open up.

Note the fuel pump control line frequency of almost 9600 hertz.

Ford Electronic Returnless Fuel

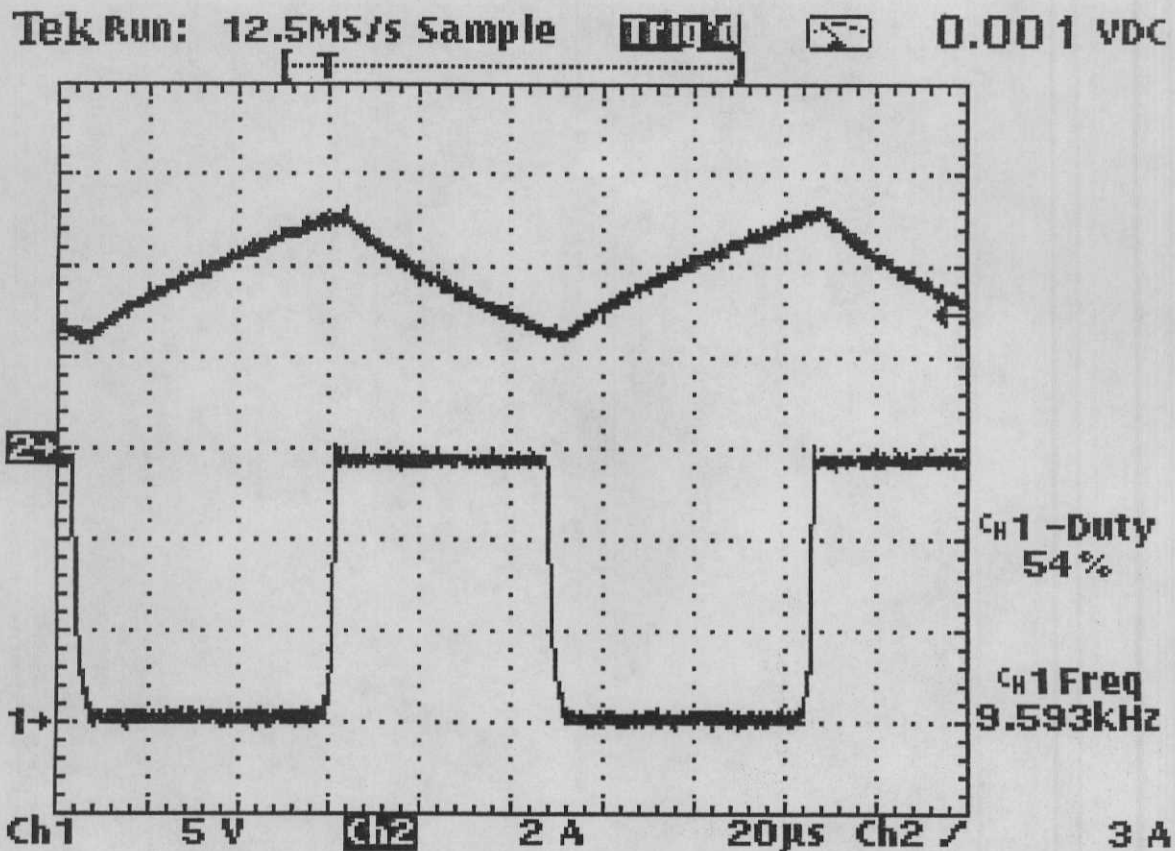


Channel 1 is connected to the fuel pump control line at the FPDM, and Channel 2 is connected to a current probe clamped around one of the fuel pump wires.

The fuel pump driver module is controlling the feed side of the fuel pump.

Note the ringing seen in the fuel pump current pattern. This is to be expected when coils of wire are turned on and off 9600 times a second.

Ford Electronic Returnless Fuel

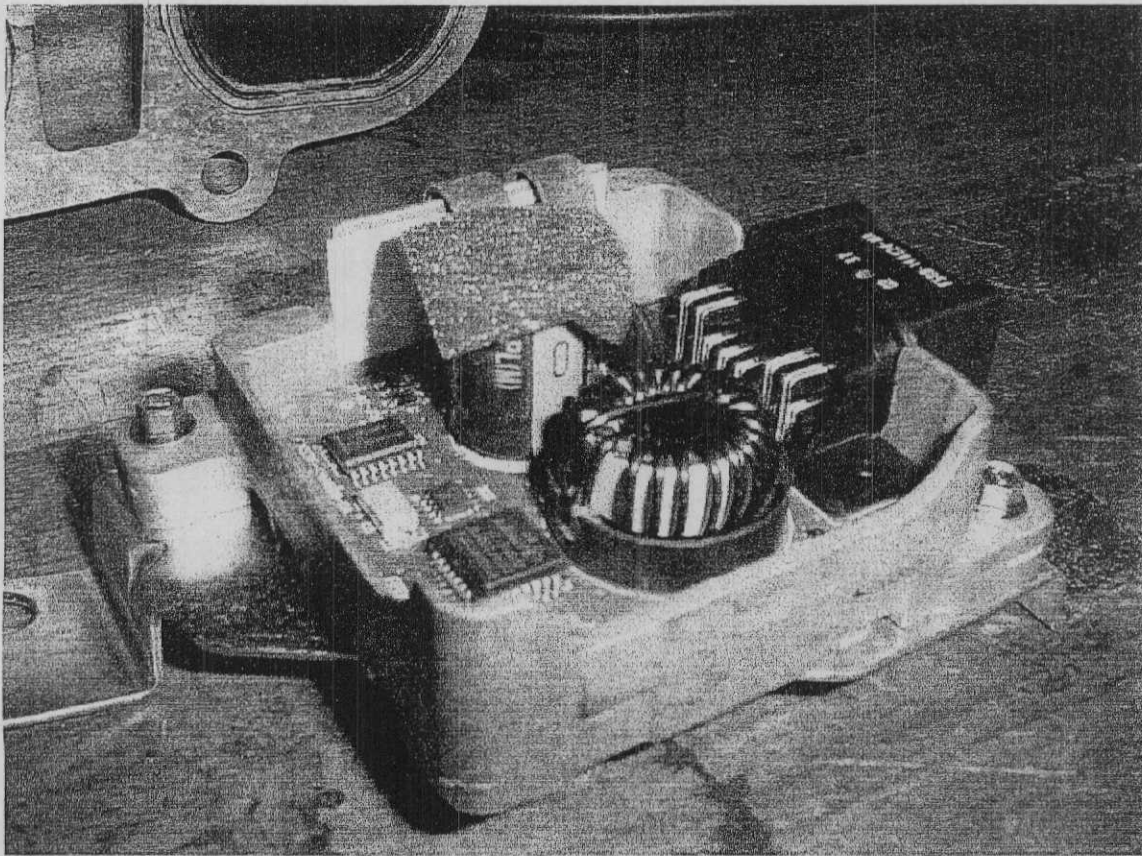


This pattern is not from the 2000 Continental.

Channel 1 is connected to the fuel pump control line at the fuel pump driver module, and Channel 2 is connected to a current probe clamped around one of the fuel pump wires.

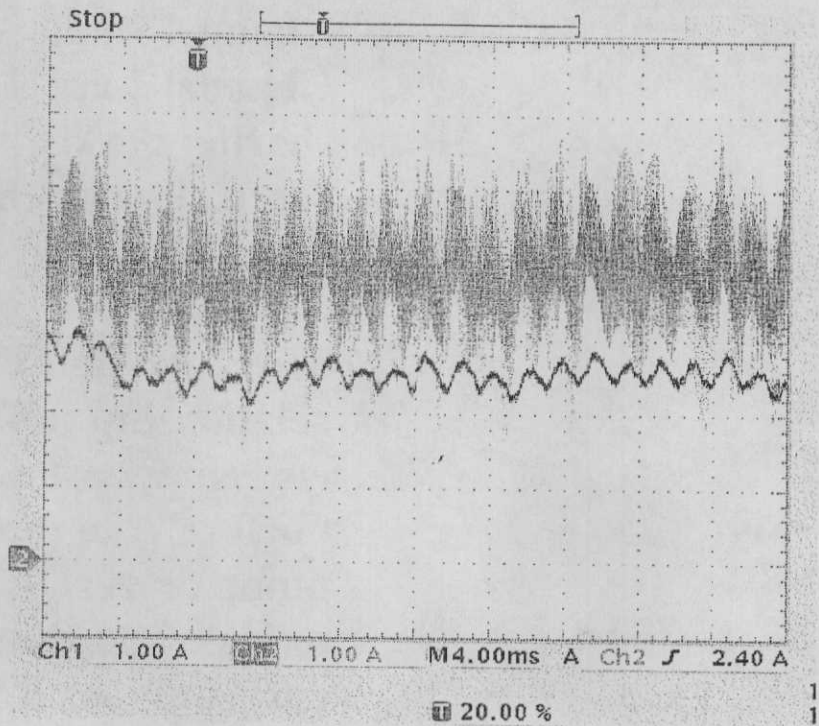
The fuel pump driver module is controlling the ground side of the fuel pump.

Ford Electronic Returnless Fuel

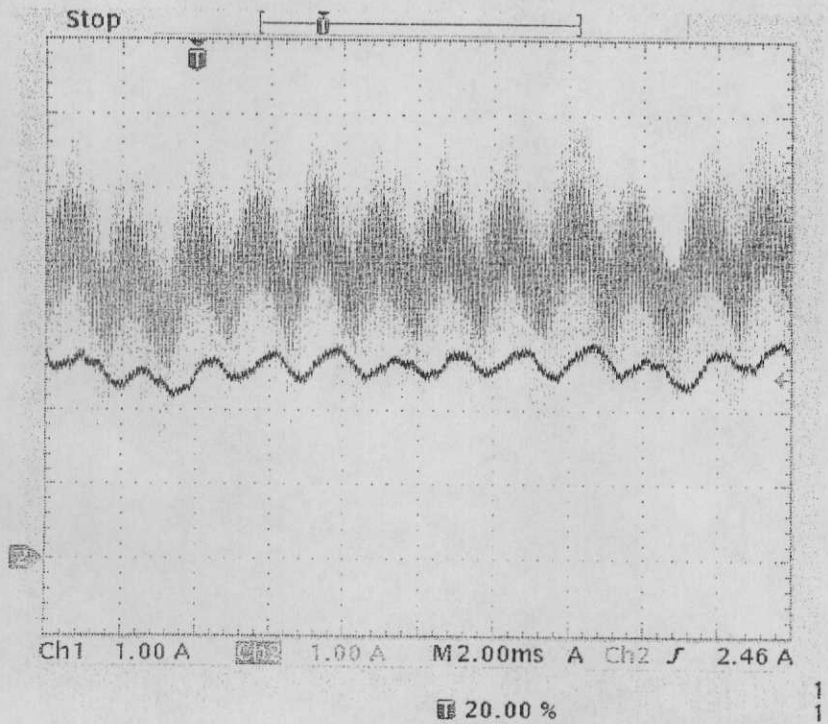


This fuel pump driver module is from a Ford Focus. Note the rather large capacitor (35 volt, 1800 microfarad) and the toroid coil next to it.

