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# Hybrid Braking Systems

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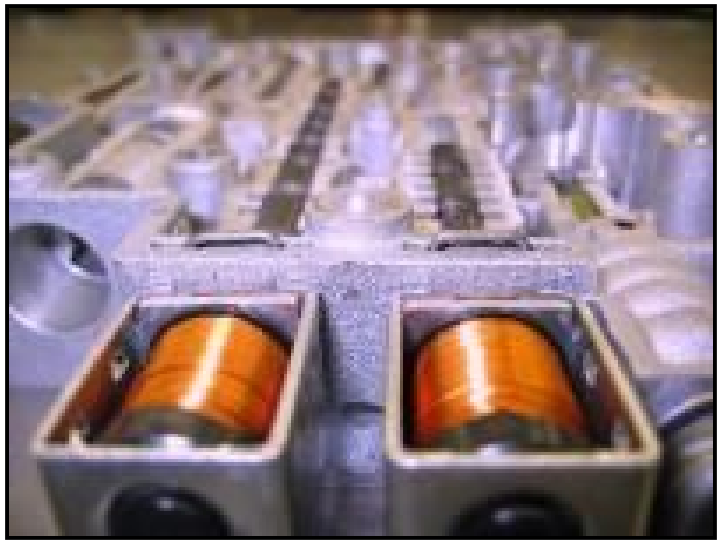
Note: Some illustrations, graphics, images, tables, and procedures are from Honda Motors Company, Ford Motor Company, and Toyota of North America

# About SIUC

- 11 Faculty
- Over 30,000 sq. ft.
- 4 labs
- 1 office building

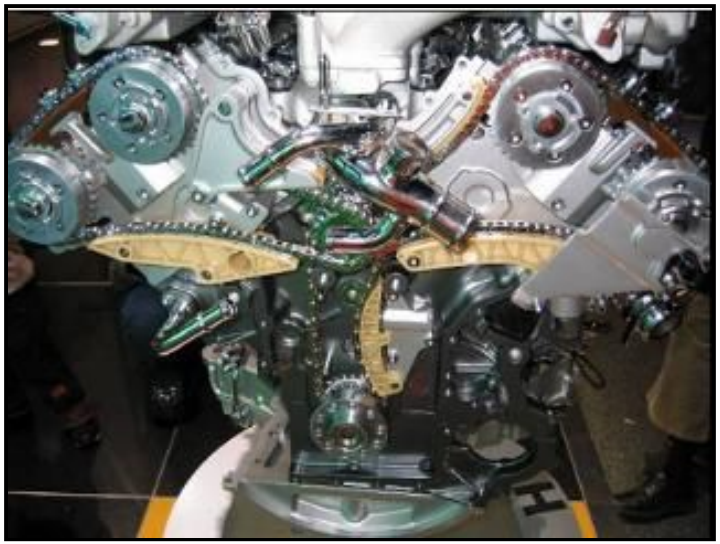
# Service Technology

- Focus on the technical and management aspects of automotive service
- Research
  - Serviceability Studies
  - Diagnostic Routine Development
  - Procedure and Equipment Validation



# Courses Offered

- First and Second Years
  - Basic Electricity
  - Shop Practices
  - Engine Electrical
  - Drivetrains
  - Steering and Suspension
  - Brakes
  - Engines
  - Air Conditioning
  - Engine Management I and II



# Advanced Level Courses

- Third and Fourth Years
  - Body and Chassis Electronics
  - Emissions and Drivability
  - Compressive Vehicle Diagnostics
  - Automatic Transmissions
  - Alternative Fuels
  - NVH and Vehicle Stability

# SIUC Automotive Technology

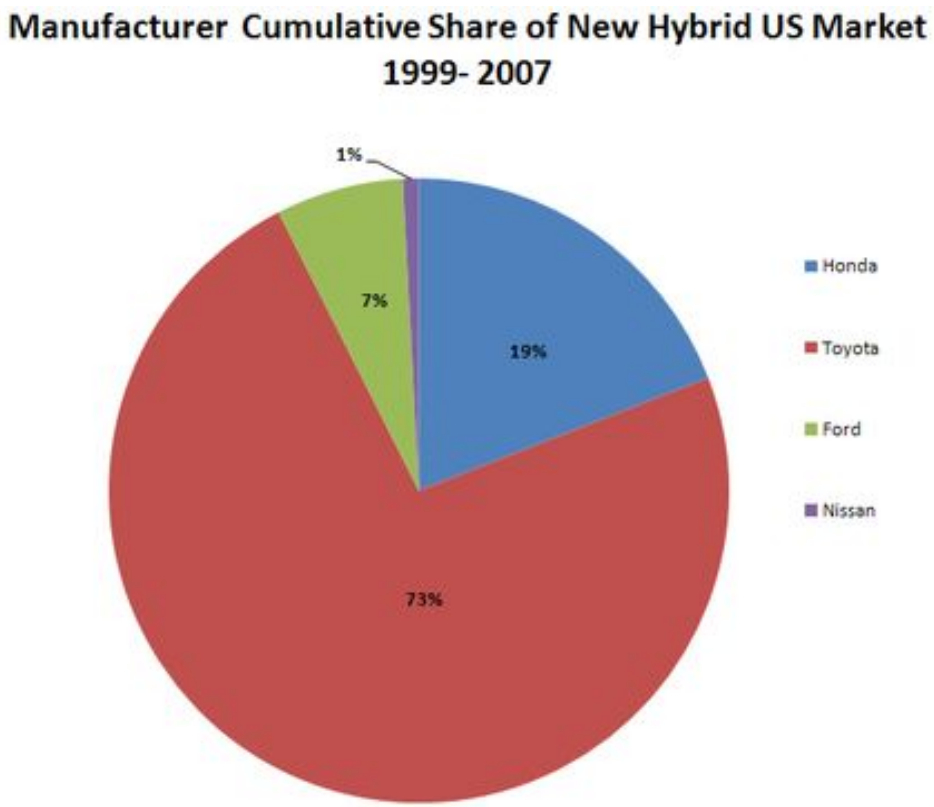
- What do we do?
  - Sean:
    - Automatic Transmission
    - Drivetrains
    - Comprehensive Vehicle Diagnostic
  - Tim:
    - Advanced Emissions
    - Vehicle Stability and NVH
- Applied Studies
  - Research interests focused on undercar, transmission, and engine controls diagnostics
  - Special interests in Hybrid vehicles

# Presentation: Hybrid Braking Systems

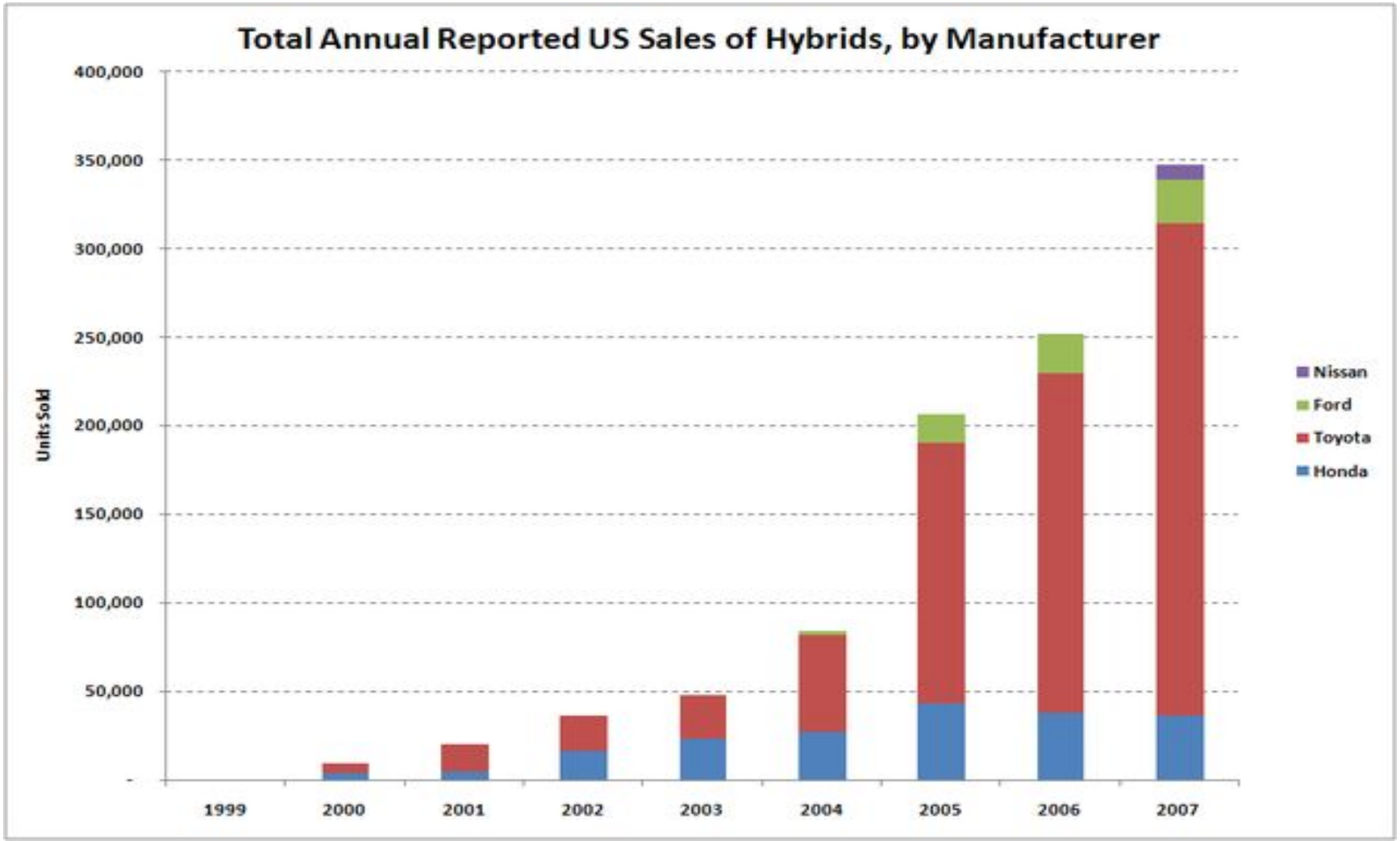
- Hybrid Braking Systems
- What's so different?
  - Honda Civic
  - Toyota Prius/Camry/Highlander
  - Ford Escape
- Who's working on them?

# Hybrid Sales (green car congress)

- Toyota Hybrid web site claims over 1,000,000 sold world wide.
- Green Car Congress claims in 2007 hybrid sales passed 1,002,000 without GM's report.



# Hybrid Sales (green car congress)



# Honda Hybrid Sales: December 06 to 07

- Honda's Civic Hybrid
  - 3,223
  - +34%
  - 11.9% of all Civic models sold

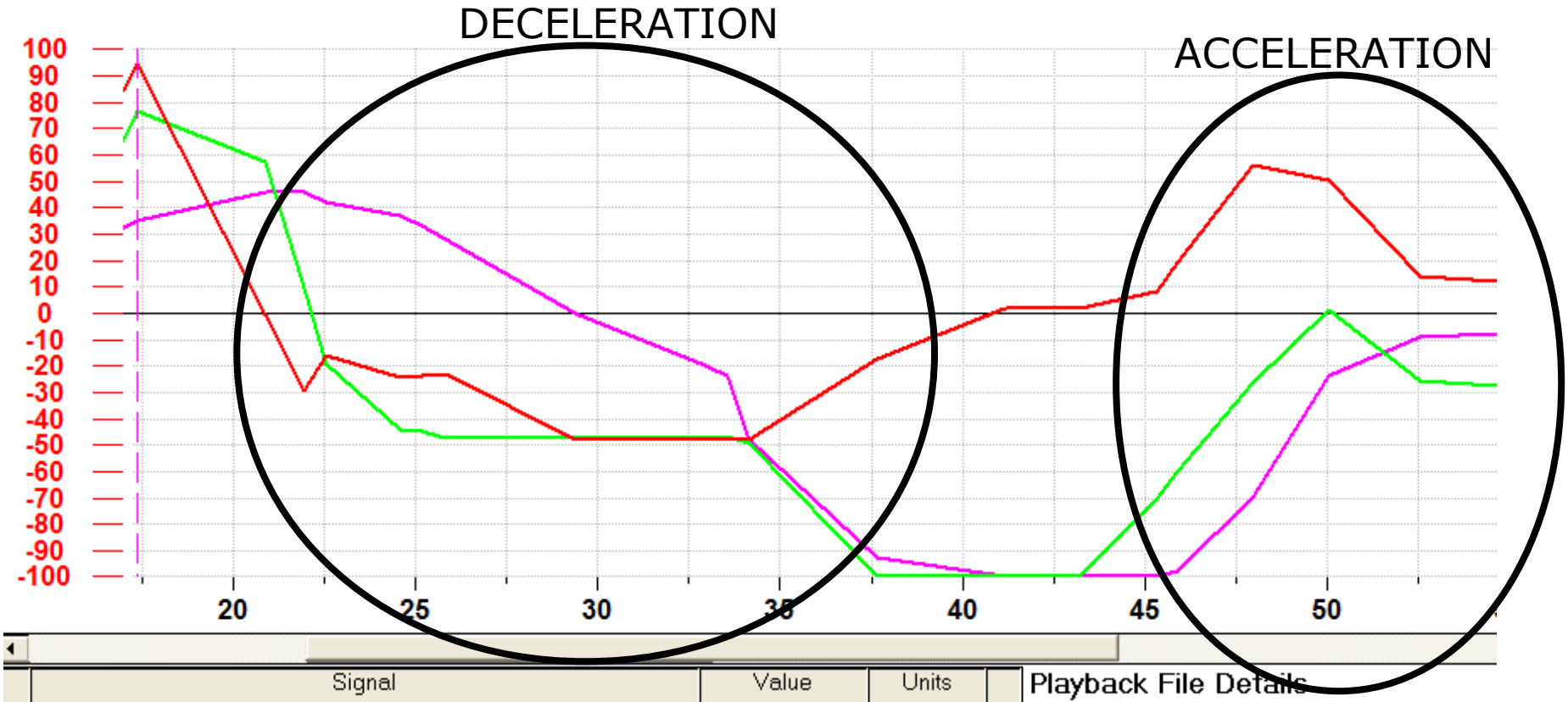
# Ford Hybrid Sales: December 06 to 07

- Ford's Escape and Mariner:
  - 2,265
  - +15%
  - 14.6% of all Escape and Mariners sold

# Hybrid Braking Systems: Honda

- Why do some hybrids have unique brake systems?
  - To maximize the regenerative braking system by letting the electric motors slow the vehicle down instead of the friction brakes
  - To provide power brakes while the engine is not running

# Hybrid Braking Systems: Honda

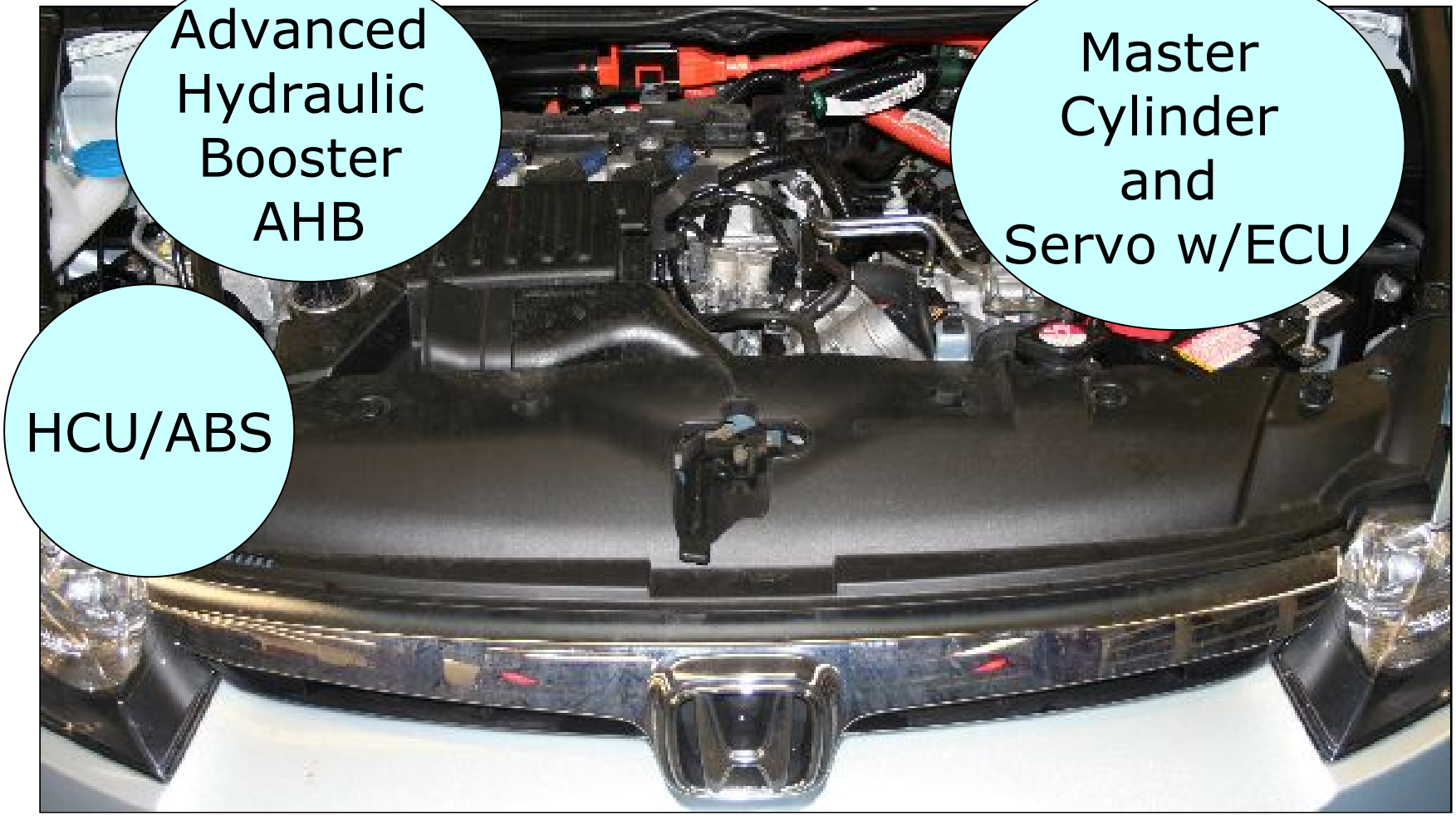



| Signal | Value | Units |
|---|---|---|
| BATTERY CURRENT SENSOR | 94.57 | A |
| Motor Speed(MCM) | 4402 | RPM |
| VSS(MCM) | 47 | MPH |

Playback File Details

Model: CIVIC HYBRID
Model Year: 2007
Odometer: 8580
System: IMA
VIN: JHMFA36267S022647
Date: 05/19/2003 04:51:26
Trigger Type: Manual

# 06’ to current Honda Civic

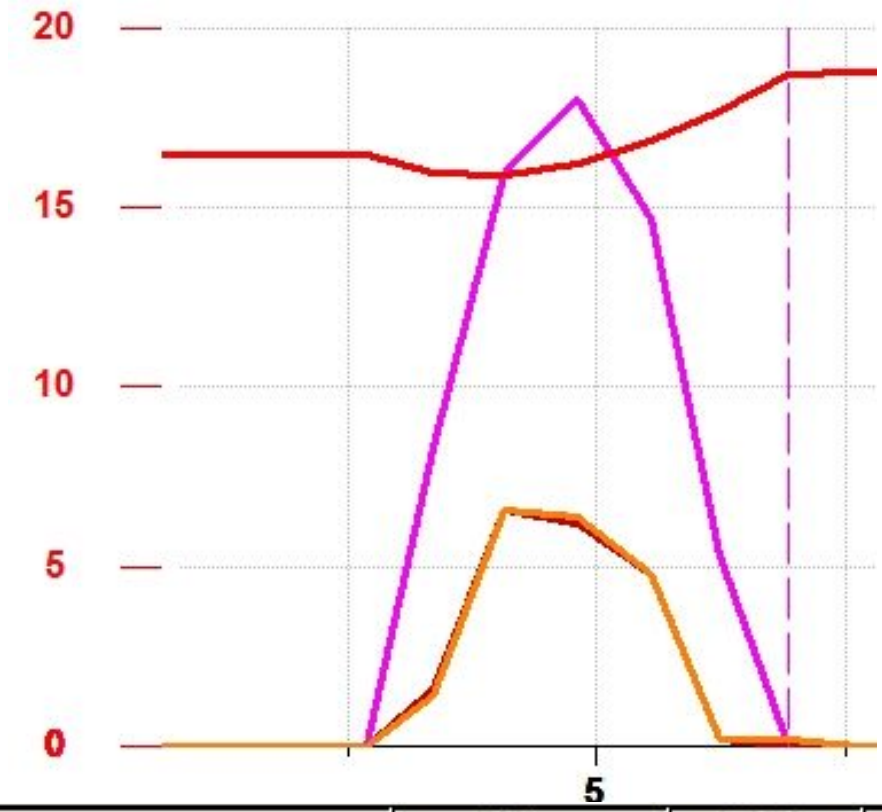


# Advanced Hydraulic Booster (AHB)

- Replaces the traditional vacuum booster
- Generates ALL hydraulic pressure during normal operation
- Hyd pump controlled by Servo ECU

# Advanced Hydraulic Booster (AHB)

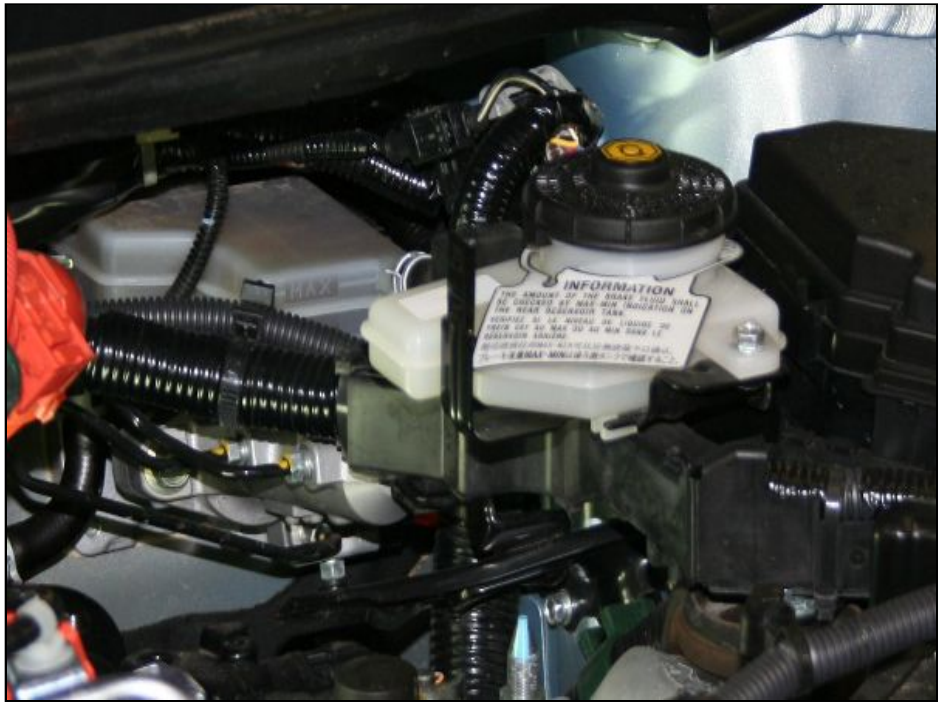
- Accumulator stores 2300 – 2800 psi
- Pressure sensors measure accumulator, servo regulator, and MC pressures




| Signal | Value | Units |
|---|---|---|
| ACCUMULATOR PRESSURE VALUE | 18.70 | MPa |
| MASTER CYLINDER PRESSURE VALUE | 0.10 | MPa |
| BRAKE PEDAL STROKE VALUE | 0.0 | mm |
| SERVO REGULATOR PRESSURE SENSOR VALUE | 0.00 | MPa |

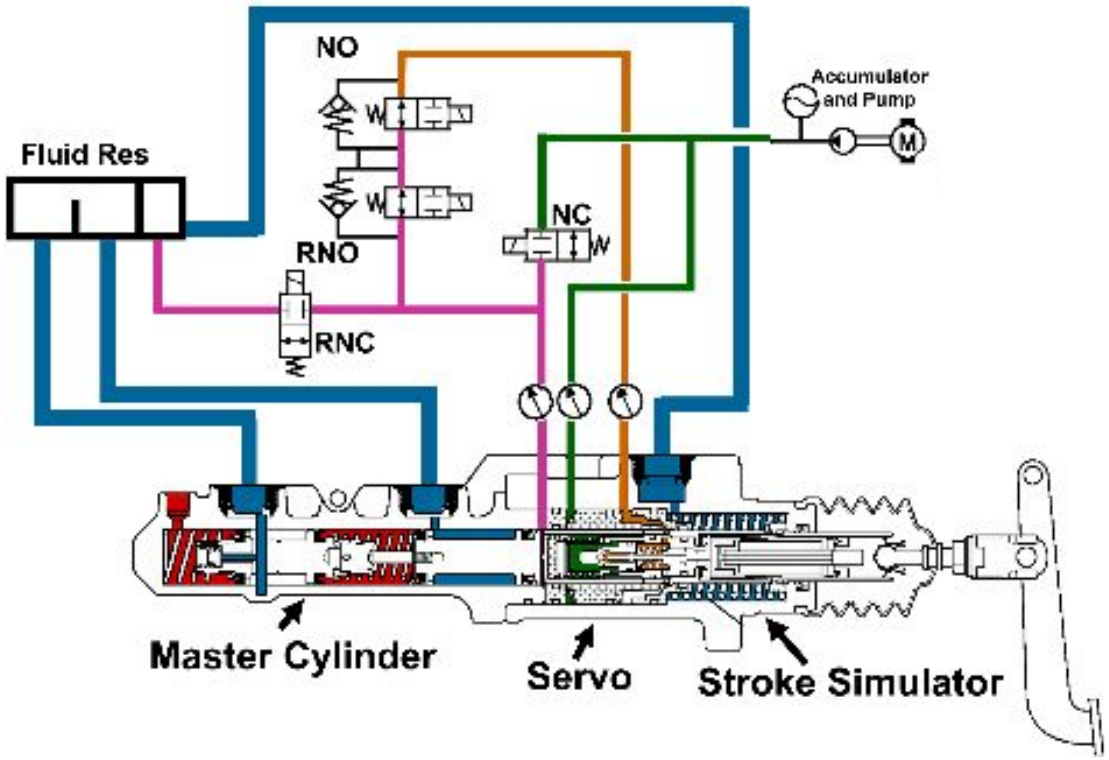
# Master Cylinder with Servo

- Traditional style MC coupled to a servo unit
- Servo unit with ECU
- Stroke Simulator