Ford Electronic Returnless Fuel



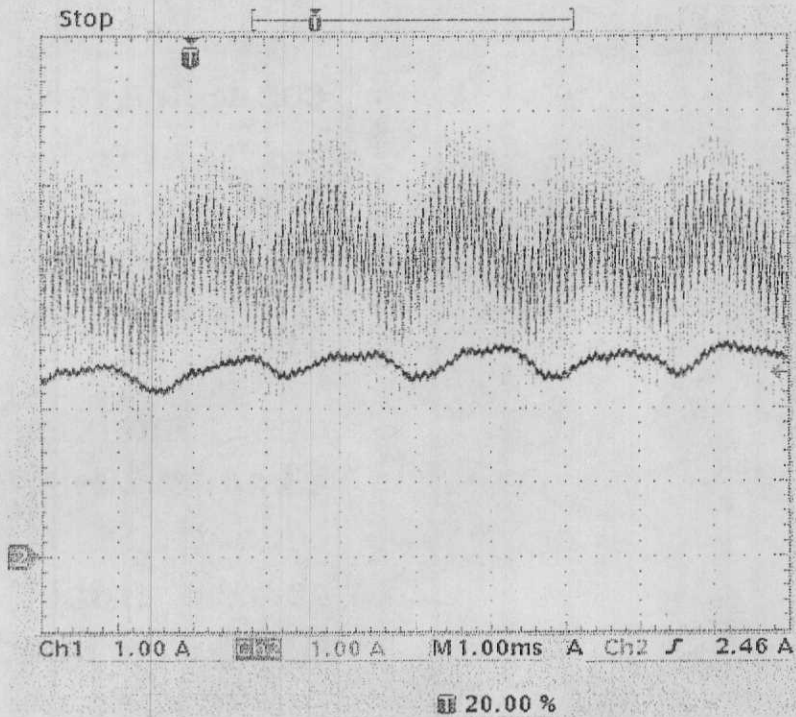
Channel 1 is connected to a current probe clamped around the fuel pump feed wire at the fuel pump driver module. Channel 2 is connected to a current probe clamped around the fuel pump driver module feed.



The timebase has been changed from 4 millisec/div to 2 millisec/div.

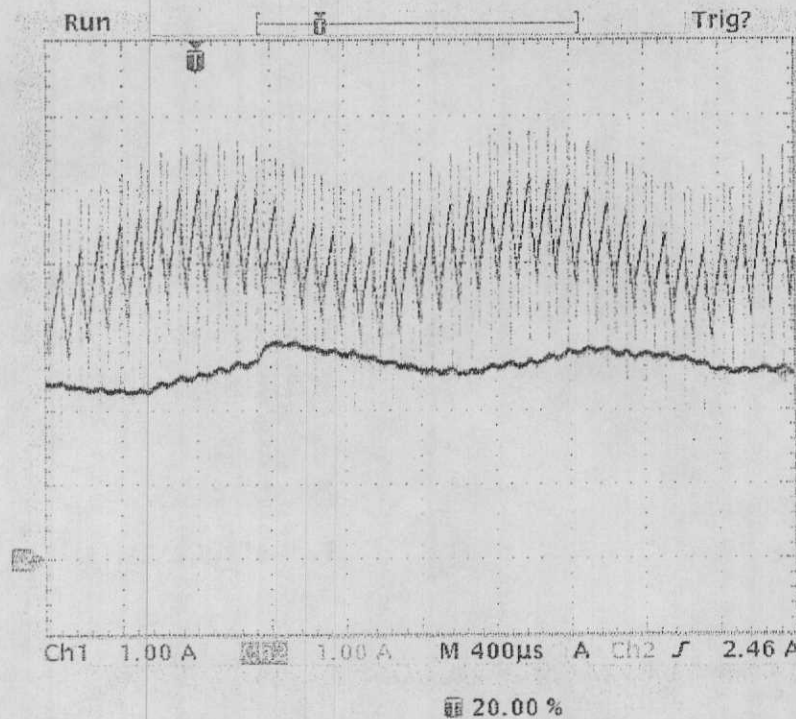
Note the relationship.

Ford Electronic Returnless Fuel

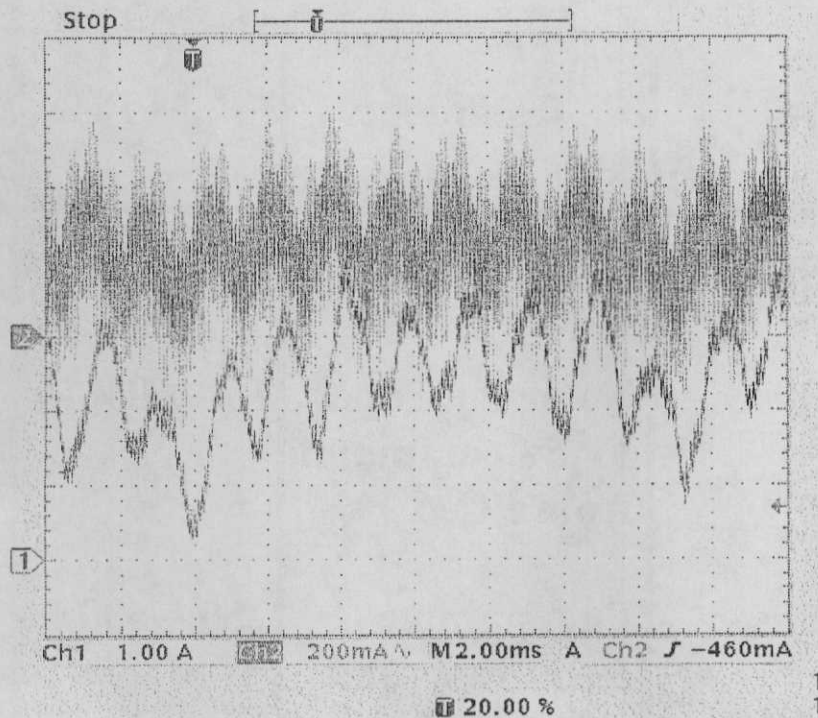


Channel 1 and Channel 2 are sharing the same "zero" line on the scope.

There is a definite relationship to the current measured "before" the fuel pump driver module and the current measured "after" the fuel pump driver module.

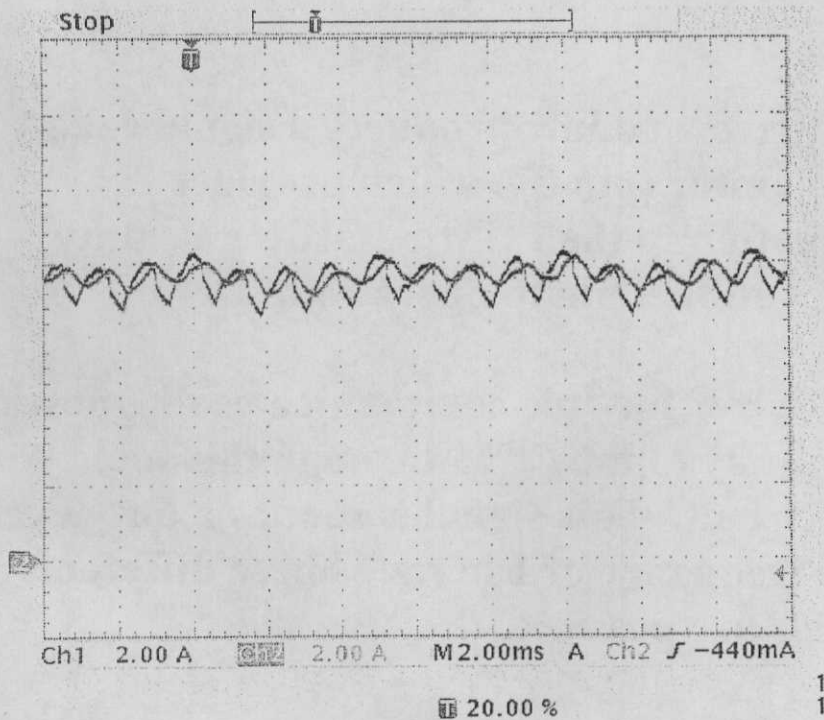


Ford Electronic Returnless Fuel



Channel 1 has been AC coupled so as to better compare current humps of the fuel pump motor.

This provides a reliable method to measure fuel pump rpm.



The scan tool has been used to command the fuel pump to run at full speed (50% fuel pump control duty cycle).