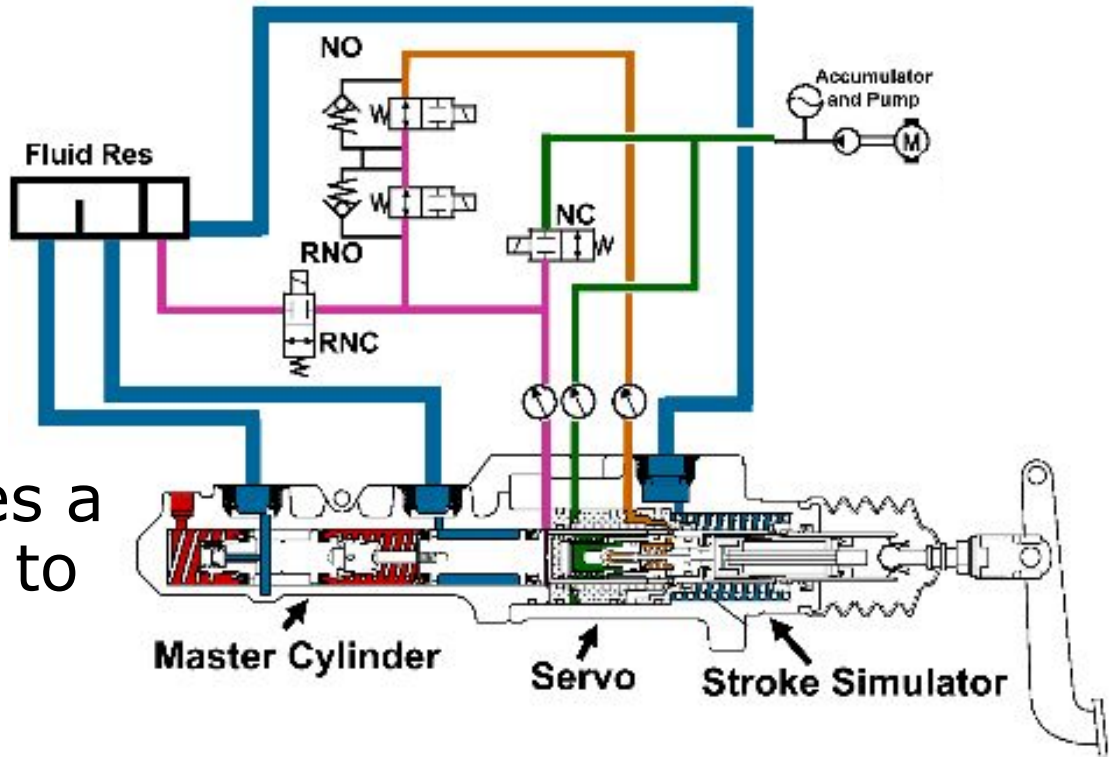
# Master Cylinder with Servo

- Traditional style MC coupled to a servo unit
- Solenoids direct high pressure to the master cylinder secondary valve to meet braking demands



# Master Cylinder with Servo

- Servo assy directs accumulator pressure to the solenoids
- The Servo ECU controls the solenoids for proper brake application
- The stroke simulator provides a typical pedal feel to the driver



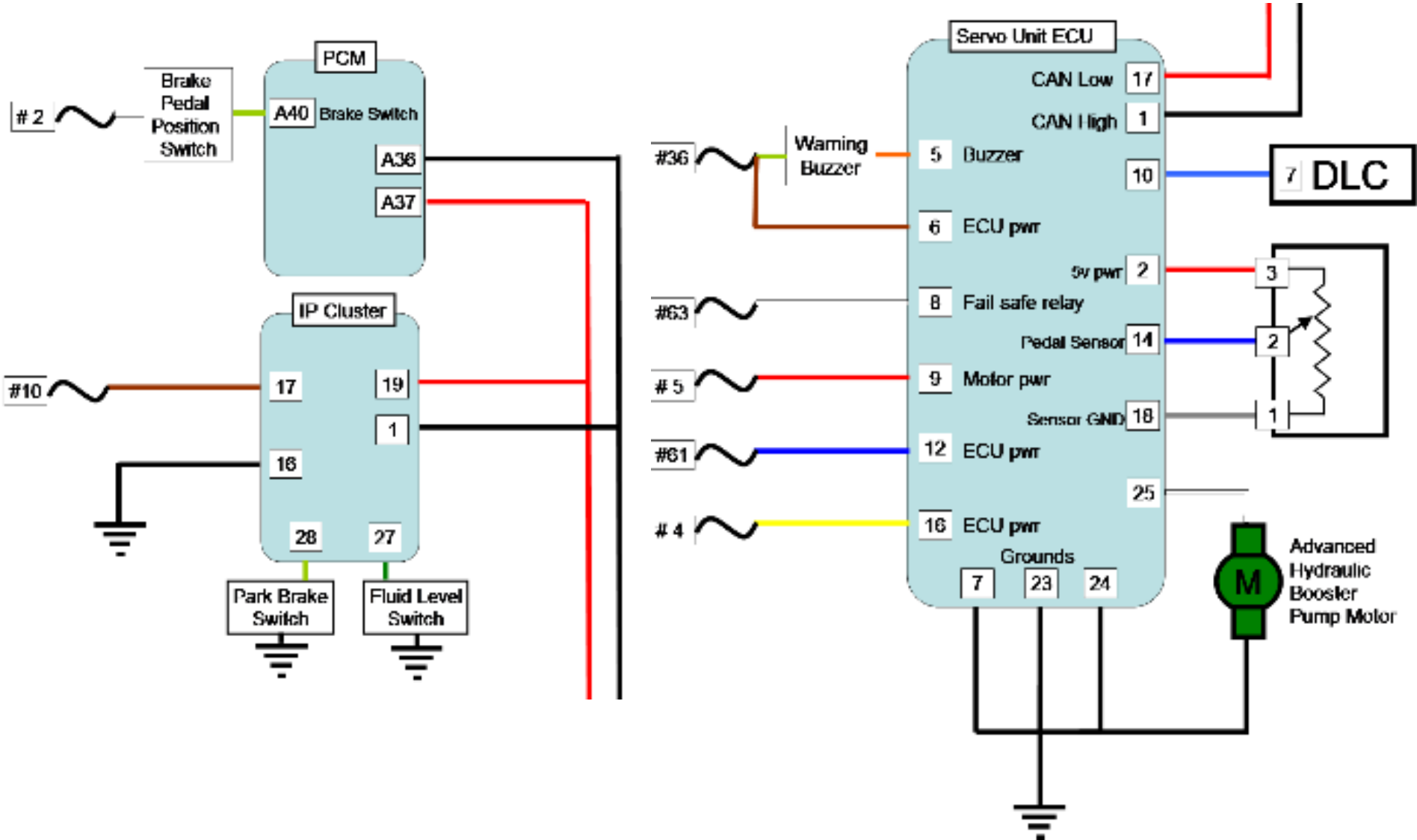
# ABS HCU

- Traditional ABS style HCU
- Same functions as a typical ABS: Hold, Release, Reapply
- Magneto Resistive WSS

# Pedal Stroke Sensor

- Input to the servo unit ECU for brake pedal:
  - Travel
  - Speed
- ECU can determine if vehicle is in a normal braking or a panic stop situation
- 3-wire potentiometer

# Electrical Diagram

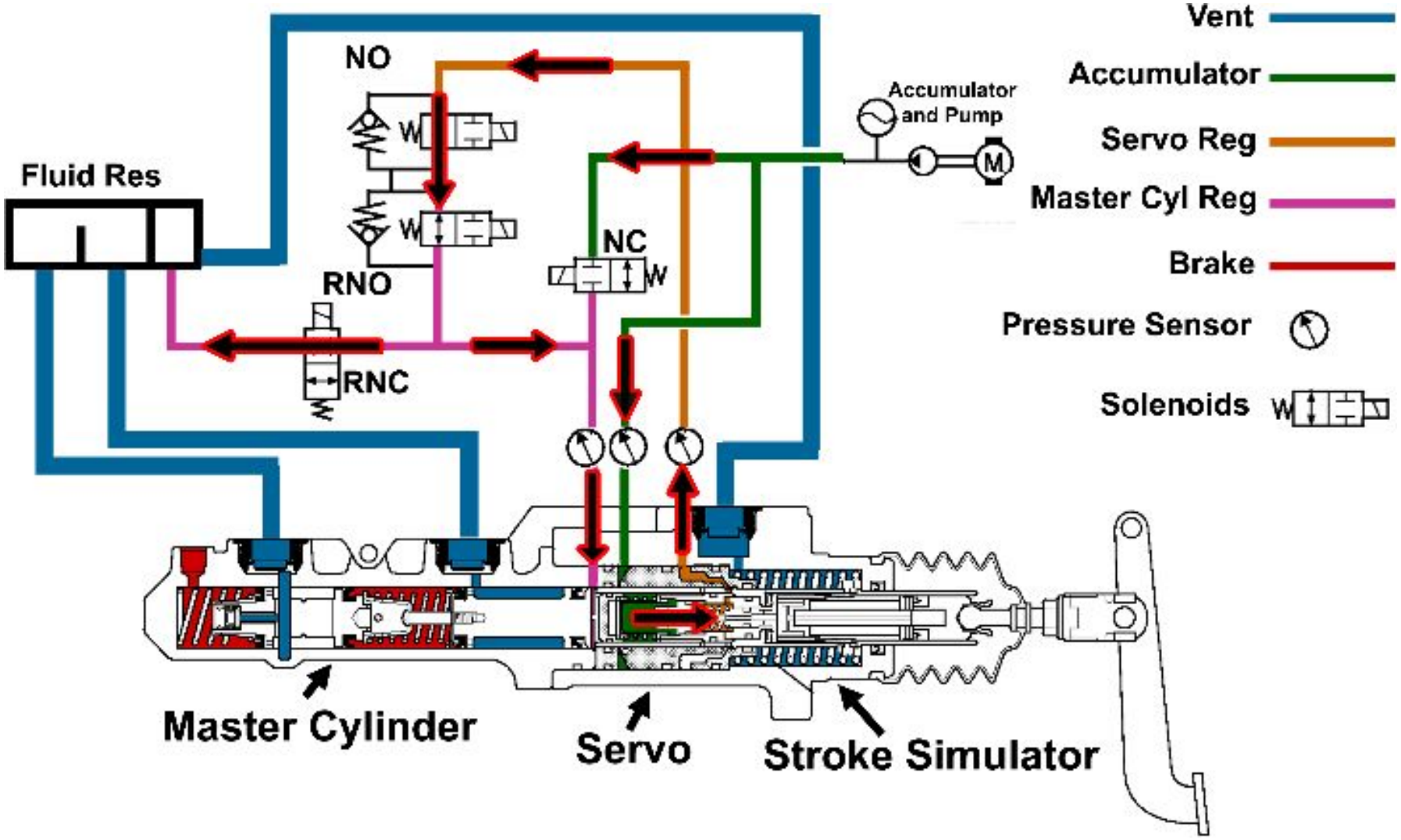


# Regeneration Cooperation

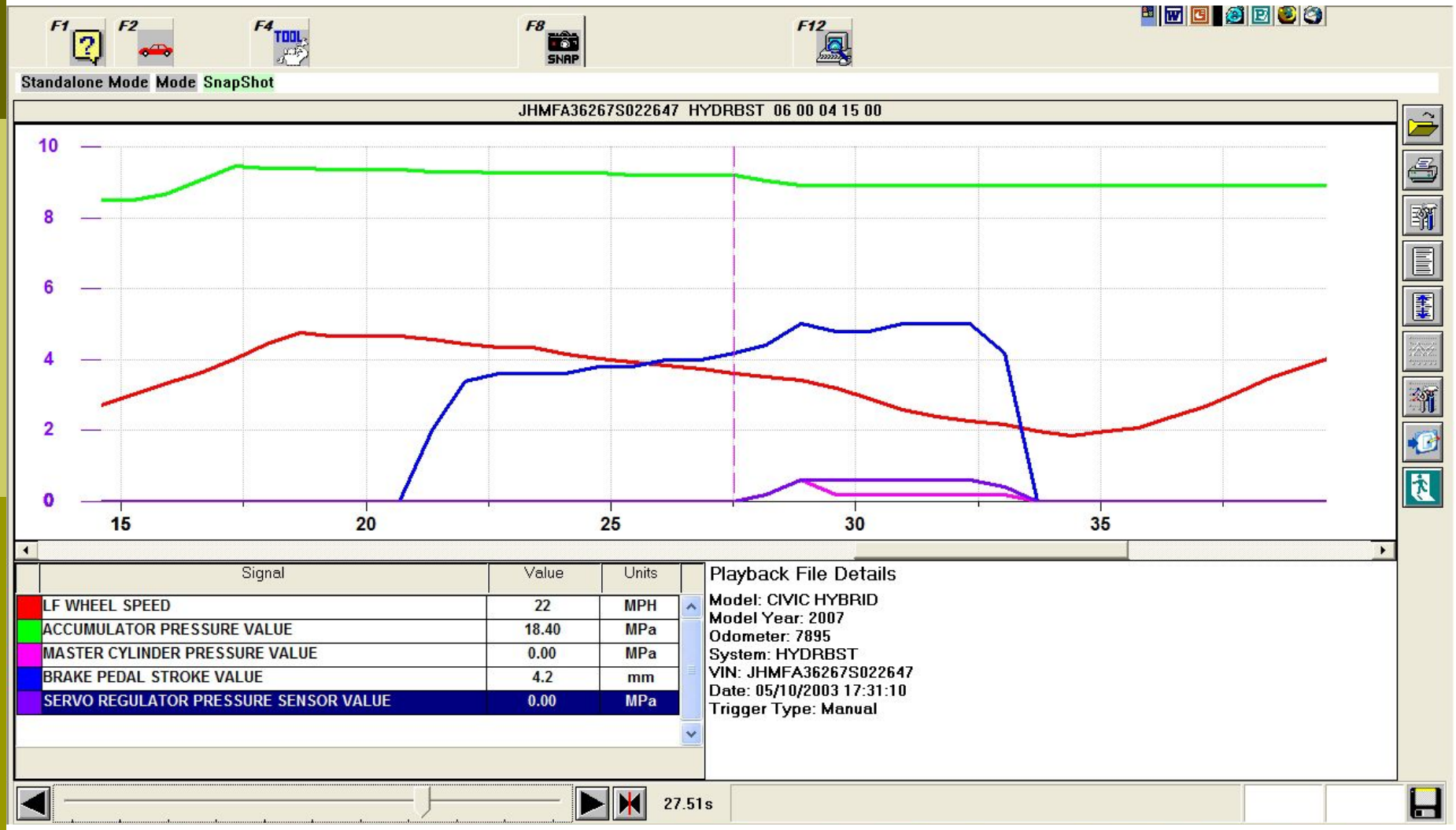
- Normal Operation
  - Uses Integrated Motor (IM) loading to slow vehicle down
  - Friction brakes add additional stopping power as necessary and for low speeds
  - IM loading is similar to engine braking, but the IMA control unit can vary the amount of loading depending on conditions

| Control Solenoid Valve | NO | NC | RNO | RNC |
|---|---|---|---|---|
| Regenerate Cooperation Control | | | PWM | PWM |
| CAS Control | PWM | | | |
| Brake Assist Control | PWM | PWM | | |

# Regeneration Cooperation



# Regeneration Cooperation

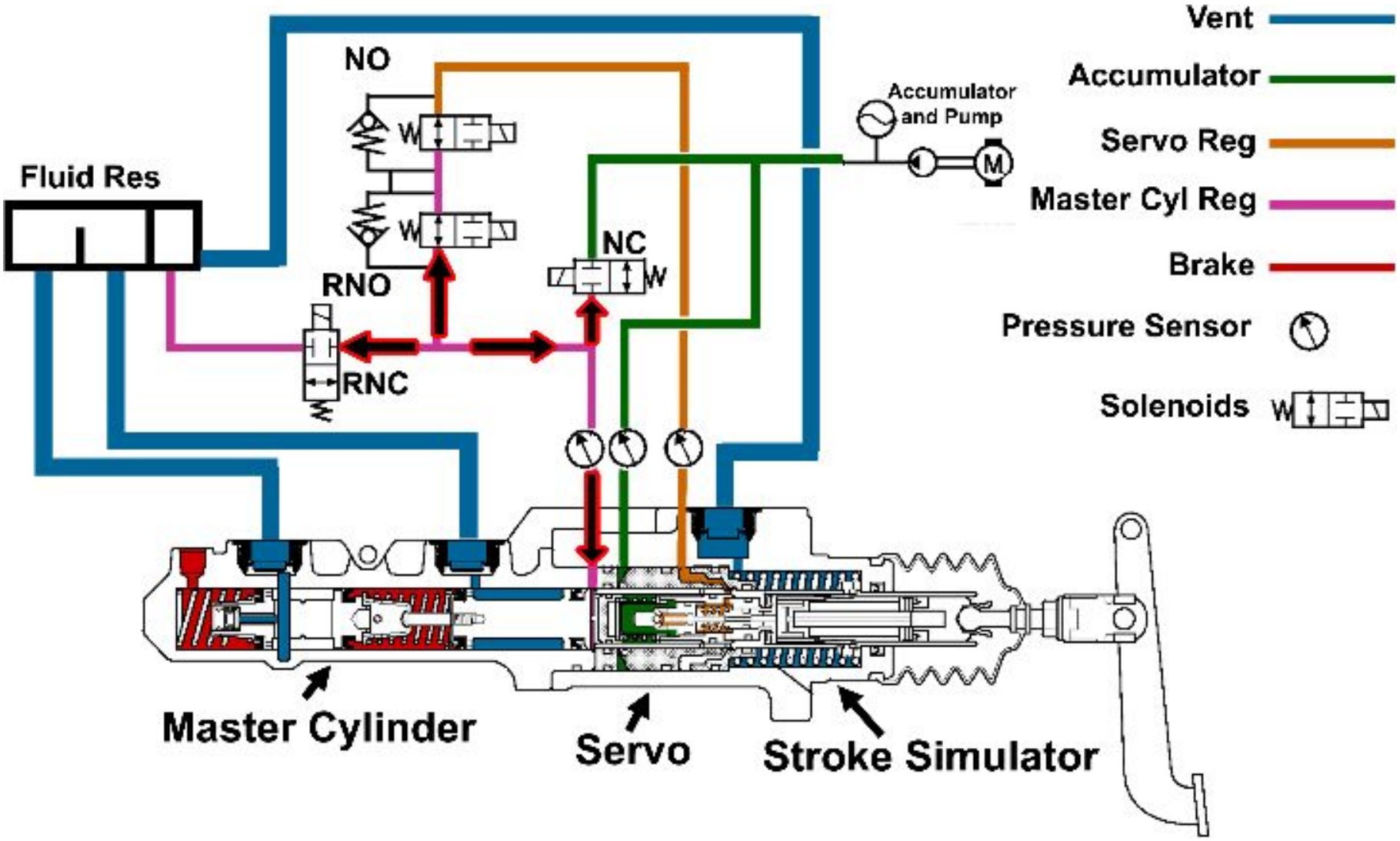


# Creep Aid

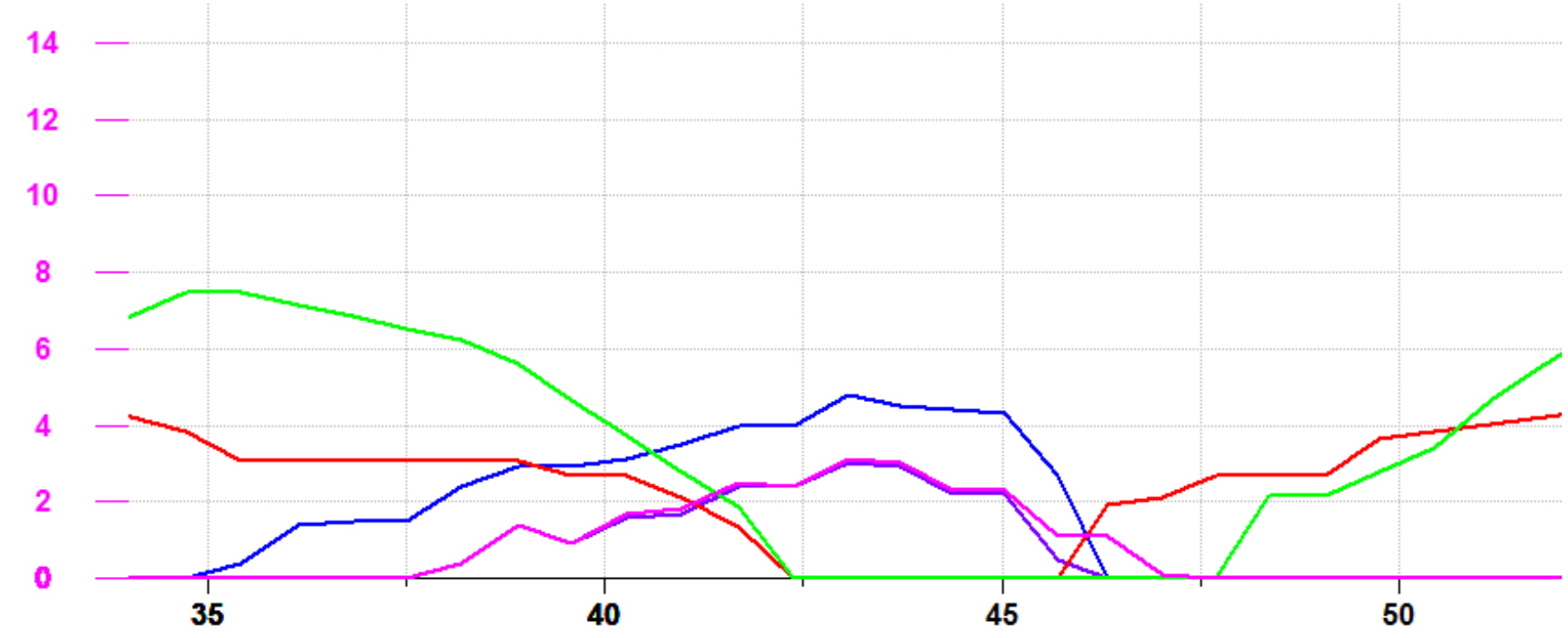
- Creep Aid keeps the brakes applied when the vehicle is in “idle stop” mode
- This prevents the vehicle from rolling until the engine starts
- Brake pressure is trapped at the wheels by the NO solenoid and then release soon after the engine starts

| Control Solenoid Valve | NO | NC | RNO | RNC |
|---|---|---|---|---|
| Regenerate Cooperation Control | | | PWM | PWM |
| CAS Control | PWM | | | |
| Brake Assist Control | PWM | PWM | | |

# Creep Aid


Vent
Accumulator
Servo Reg
Master Cyl Reg
Brake
Pressure Sensor
Solenoids
NO
NC
RNO
RNC
Fluid Res
Accumulator and Pump
M
Master Cylinder
Servo
Stroke Simulator

# Creep Aid




| Signal | Value | Units |
|---|---|---|
| ENGINE REVOLUTION DATA | 832 | RPM |
| LF WHEEL SPEED | 6 | MPH |
| MASTER CYLINDER PRESSURE VALUE | 0.00 | MPa |
| BRAKE PEDAL STROKE VALUE | 0.0 | mm |
| SERVO REGULATOR PRESSURE SENSOR VALUE | 0.00 | MPa |

**Playback File Details**

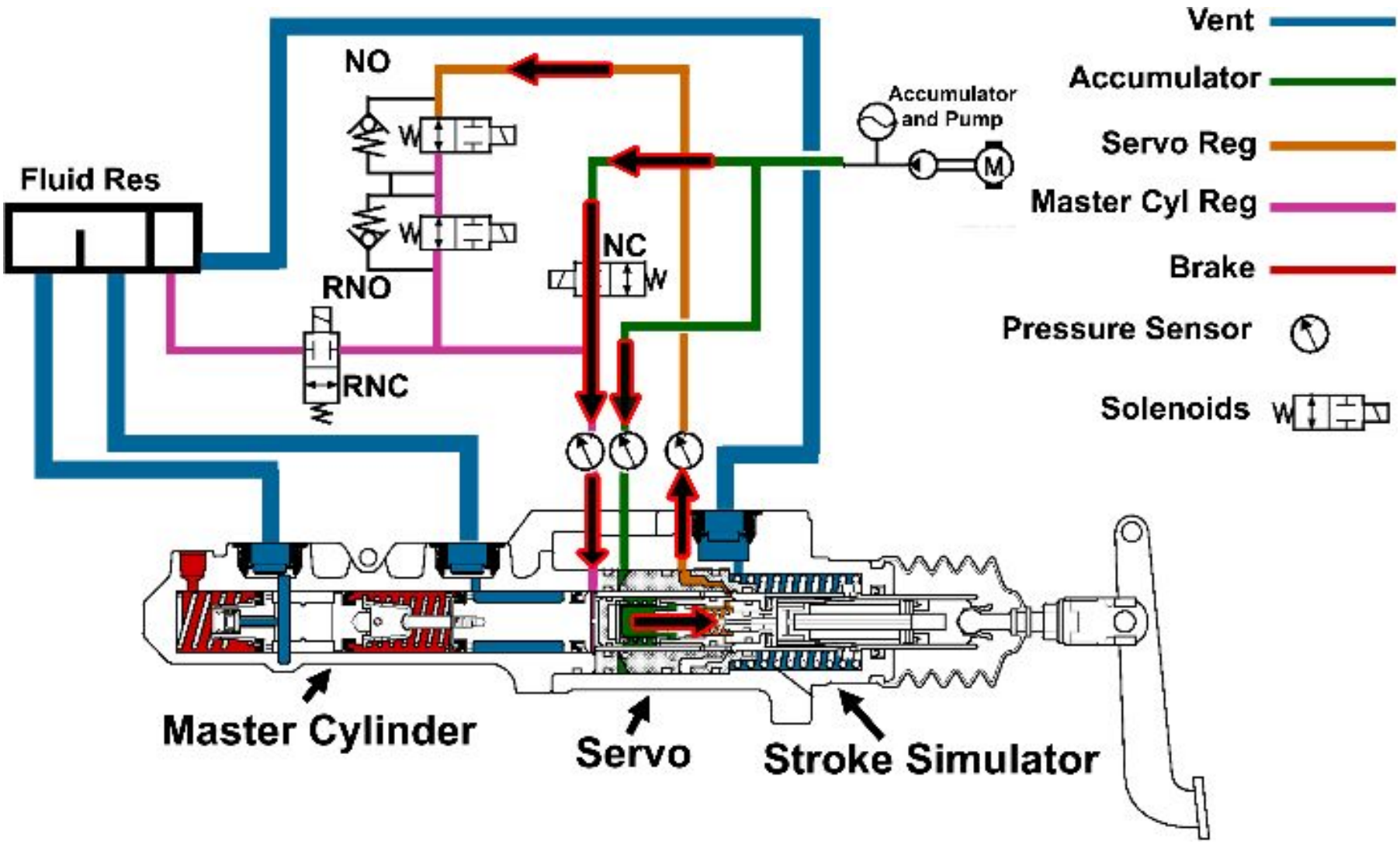
Model: CIVIC HYBRID
Model Year: 2007
Odometer: 8585
System: HYDRBST
VIN: JHMFA36267S022647
Date: 05/19/2003 05:12:16
Trigger Type: Manual