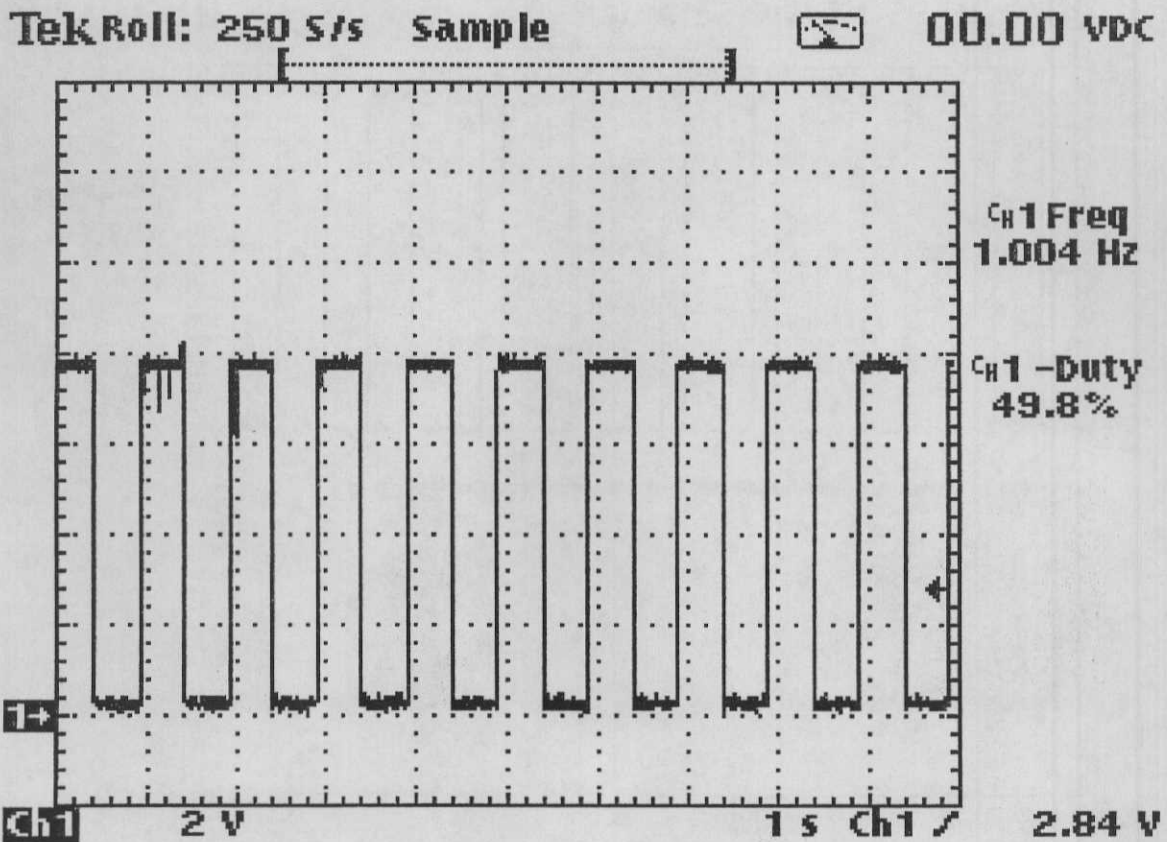
Ford Electronic Returnless Fuel

Duty Cycle	On-time (milliseconds)	Comments	FP_M PID
50%	500 millisec	All Ok	80 – 125%
25% (high)	250 millisec	No or improper FP % command from PCM	15 – 60%
75% (high)	750 millisec	Fuel pump feed or ground side switching fault	250 – 400 %

The fuel pump driver module produces a signal called the fuel pump monitor (pin #7) which provides feedback information to the PCM regarding its duty cycle command and fuel pump operation.

The fuel pump driver module communicates diagnostic information digitally to the PCM through this fuel pump monitor circuit. This signal is sent as a duty cycle input at a fixed frequency of 1 hertz. Three different duty cycle signals are possible.

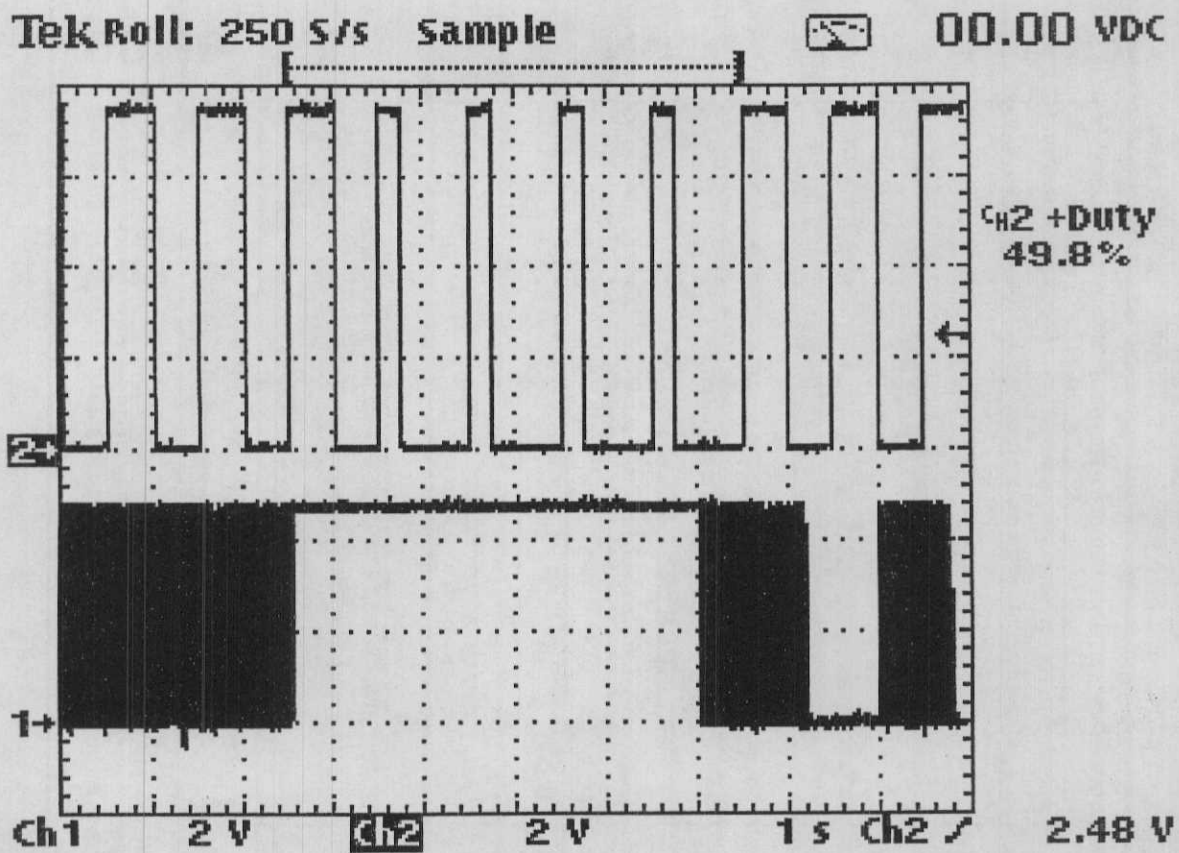
Ford Electronic Returnless Fuel



This pattern shows a known good (1 hertz, 50% duty cycle) fuel pump monitor (FPM) signal. Note the 8 volt amplitude.

The PCM receives diagnostic information (feedback) from this signal. If there is a problem, the FPM signal duty cycle will change.

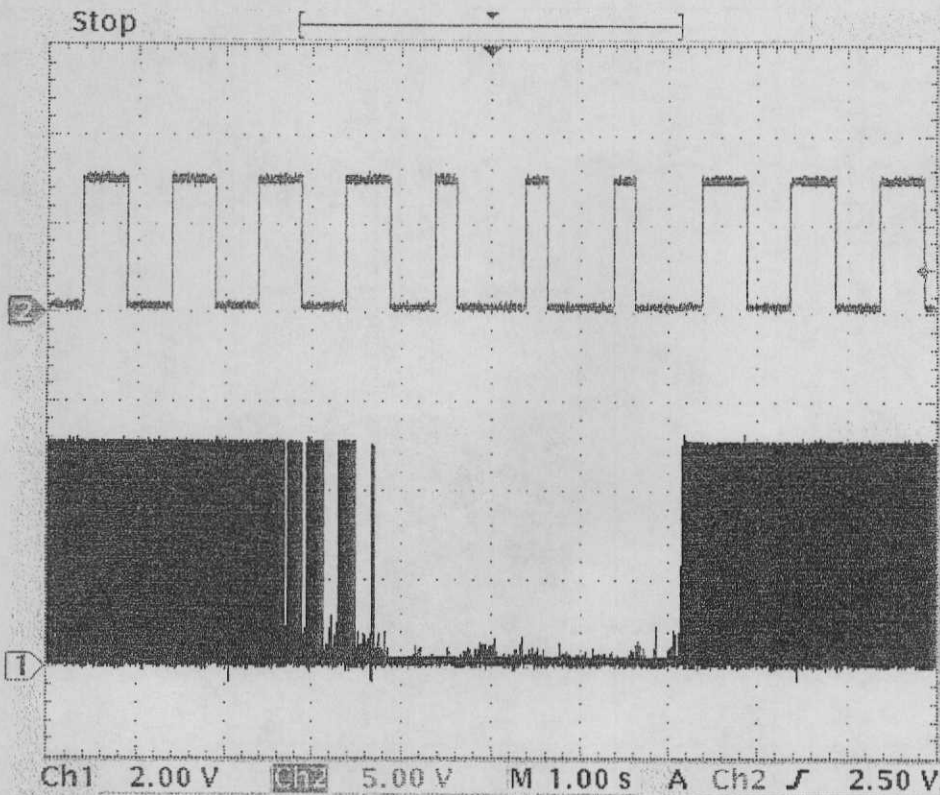
Ford Electronic Returnless Fuel



This pattern shows a problem occurring. Note the duty cycle change (from 50% to 25%) in the fuel pump monitor signal. There are 4 pulses with a 25% duty cycle. This indicates a fault to the PCM.

At times the fuel pump control duty cycle command line (Pin #1) was not being pulled to ground by the PCM.

Ford Electronic Returnless Fuel

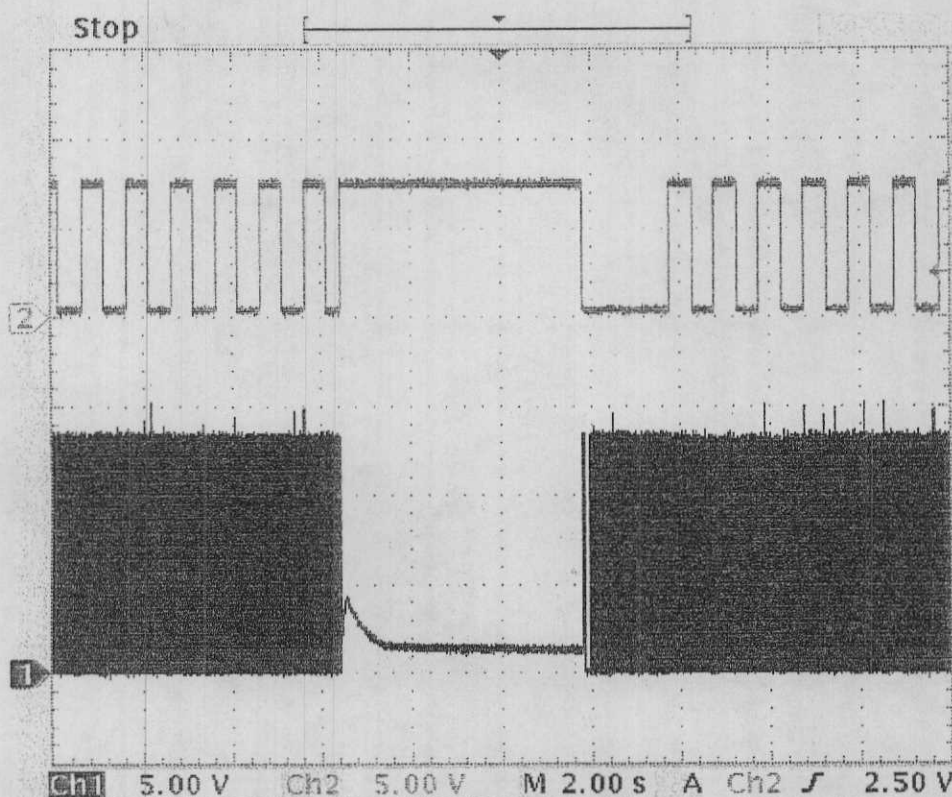


17 Aug 2003
12:46:03

Channel 1 is connected to the fuel pump control duty cycle line, and Channel 2 is connected to the fuel pump monitor line.