# Brake Assist

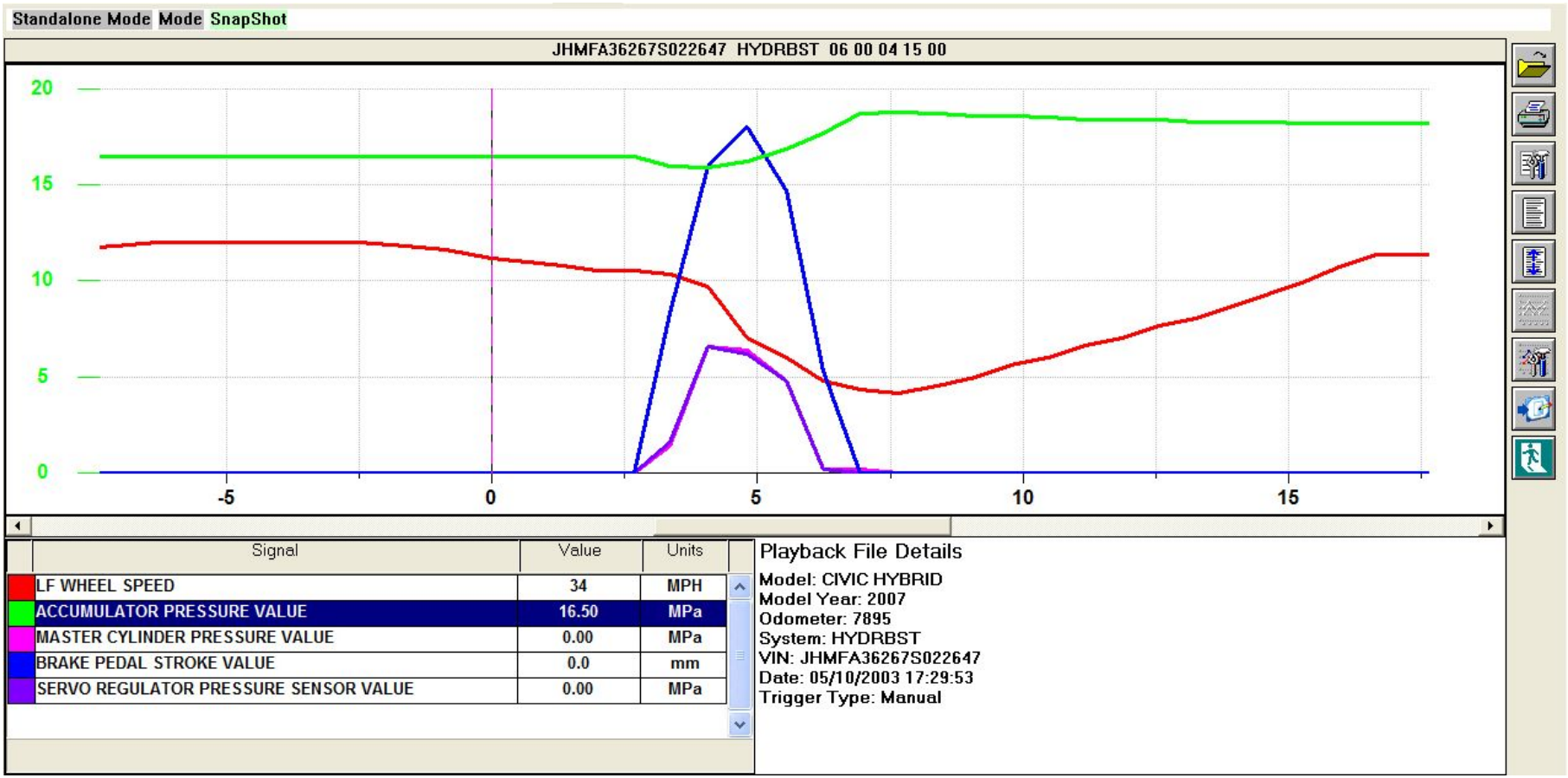
- Brake assist mode will apply the master cylinder piston with more force than the driver is exerting
- The NC solenoid can divert high accumulator pressure directly to the secondary valve in the master cylinder

| Control Solenoid Valve | NO | NC | RNO | RNC |
|---|---|---|---|---|
| Regenerate Cooperation Control | | | PWM | PWM |
| CAS Control | PWM | | | |
| Brake Assist Control | PWM | PWM | | |

# Brake Assist



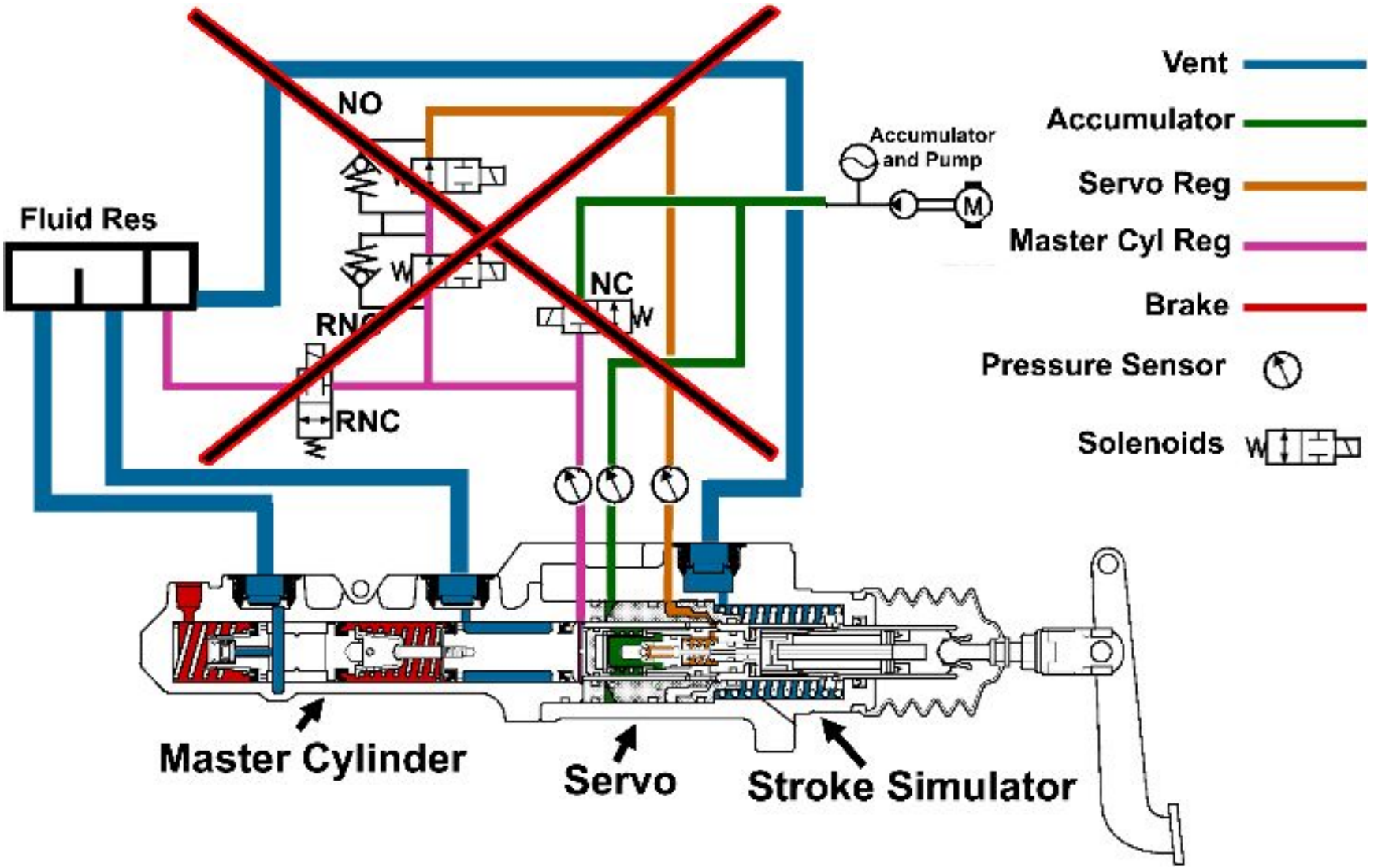
# Brake Assist



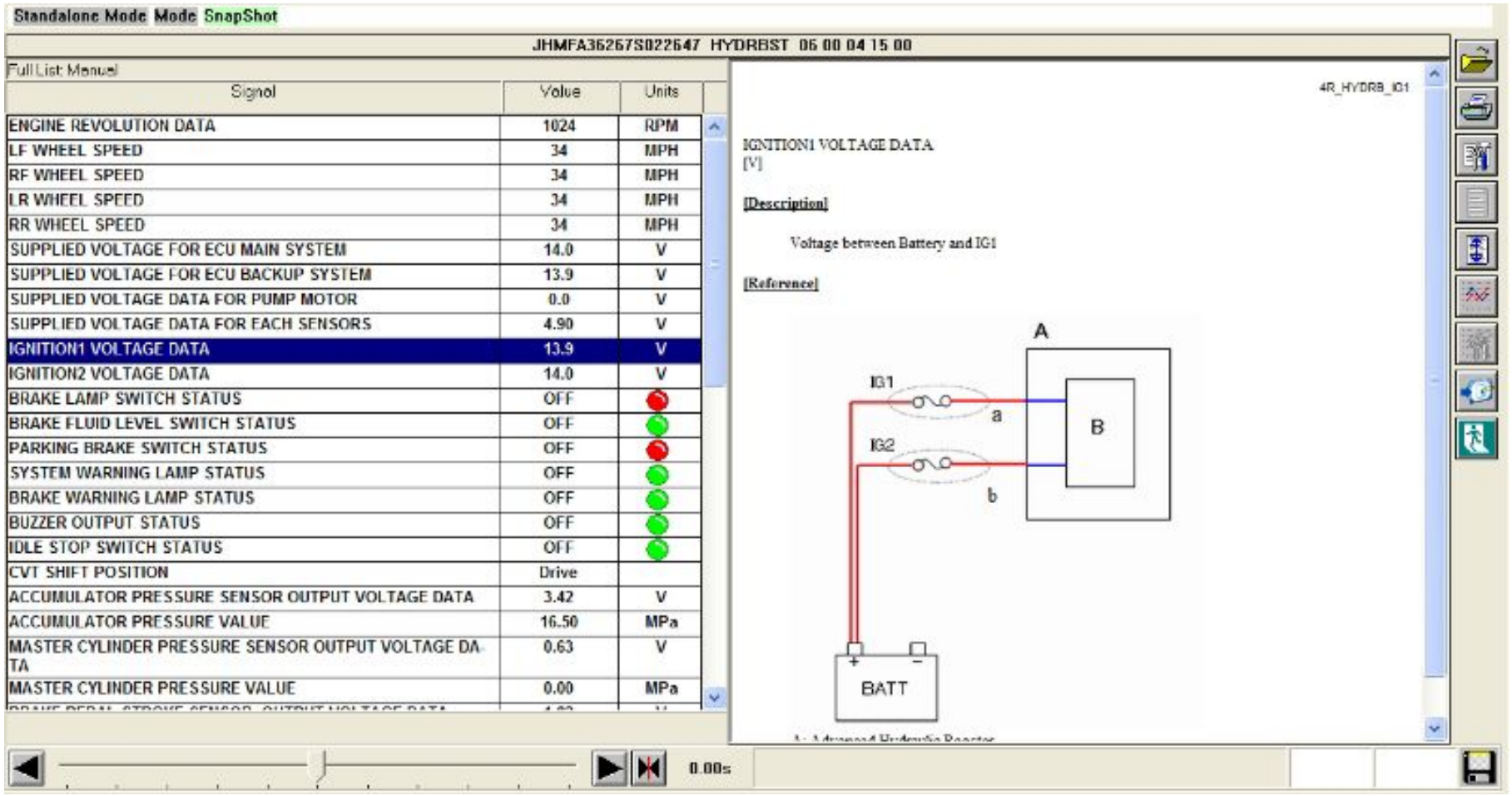
# Failure Mode

- When in failure mode, the solenoids are in their "resting" state
- If the pump is not running, there will be no high pressure available
- The pedal input will travel through the stroke simulator and servo unit to act on the master cylinder secondary piston
- The system will operate like a brake system without any boost or assist
- Braking efficiency will be greatly reduced

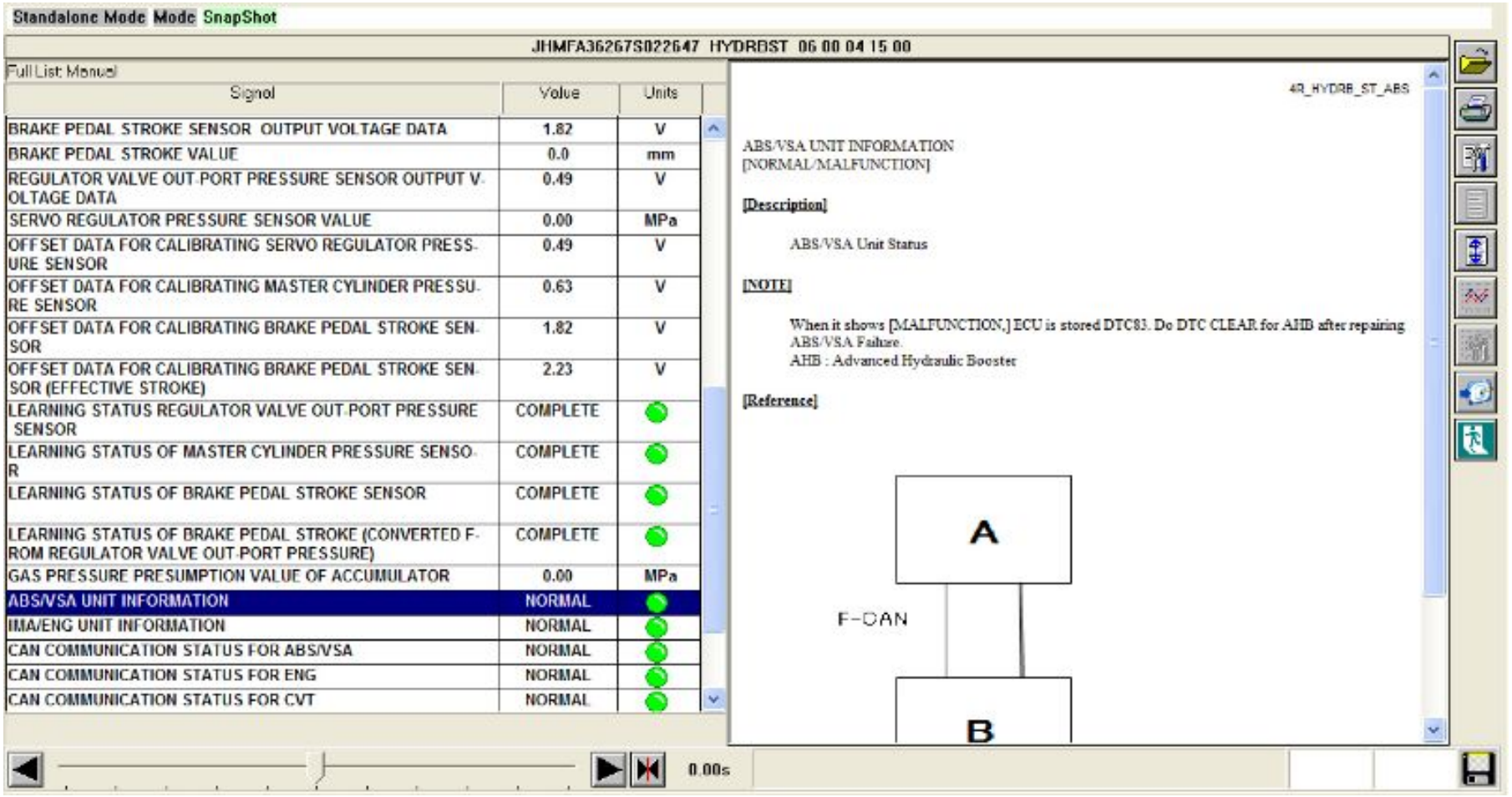
# Failure Mode



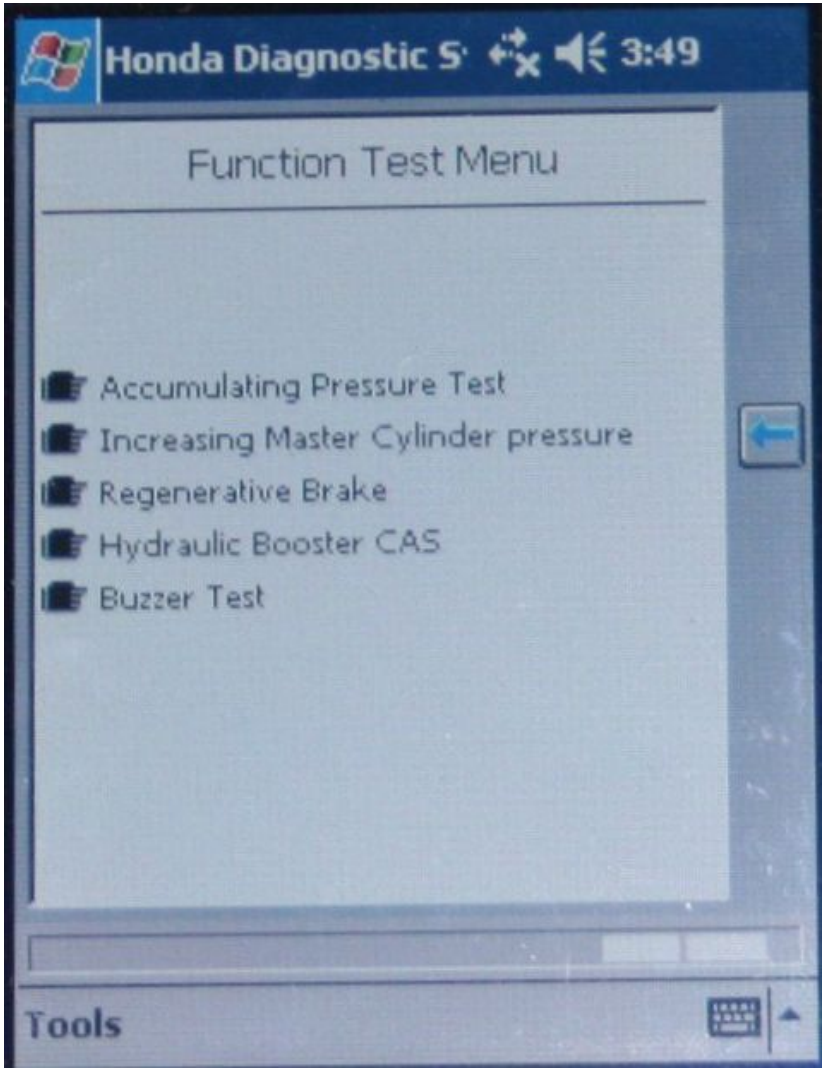
# Scan Tool Diagnostics

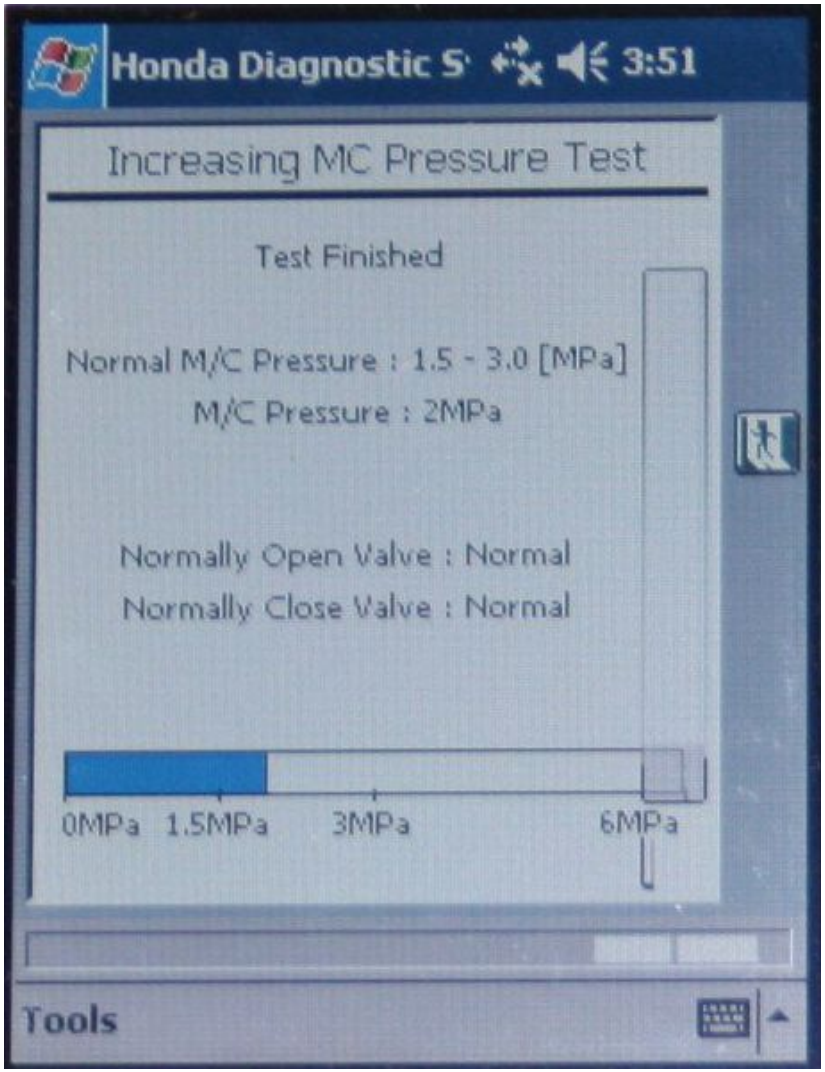


# Scan Tool Diagnostics

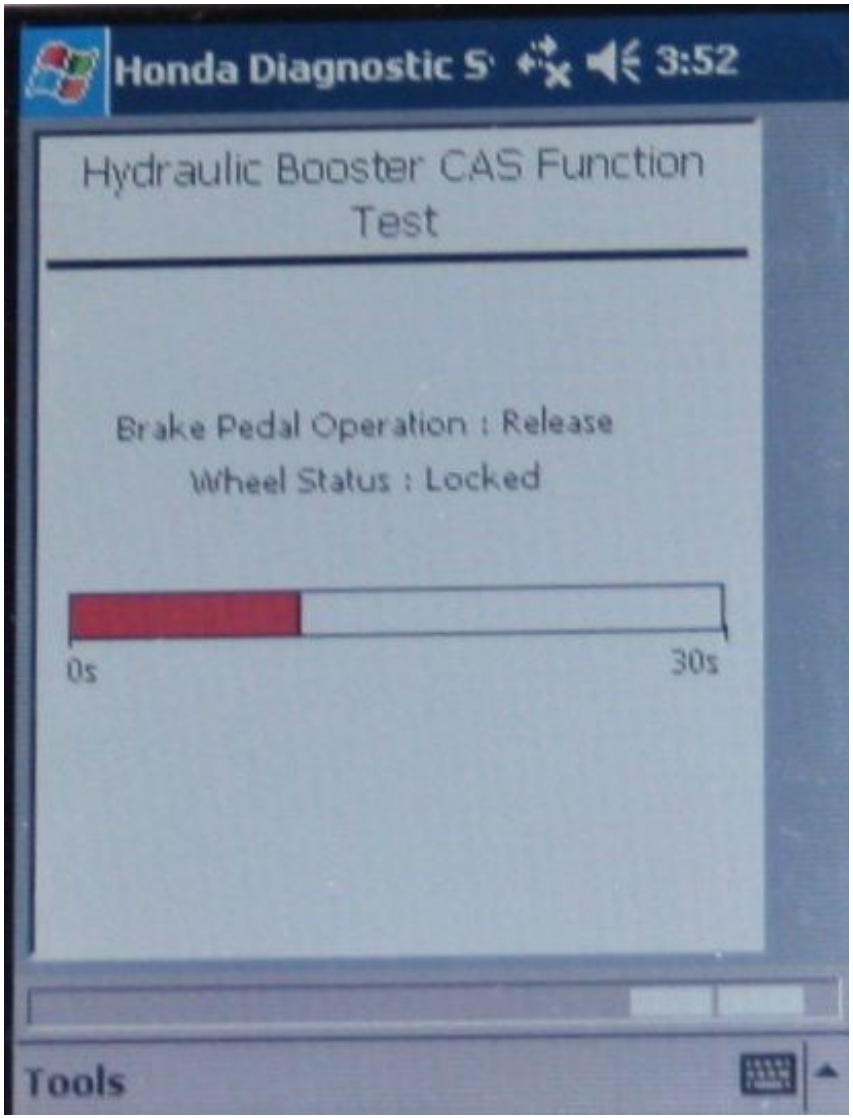


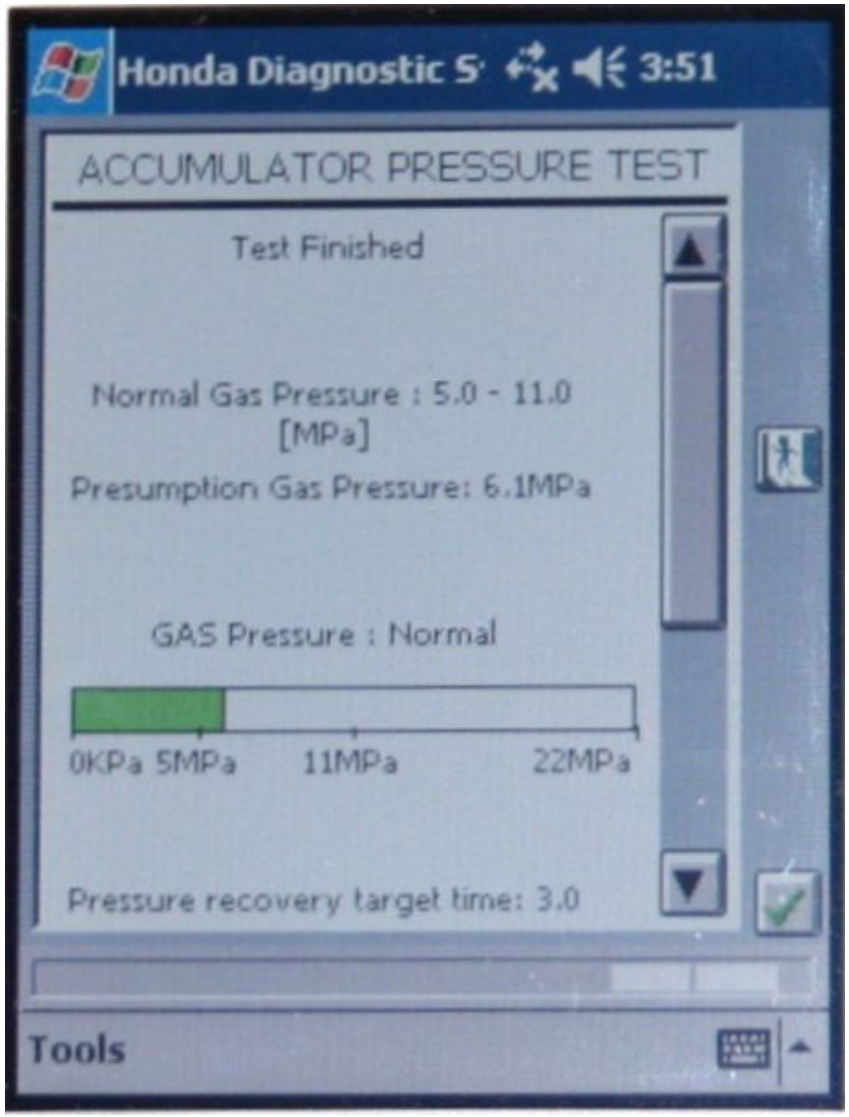
# HDS Pocket Tester



# HDS Pocket Tester



# Bleeding Procedures

- If the conventional brakes (i.e. ABS system, calipers, master cylinder) need to be bled, do this first.
- Bleed the brake system the traditional "pedal-pump" method and bleed the system at the wheels in a LF, RF, RR, LR fashion.
- Once the conventional brakes are bled, continue with the high pressure bleeding procedure.