As the fuel pump control duty cycle line is shorted to ground, the fuel pump monitor signal duty cycle changes from 50% to 25%.

Ford Electronic Returnless Fuel



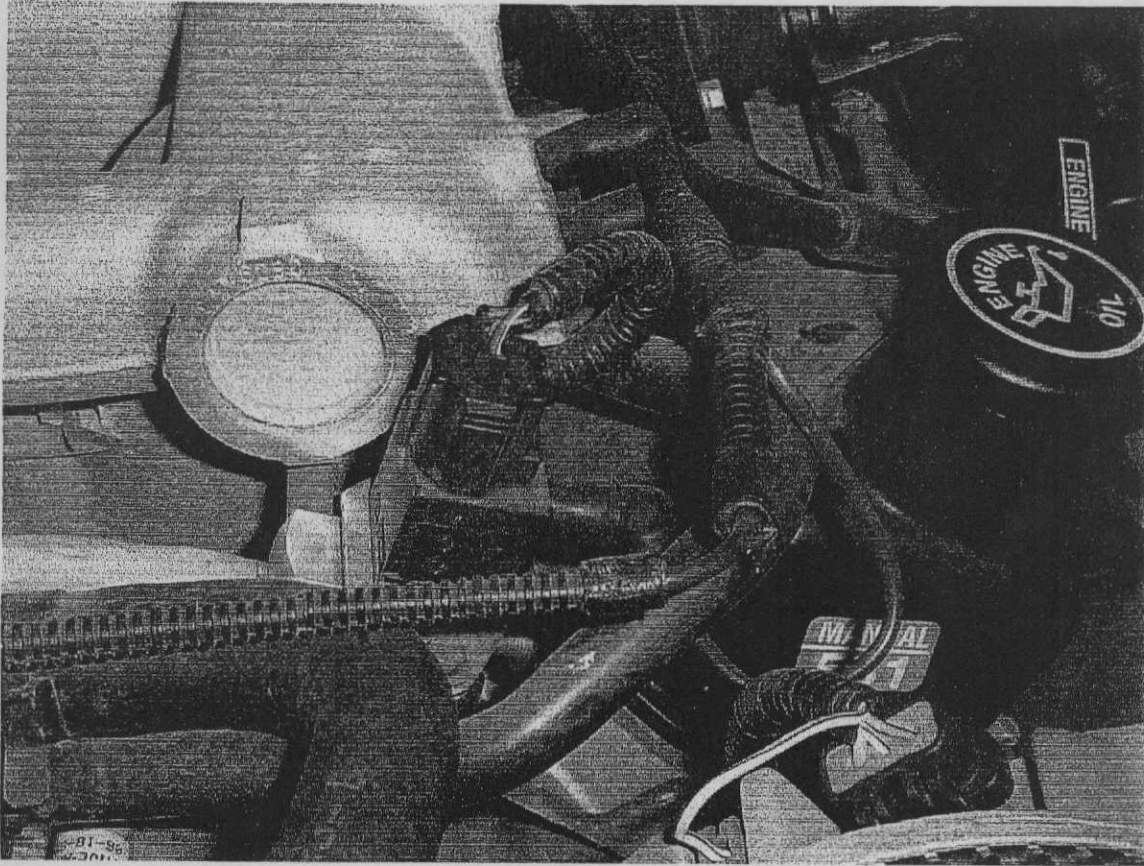
17 Aug 2003
12:54:07

Channel 1 is connected to the fuel pump ground line, and Channel 2 is connected to the fuel pump monitor line.

The fuel pump fuse was pulled for about 6 seconds. Note how the PCM produced 8 volts for the fuel pump monitor circuit stayed high.

Ford Electronic Returnless Fuel

Fuel Rail Pressure Sensor



The FRP sensor is a 3 wire pressure transducer that senses the pressure difference between the fuel rail and the intake manifold (the pressure dropped across the fuel injector). A manifold vacuum hose is attached to the FRP so it can compensate for changes in manifold vacuum.

Ford Electronic Returnless Fuel

Fuel Rail Pressure Sensor

Known good examples:

1. 2000 Lincoln Continental 4.6L

- gauge fuel pressure – 30 psi
- FRP pid – 39 psi
- FRP voltage – 2.7
- FP duty cycle – 25%

- gauge fuel pressure – 52 psi
- FRP pid – 59 psi
- FRP voltage – 3.9
- FP duty cycle – 34%

2. 2000 Escort 2.0L

- gauge fuel pressure – 30-31 psi (with vacuum)
- FRP pid – 39-40 psi (with vacuum)

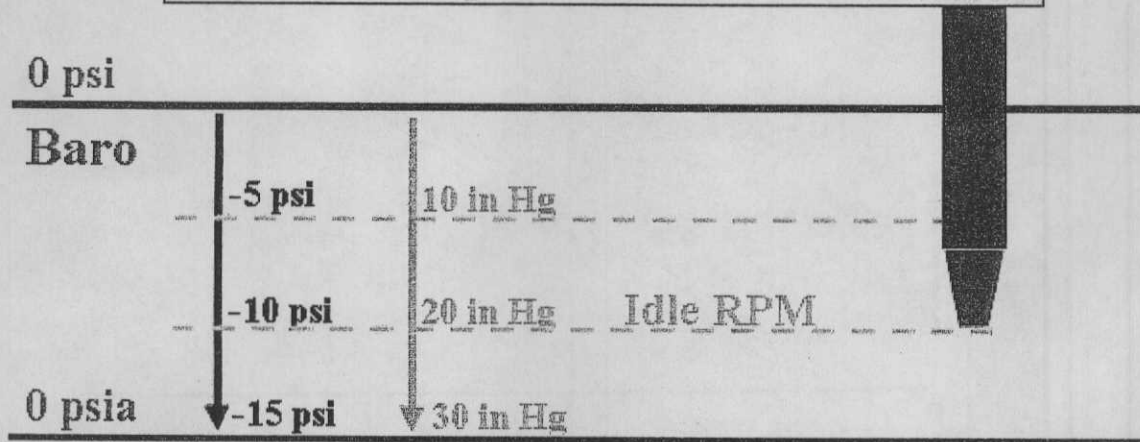
- gauge fuel pressure – 40-41 psi (without vacuum)
- FRP pid – 39-40 psi (without vacuum)

Ford Electronic Returnless Fuel

What is the fuel pressure across the fuel injector?

$$30 \text{ psi} - (-10 \text{ psi}) = 40 \text{ psi}$$

30 psi in Fuel Rail

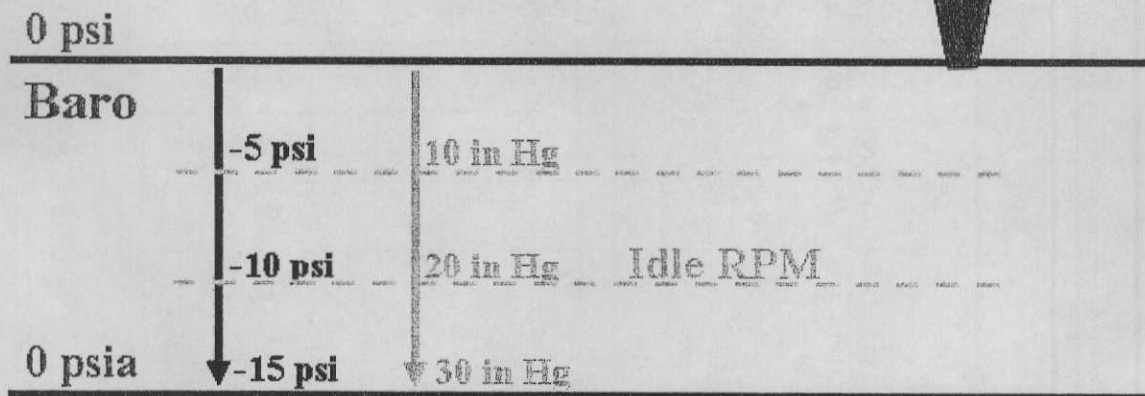


Absolute Pressure Reference

What is the fuel pressure across the fuel injector?