# High Pressure Bleeding Procedures

1. Attach a clear hose to the bleeder under the servo assembly
2. Open the bleed screw about 180 degrees
3. Turn the ignition to run and let the pump discharge brake fluid from the reservoir for one minute.  Don't operate the pump for more than 110 seconds, or you can overheat it
4. Tighten the bleeder screw once no air is found discharging through the tube
5. Turn the ignition switch off

# High Pressure Bleeding Procedures

1. Fill the fluid reservoir to the middle line
2. Turn the ignition switch to run
3. Make sure the brake lights in the IP cluster turn OFF
4. Turn the ignition switch off
5. Press the brake pedal 20 times or until the pedal becomes hard
6. Wait about 5 minutes
7. Repeat steps 6 - 11 two times

# High Pressure Bleeding Procedures

1. Inspect the brake fluid level
2. Check the brake pedal stroke
3. Clear the DTCs if necessary

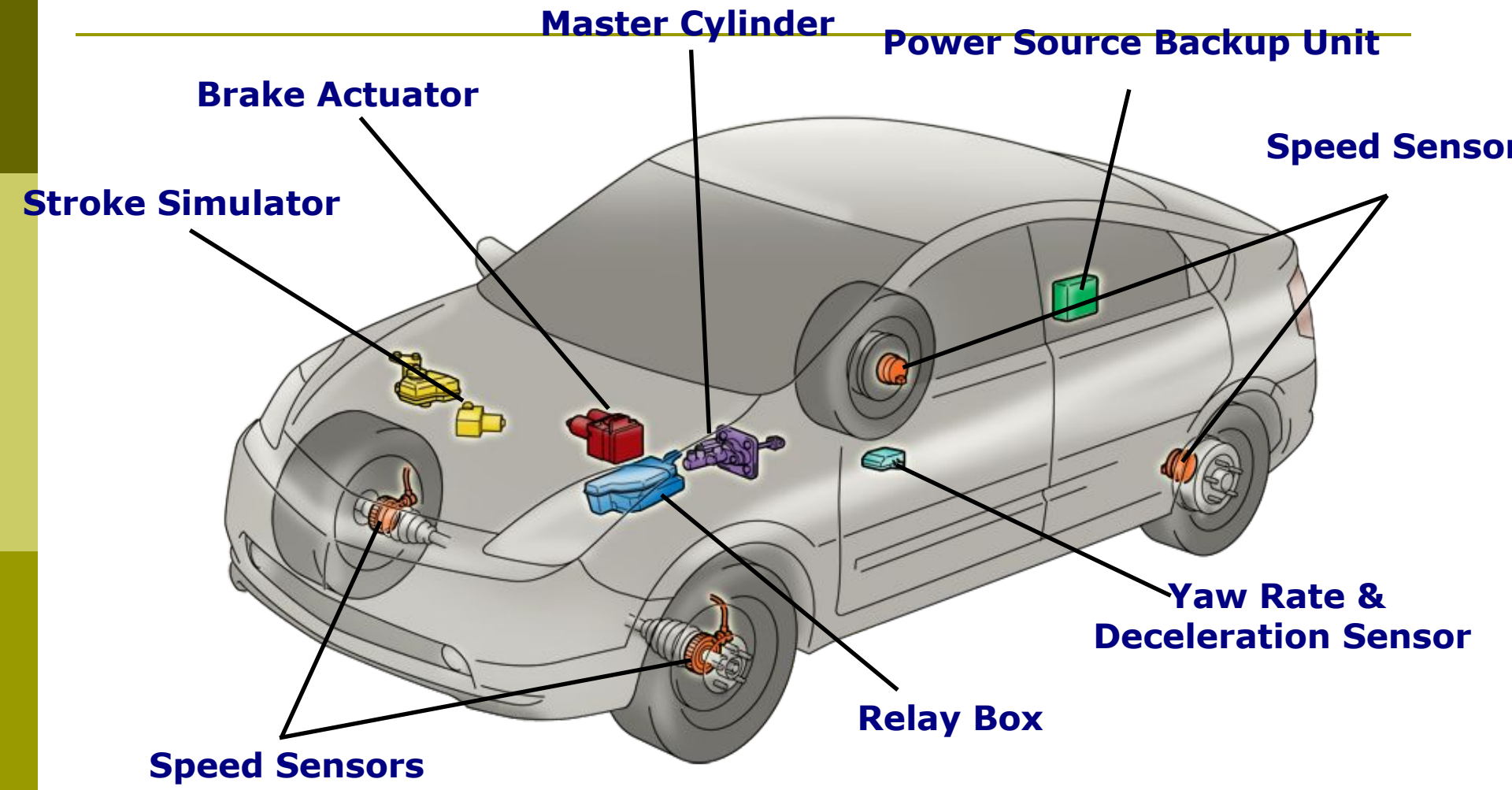
# Pedal Adjustment

1. Remove brake pedal switch by turning clockwise and pulling back
2. Pull back the carpet and remove the cutout in the padding under the brake pedal
3. Pedal height should be 6 ¼ inches

# Pedal Switch Clearance

1. Lifting pedal up, push the pedal position switch until fully seated, then rotate clockwise to lock  The gap is automatically adjusted to about .028" between the sensor body and the plunger pad
2. Make sure the brake lights work properly
3. Check pedal free play then perform the sensor zeroing procedure after installation. Pedal free play should be 1/16" to 3/16“
4. Use Scan tool to check for DTCs and to zero the pedal sensor.