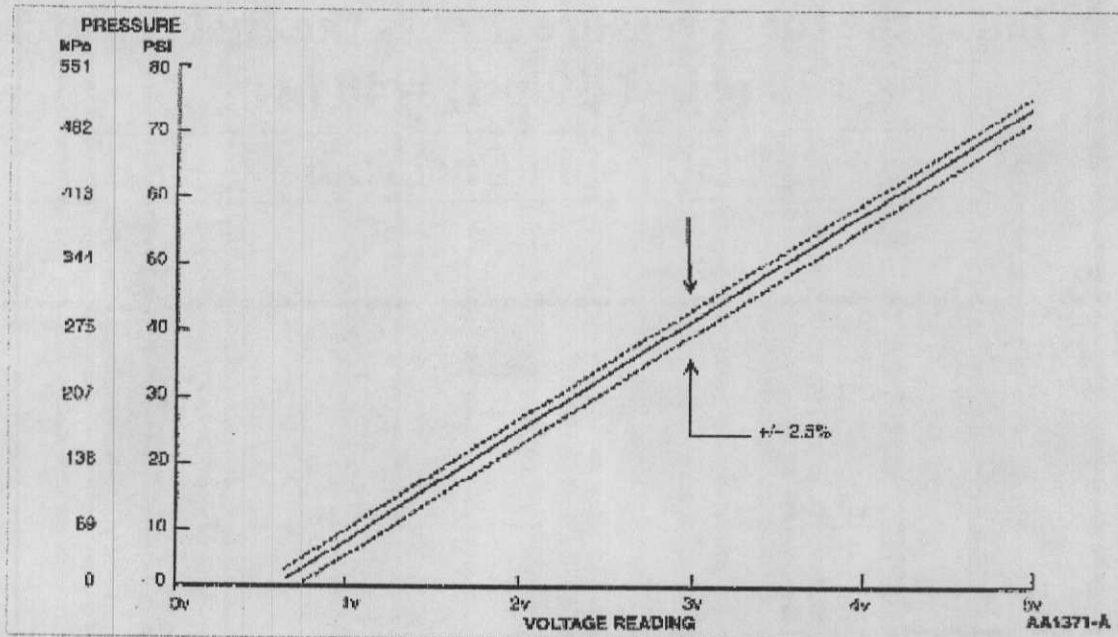
40 psi in Fuel Rail

$$40 \text{ psi} - 0 \text{ psi} = 40 \text{ psi}$$



Absolute Pressure Reference

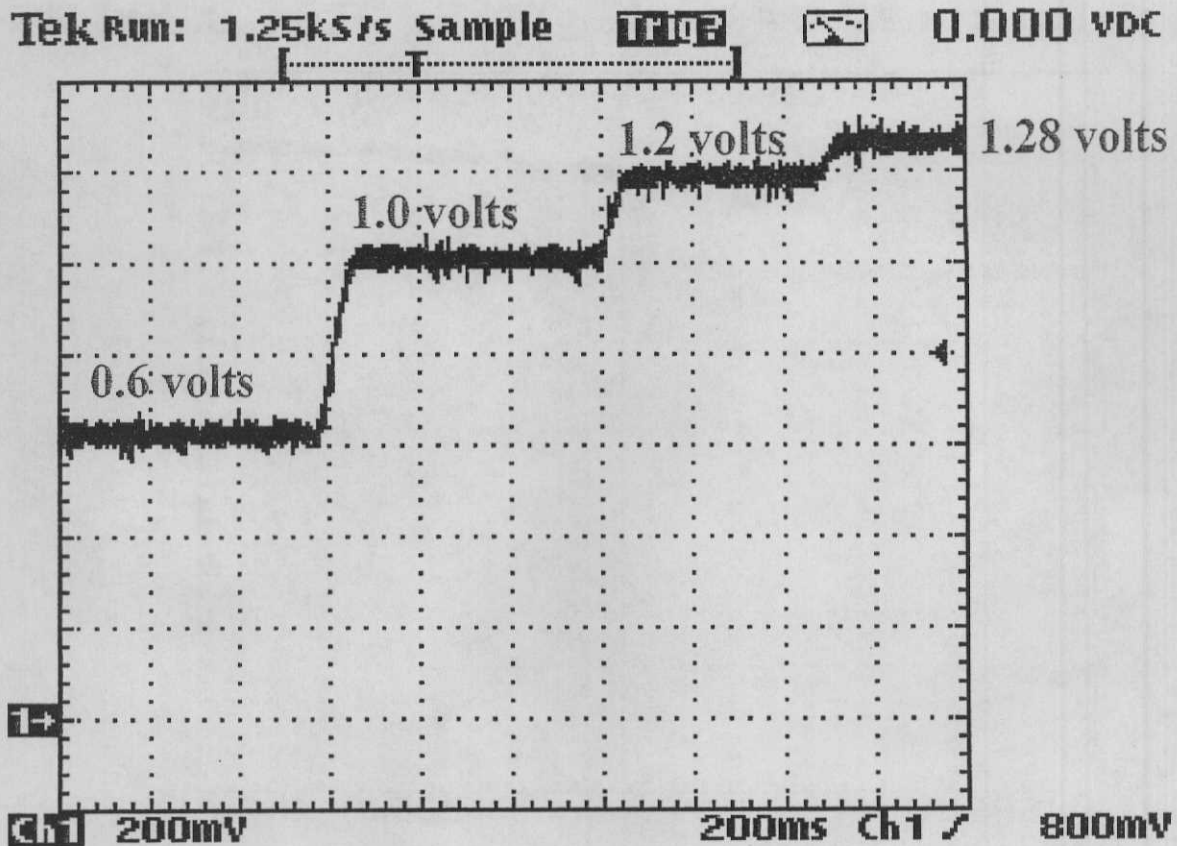
Ford Electronic Returnless Fuel



FUEL RAIL PRESSURE SENSOR EXPECTED VOLTAGE

Voltage (dcv)	Pressure (kPa)	Pressure (psi)
4.5	482	70
3.9	413	60
3.4	344	50
2.8	275	40
2.2	207	30
1.6	138	20
1.1	69	10
0.5	0	0

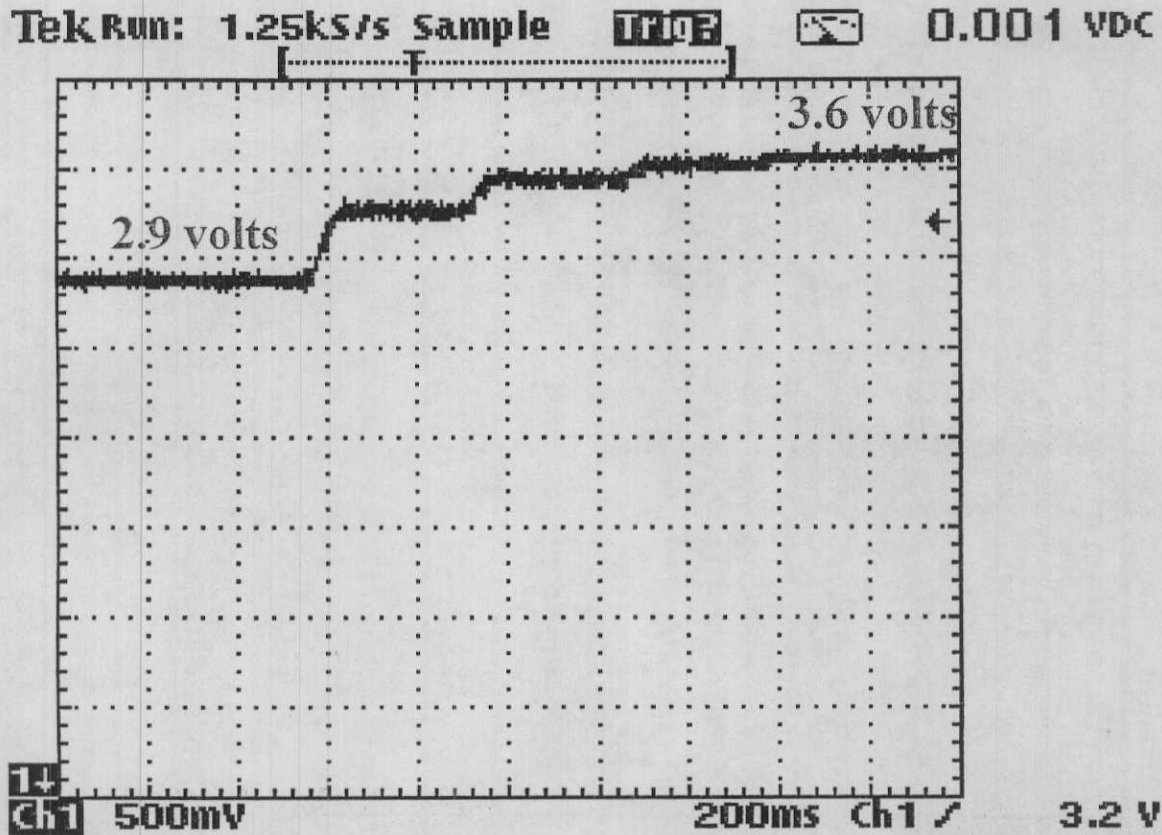
Ford Electronic Returnless Fuel



Channel 1 has been connected to the signal line of the fuel rail pressure transducer. There is no fuel pressure in the rail. A Mityvac has been connected to the transducer's vacuum nipple. Approximately 25 in. of Hg (12.5 psi) has been applied to the transducer.

0.6 volts – 0 psi
1.28 volts – 12-13 psi

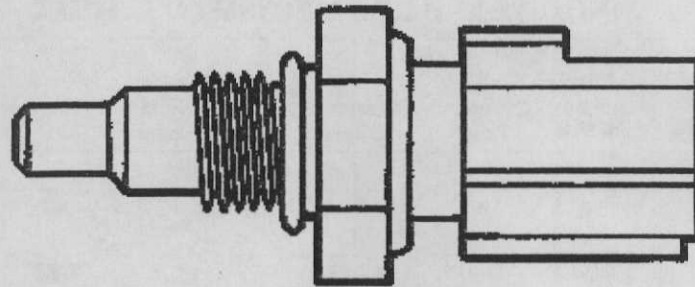
Ford Electronic Returnless Fuel



Channel 1 has been connected to the signal line of the fuel rail pressure transducer. There is approximately 40 psi in the fuel rail. A Mityvac has been connected to the transducer's vacuum nipple. Approximately 25 in. of Hg (12.5 psi) has been applied to the transducer.

2.9 volts – 40 psi
3.6 volts – 52.5 psi

Ford Electronic Returnless Fuel



Engine Fuel Temperature Sensor

ENGINE FUEL TEMPERATURE SENSOR VOLTAGE AND RESISTANCE SPECIFICATIONS

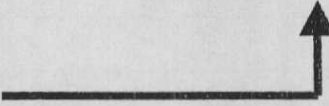
Temperature		Engine Fuel Temperature (EFT) Sensor Values	
°C	°F	Voltage (volts)	Resistance (K ohms)
150	302	0.13	0.56
135	275	0.19	0.81
120	248	0.27	1.18
110	230	0.35	1.55
100	212	0.46	2.07
90	194	0.60	2.80
80	176	0.78	3.84
70	158	1.02	5.37
60	140	1.33	7.70
50	122	1.70	10.97
40	104	2.13	16.15
30	86	2.60	24.27
20	68	3.07	37.30
10	50	3.51	58.75
-40	-40	4.54	92.5

1998 Continental

Ford Electronic Returnless Fuel

2000 MY Fuel Pressure Chart

Engine Application	Part Number 9F 593	Connector Color	Resistance Ohms	Flow Lb./Hr.	Fuel System	KOEO Pressure kPa	KOEO Pressure PSI	Bosch Denso Siemens Visteon
Car:								
2.0L 2V Focus	YS4E-A5A	Ivory	13.8-15.2	17	3	240-380	35-55	B
2.0L 4V Focus	XS4U-AA	Gray	11.4-12.6	21	3	240-380	35-55	B
2.0L Escort ZX2	XS4U-AA	Gray	13.8-15.2	17	3	240-380	35-55	B
2.5L Contour/Mystique/Cougar	XS2E-A5C	Ivory	13.8-15.2	17	3	240-380	35-55	B
2.5L Contour FFV	XS2E-C5A	Green	13.8-15.2	19	3	240-380	35-55	B
2.5L Contour SVT	XS2E-C5A	Green	13.8-15.2	19	3	240-380	35-55	B
3.0L 2V Taurus/Sable	YF1E-FC	Gray	11-18	14	3	207-310	30-45	D
3.0L Taurus FFV E22 (4V)	XF1E-C5A	Fuschia	13.8-15.2	24	3	240-380	35-55	B
3.0L Taurus/Sable FFV EB5	F6DE-A2B	Blue/Green	11-18	25	3	207-310	30-45	D
3.0L 4V Taurus	YF1E-A2C	Dark Gray	11-18	22	3	240-380	35-55	D
3.0L Lincoln LS6	XW4E-A5C	Gray/Black	13-16	24	3	240-380	35-55	B
3.8L Mustang	YR3E-A4A	Gold	9-16	21	3	240-380	35-55	V
3.9L Lincoln LS8	XW43-CA	Black	11.4-12.6	21	3	240-380	35-55	S
4.6L Crown Victoria/Grand Marquis/Town Car	XL2E-C5A	Orange	11-18	19	1	207-310	30-45	B
4.6L 2V Mustang	F0TE-D5B	Yellow/Black	11-18	19	3	207-310	30-45	B
4.6L 4V Mustang/Continental	XR3E-C5B	Olive Green	11-18	24	3	310-415	45-60	B
4.6L Crown Victoria NGV	XL3E-C5A	Turquoise	4-6	91	1	552-827	80-120	B

Fuel System Type: _____ 

1. Return Line System
2. Mechanical Returnless
3. Electronic Returnless

Ford Electronic Returnless Fuel

SCAN TOOL - 2001 Ford Car Focus 2.0 (3)

File Vehicle Options User Library View Help

BB DTC O2 I/M

Test Description: Fuel Pump Duty Cycle (percent) | Pre-condition: engine off or engine on | Notes: Engine

Parameter Substitution	Description	Value	Units
Parameter	2 Fuel Pump Ctrl Duty Cycle	40.0	%
? Air Assist Injector Duty Cycle	1 Fuel Tank Level % Full	87.5	%
? Canister Vent Duty Cycle	3 Fuel Pump Mon Approx Cyc	0.00	
? EGR Duty Cycle	4 Fuel Pump Control Mode	OFF	
? Electric Air Pump Command	5 Fuel Pump Mon Approx Mode	YES FAULT	
? Evap Purge Duty Cycle	6 Fuel Pump Ctrl Mode - Mod	ON	
✓ Fuel Pump Duty Cycle	7 Fuel Pump Output Fault	NO FAULT	
? Fuel Trim Bank 1	8 Fuel Pump Monitor 2 is High	ON	
? Fuel Trim Bank 2	9 Fuel Rail Press Bef FMEM	82.2	psig
? H02S11 Heater	10 Fuel Rail Press Trans - Raw	4.81	V
	11 Engine RPM	0	RPM
	12 TP before FMEM	0.94	V
	13 Vehicle Speed	0.0	MPH
	14 Vehicle Speed	0.0	MPH

Fuel Pump Ctrl Duty Cycle: 40.0

40%

EXECUTE Abort

Choose Parameter Set: 1975 Scan FORD ODD2 PCMOD2 Reorder Setup... Help

The scan tool has allowed a bi-directional fuel pump control duty cycle command of 40% to be sent to the PCM. Note the fuel rail pressure sensor feedback of 82.2 psi.

Ford Electronic Returnless Fuel

SCAN TOOL - 2001 Ford Car Taurus 3.0 (2) W/ TC

File Vehicle Options User Library View Help

DTC O2 I/M

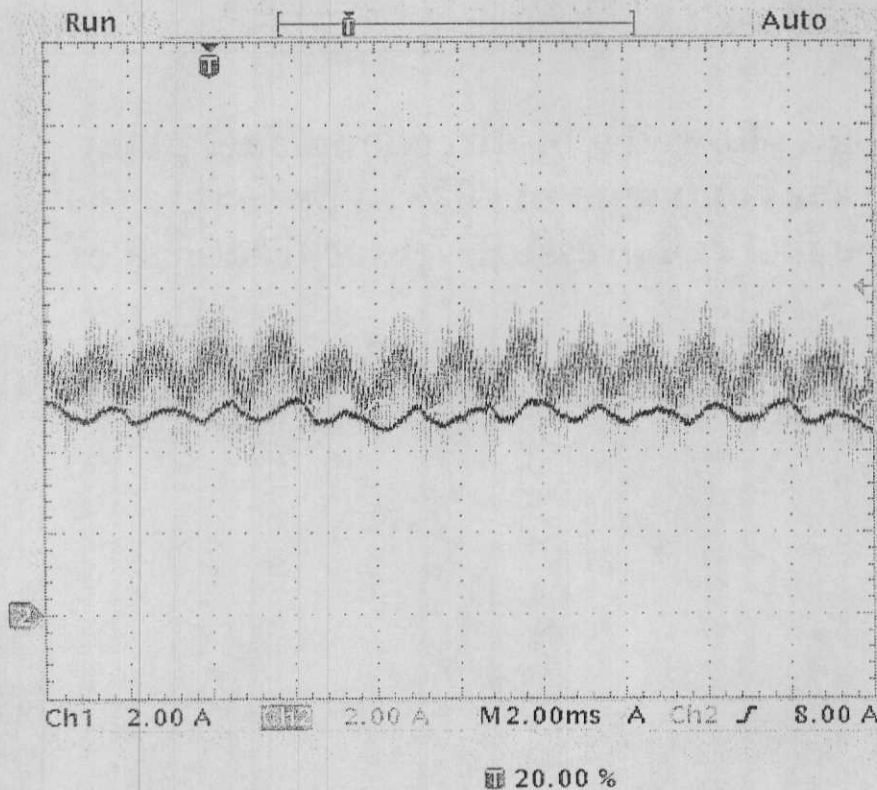
Test Description: Fuel Pump Duty Cycle (percent) | Pre-condition: engine off or engine on | Notes: Engine

Parameter Substitution	Description	Value	Units
10 Fuel Rail Press Bef FMEM	58.5	psig	
11 Fuel Rail Press Trans - Raw	3.84	V	
3 Fuel Pump Ctrl Duty Cycle	40.0	%	
15 Engine RPM	0	RPM	
2 Fuel Level Input Voltage	2.6	V	
1 Fuel Tank Level % Full	89.5	%	
4 Fuel Pump Mon Approx Cyc	0.00		
5 Fuel Pump Control Mode	OFF		
6 Fuel Pump Mon Approx Mode	YES FAULT		
7 Fuel Pump Ctrl Mode - Mod	ON		
8 Fuel Pump Output Fault	NO FAULT		
9 Fuel Pump Monitor 2 is High	OFF		
12 Fuel Tank Press Transducer	2.63	V	
13 Fuel Pressure (gage)	56.3	psig	
14 Fuel Control Type	MET		

Fuel Pump Ctrl Duty Cycle: 40.0

EXECUTE Abort

Choose Parameter Set: 892 | Scan: FORD OBD2 PCMOBD2 | Reorder | Setup... | Help



A fuel pump command of 35% translates to a fuel pump speed of 5172 rpm.

Ford Electronic Returnless Fuel

SCAN TOOL - 2001 Ford Car Taurus 3.0 [2] W/TC

File Vehicle Options User Library View Help

DTC O2 I/M

Test Description: Fuel Pump Duty Cycle (percent) Pre-condition: engine off or engine on Engine

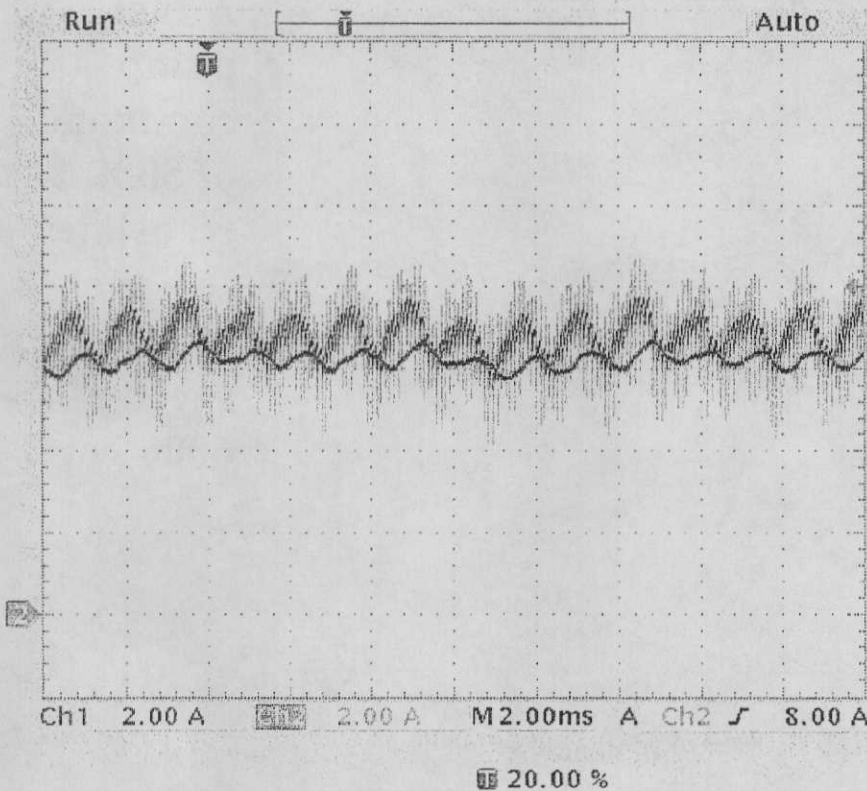
Parameter Substitution	Description	Value	Units
Parameter	10 Fuel Rail Press Bef FMEM	67.5	psig
?	11 Fuel Rail Press Trans - Raw	4.36	V
?	3 Fuel Pump Ctrl Duty Cycle	45.0	%
?	15 Engine RPM	0	RPM
?	2 Fuel Level Input Voltage	2.6	V
?	1 Fuel Tank Level % Full	89.4	%
<input checked="" type="checkbox"/>	4 Fuel Pump Duty Cycle	45.0	%
?	4 Fuel Pump Mon Approx Cyc	0.00	
?	6 Fuel Pump Control Mode	OFF	
?	6 Fuel Pump Mon Approx Mode	YES FAULT	
?	7 Fuel Pump Ctrl Mode - Mod	ON	
?	8 Fuel Pump Output Fault	NO FAULT	
?	9 Fuel Pump Monitor 2 is High	OFF	
?	12 Fuel Tank Press Transducer	2.62	V
?	13 Fuel Pressure (gage)	67.4	psig
?	14 Fuel Control Type	MET	

Fuel Pump Ctrl Duty Cycle: 45.0

EXECUTE Abort

Choose Parameter Set: 1297 Scan Reorder Setup... Help

FORD OBD2 PCMOBD2



A fuel pump command of 45% translates to a fuel pump speed of 5454 rpm.

Ford Electronic Returnless Fuel

IST:SCAN 1.00L - 2001 Ford Car Taurus 3.0 (2) W/TC

File Vehicle Options User Library View Help

DTC O2 I/M

Test Description	Pre-condition	Notes
Fuel Pump Duty Cycle (percent)	engine off or engine on	Engine

Parameter Substitution	Description	Value	Units
Parameter	10 Fuel Rail Press Bef FMEM	82.3	psig
?	11 Fuel Rail Press Trans - Raw	4.81	V
?	3 Fuel Pump Ctrl Duty Cycle	50.0	%
?	15 Engine RPM	0	RPM
?	2 Fuel Level Input Voltage	2.6	V
?	1 Fuel Tank Level % Full	89.8	%
?	4 Fuel Pump Mon Approx Cyc	0.00	
?	5 Fuel Pump Control Mode	OFF	
?	6 Fuel Pump Mon Approx Mode	YES FAULT	
?	7 Fuel Pump Ctrl Mode - Mod	ON	
?	8 Fuel Pump Output Fault	NO FAULT	
?	9 Fuel Pump Monitor 2 is High	ON	
?	12 Fuel Tank Press Transducer	2.63	V
?	13 Fuel Pressure (gage)	81.8	psig
?	14 Fuel Control Type	MET	

Fuel Pump Ctrl Duty Cycle: 50.0

50%

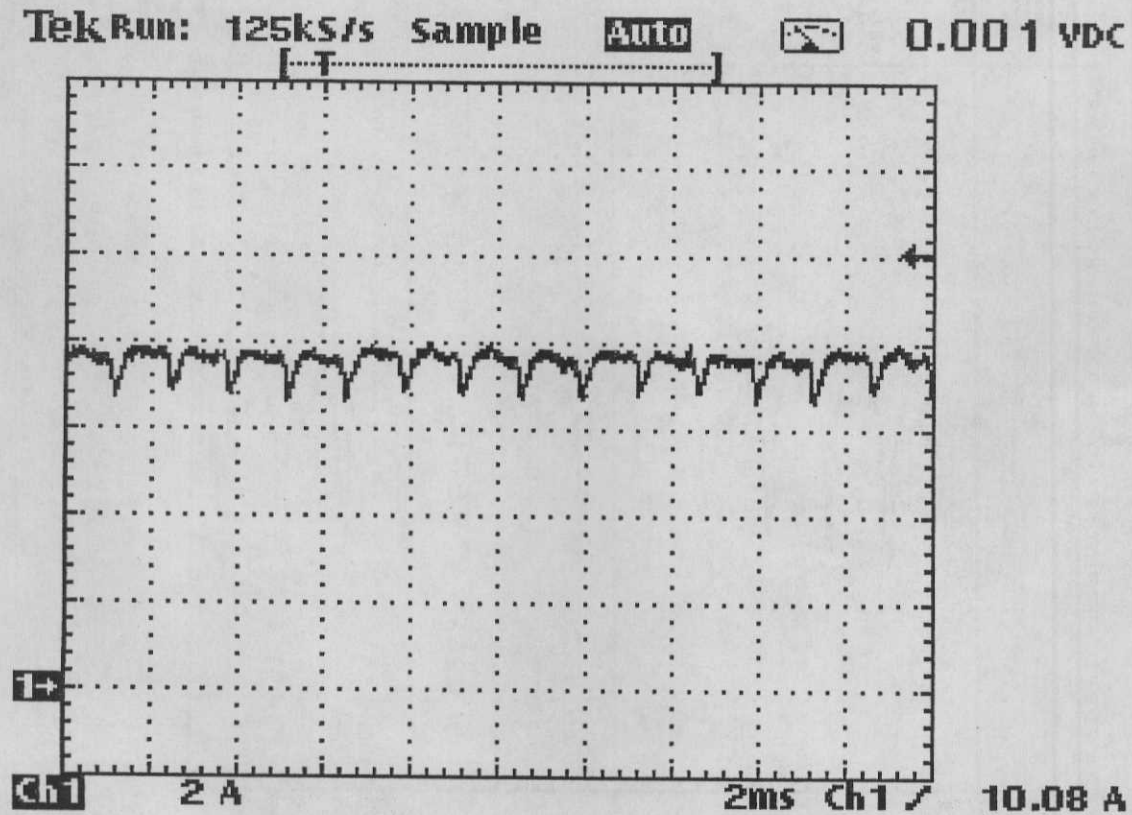
EXECUTE Abort

Choose Parameter Set 198U Scan FOR0 ODD2 PCMOD2 Reorder Setup... Help



A fuel pump command of 50% translates to a fuel pump speed of 6000 rpm.

Ford Electronic Returnless Fuel

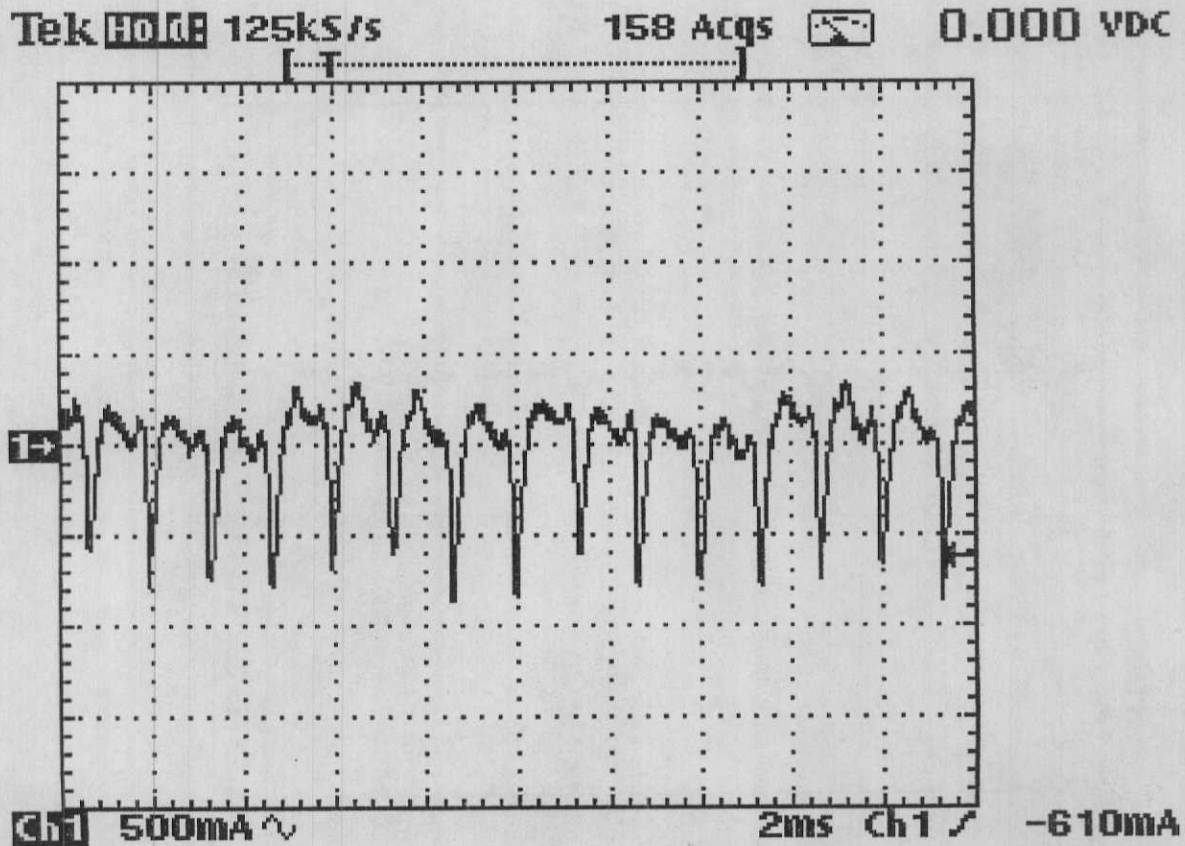


The fuel pump ground side control line has been jumpered to ground. This forces the pump to run at maximum pressure.

Additionally, this gives us the opportunity to analyze fuel pump current for ...

- the amount of current
- shape of the current humps
- fuel pump armature rpm

Ford Electronic Returnless Fuel

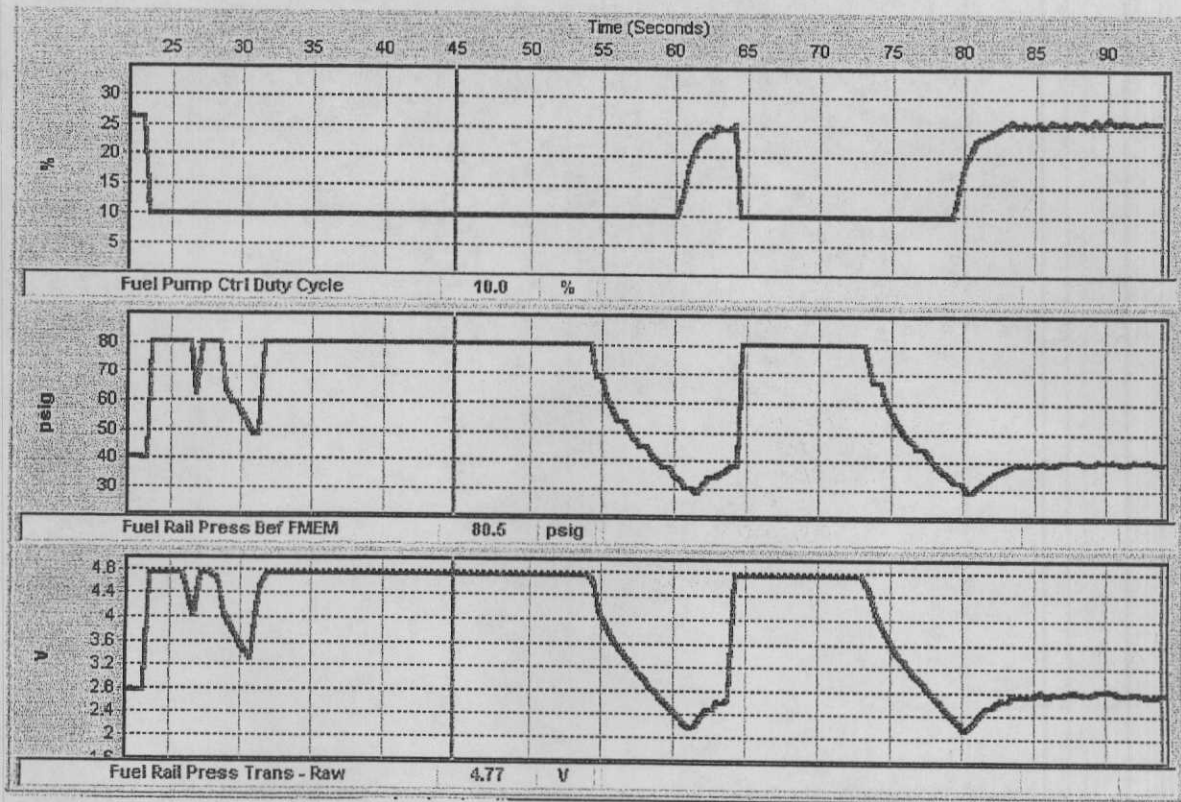


Fuel pump current has been AC coupled so as to allow us better detail when analyzing “hump” shape and armature rpm.

Maximum fuel pressure – 80 psi

Fuel Pump RPM – 5555 rpm

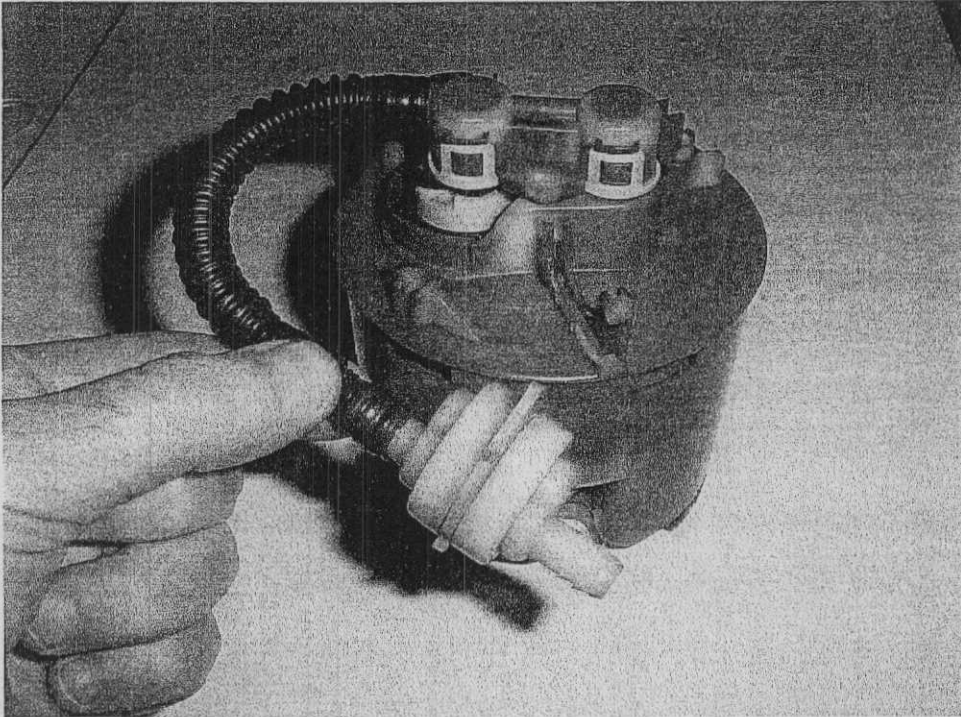
Ford Electronic Returnless Fuel



This scan recording was taken when the fuel pump ground side control line was grounded.

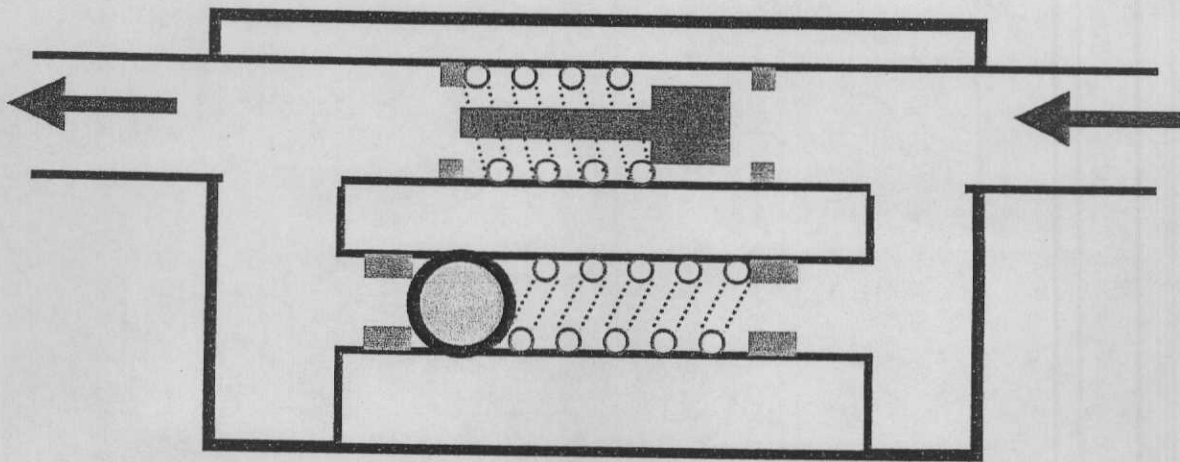
At 80 psi, the PCM is trying to reduce fuel pressure by ramping down the fuel pump duty cycle command.

Ford Electronic Returnless Fuel



The fuel pump module assembly contains a component known as a Parallel Pressure Relief Valve. This dual purpose valve provides two functions.

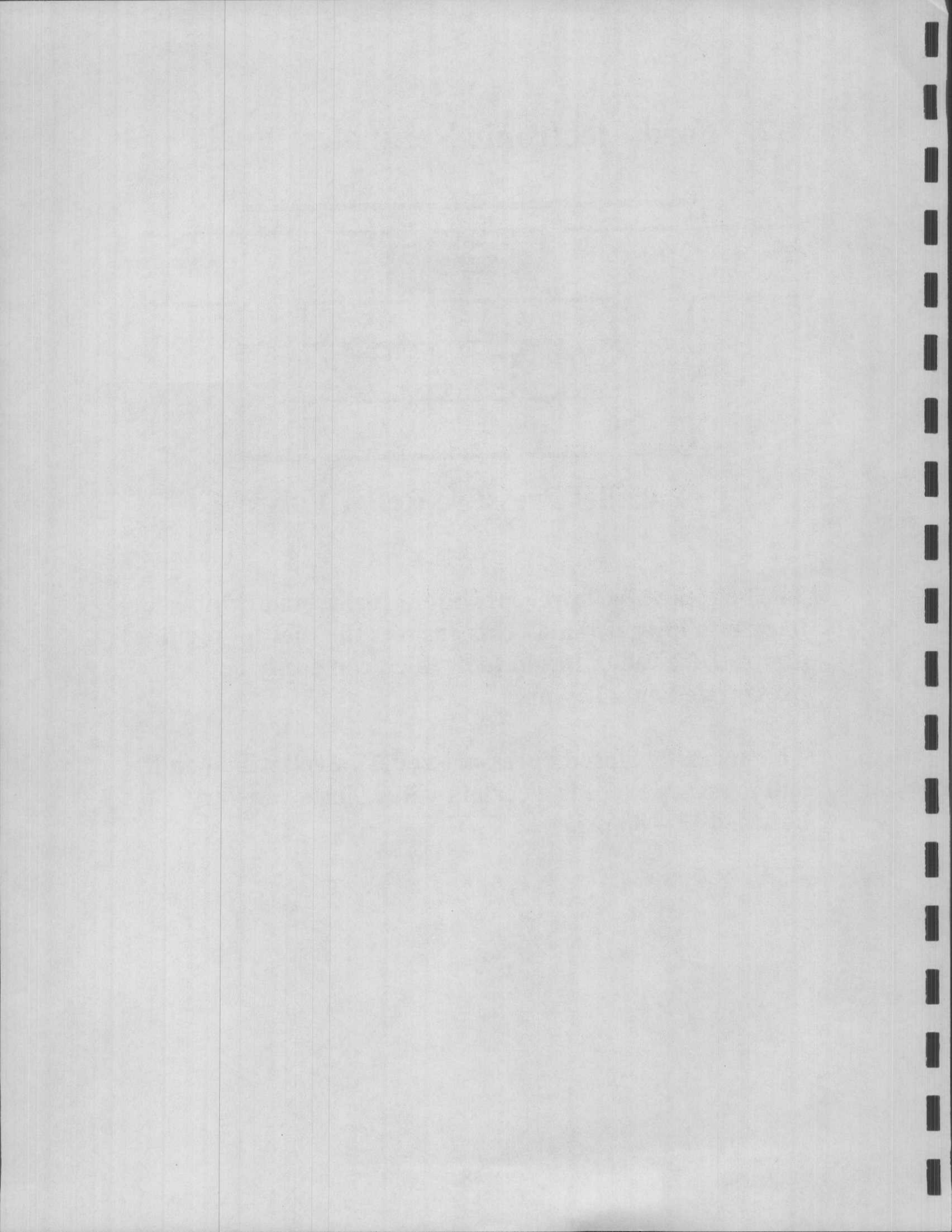
Ford Electronic Returnless Fuel



Parallel Pressure Relief Valve

The “check valve” prevents liquid fuel from draining back into the gas tank. This ensures the fuel supply line and rail are full of liquid fuel which can easily be pressurized on a key up.

The normally closed “pressure relief valve” will open if rail pressure exceeds a certain value. This can vary between 55 – 80 psi.





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