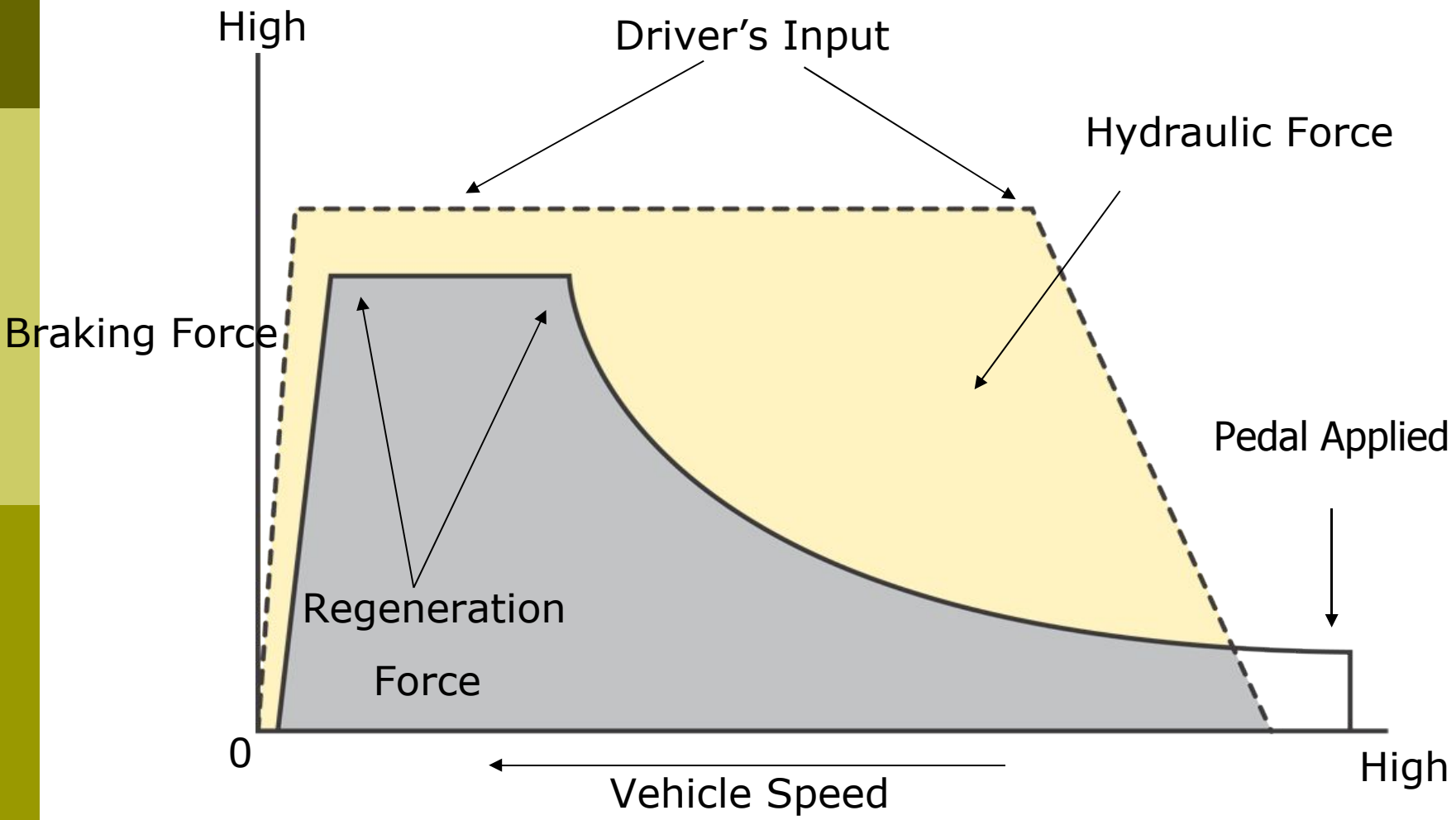
# 04 Prius Overview



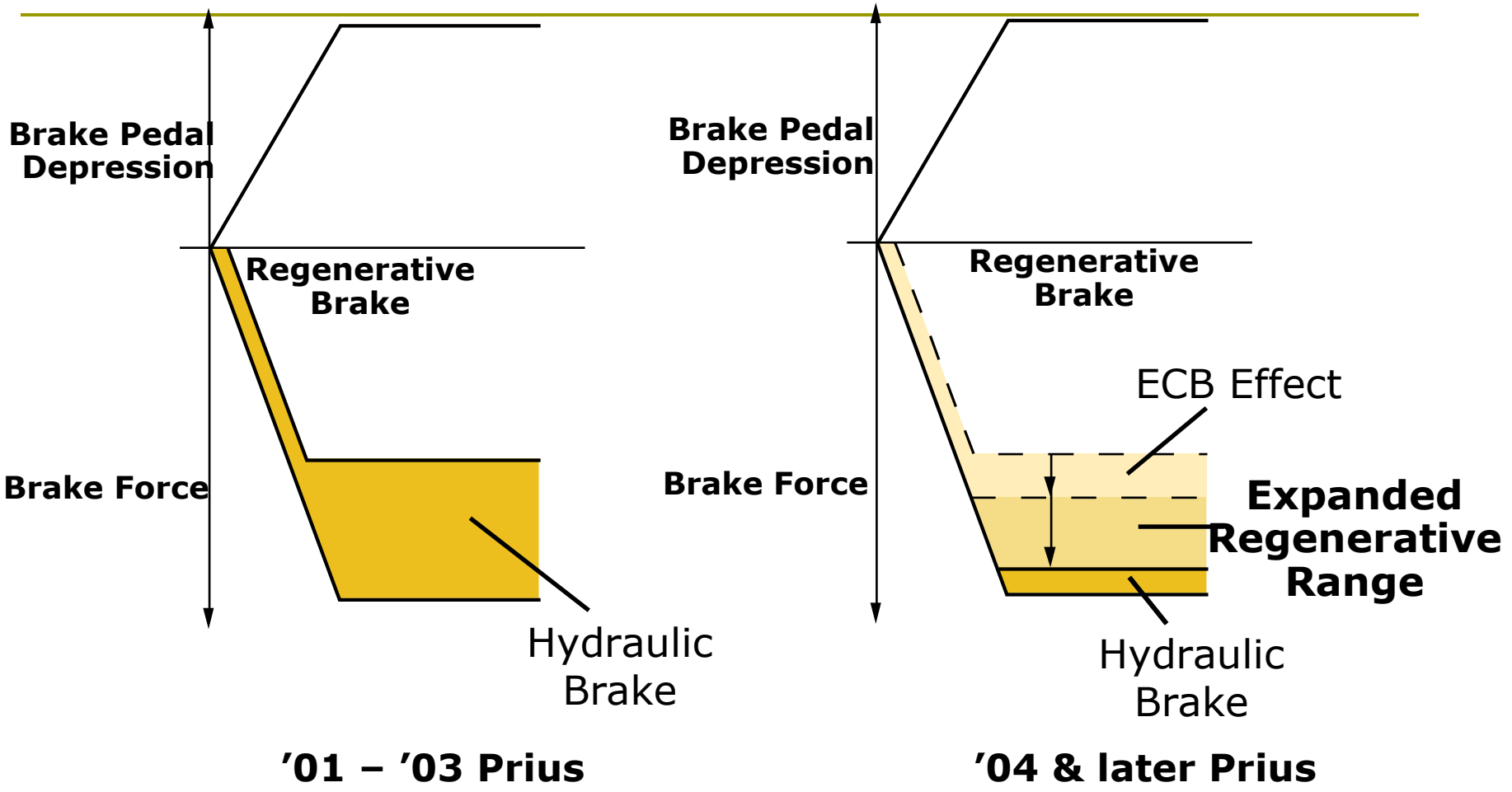
# Model Year Comparison

| '01 – '03 Prius | '04 & later Prius | Highlander Hybrid |
|---|---|---|
| Regenerative Brake Cooperative Control | Regenerative Brake Cooperative Control | Regenerative Brake Cooperative Control |
| Hydraulic Brake Booster | Electronically Controlled Braking (ECB) | Electronically Controlled Braking (ECB) |
| ABS w/ EBD | ABS w/ EBD | ABS w/ EBD |
| - | Enhanced VSC (S-VSC) | VSC |
| - | Brake Assist | Brake Assist |
| - | - | TRAC |
| - | - | Vehicle Dynamics Integrated Manage |

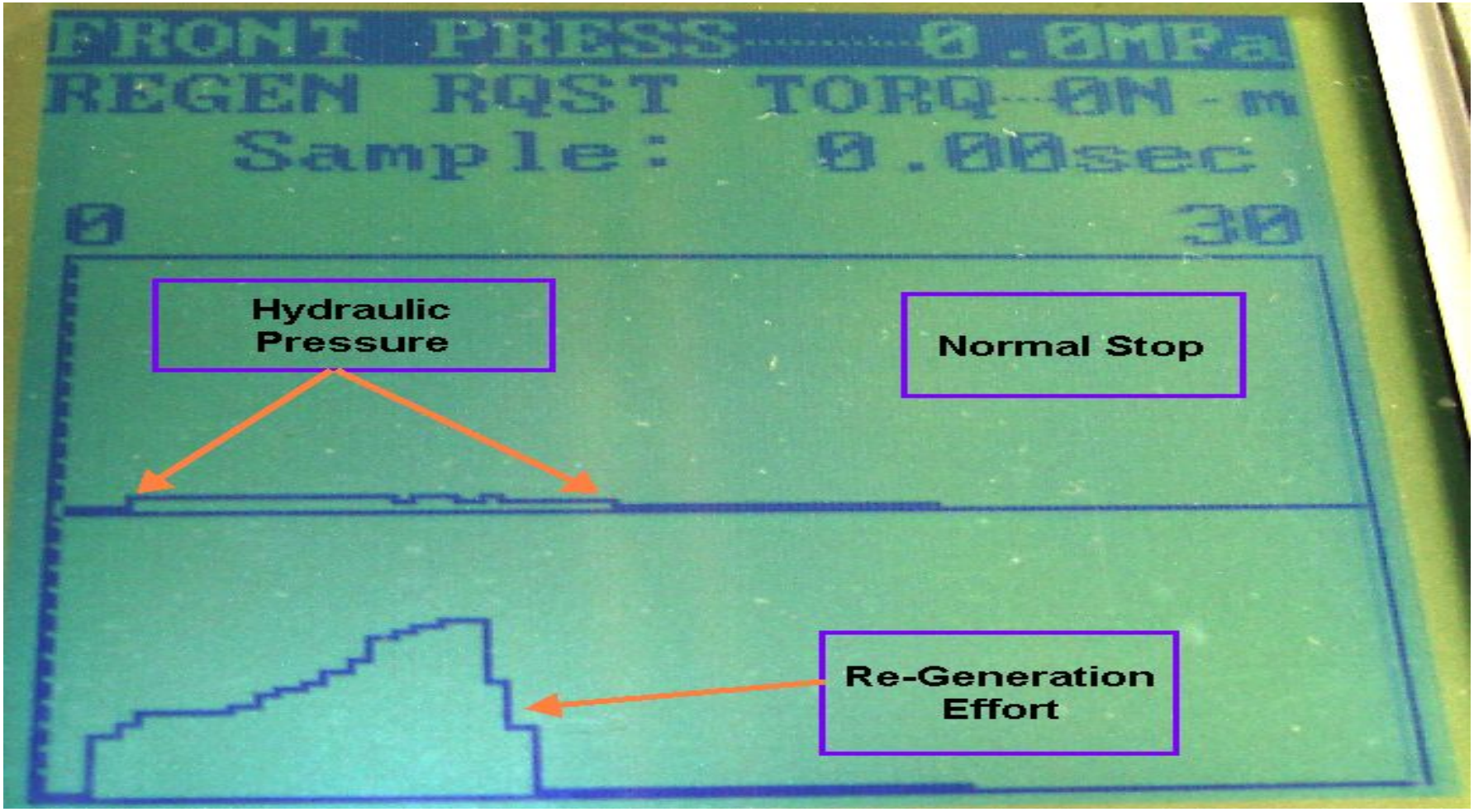
# Brake Force Proportioning



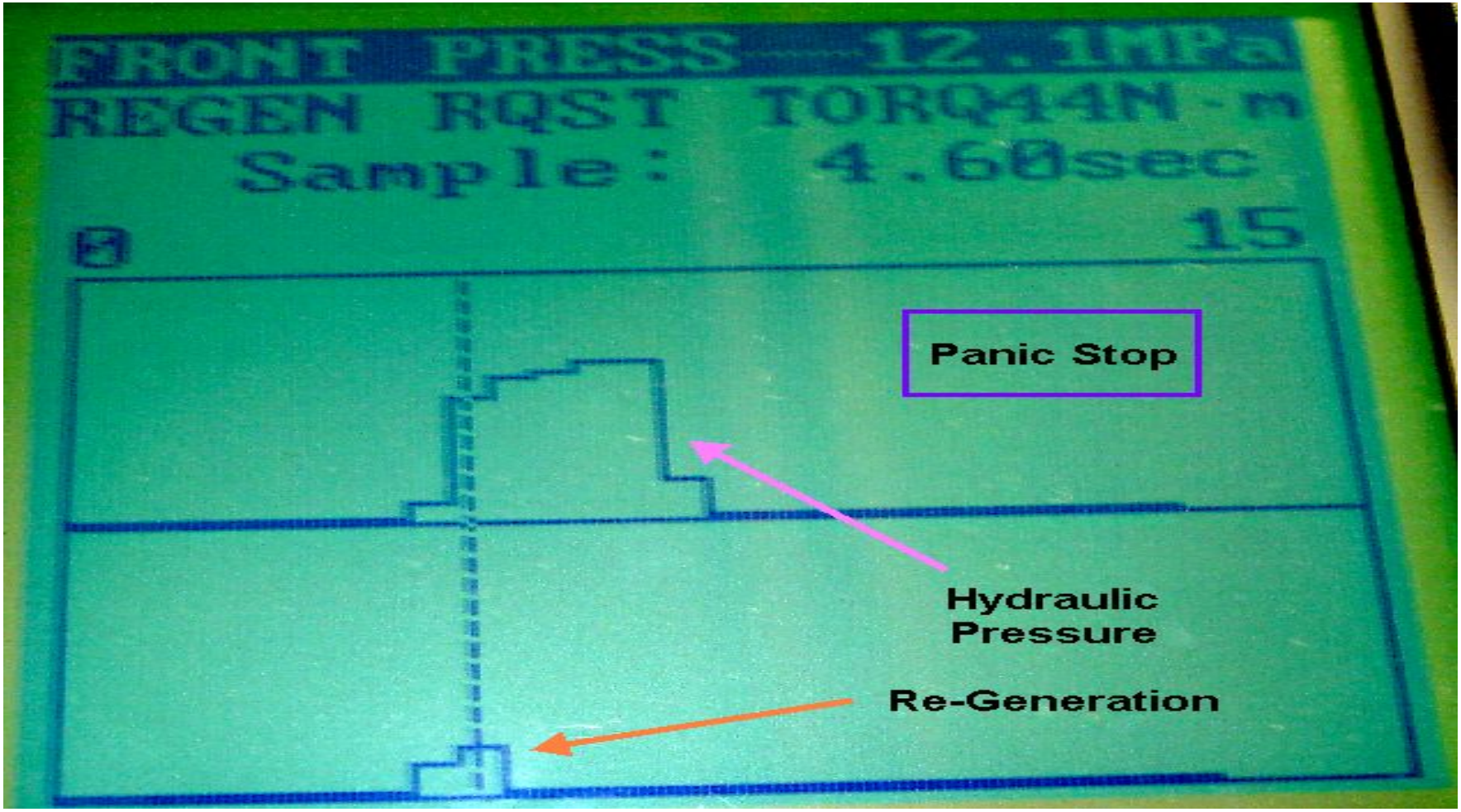
# Improved Regenerative Brake

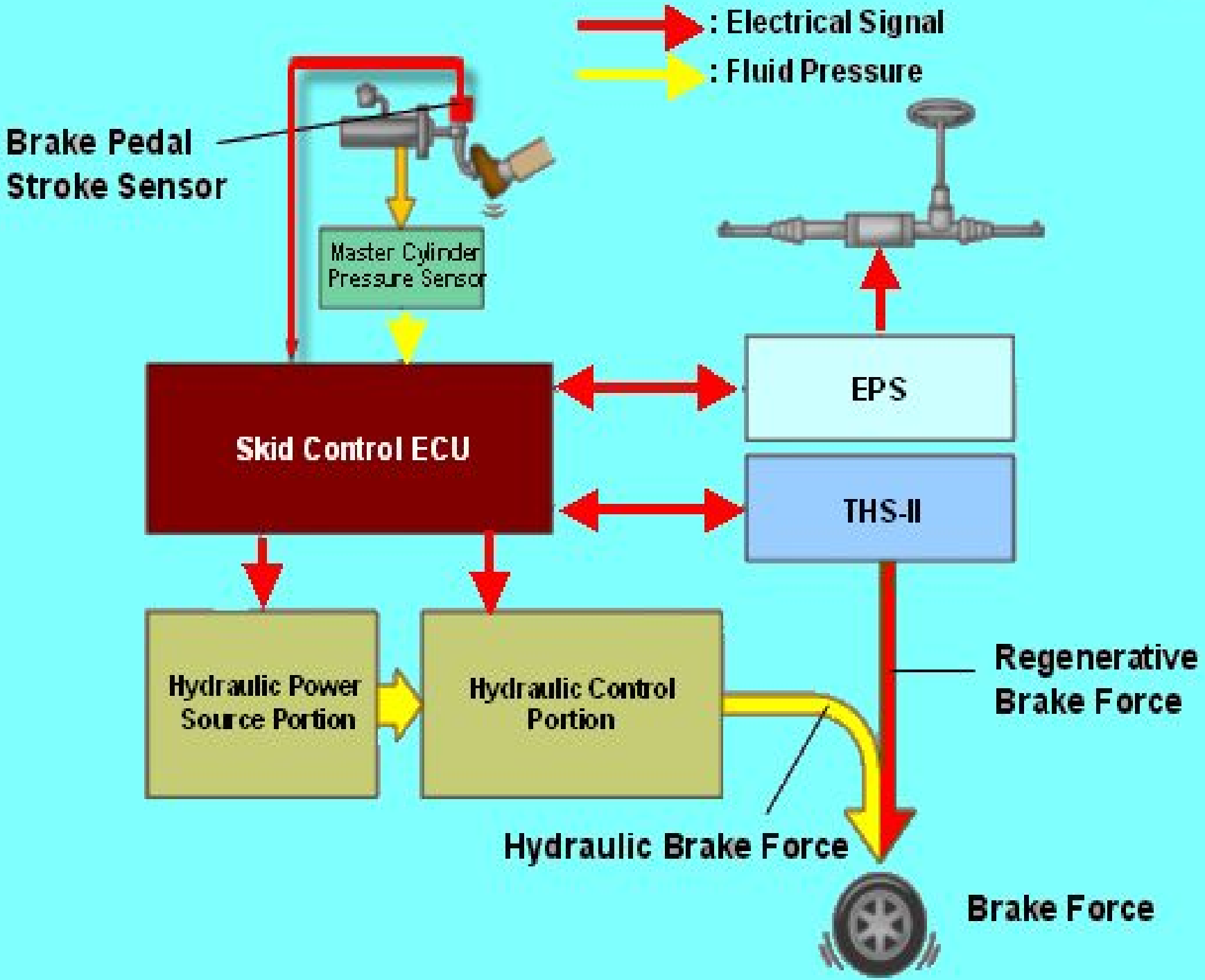


# Normal Stop

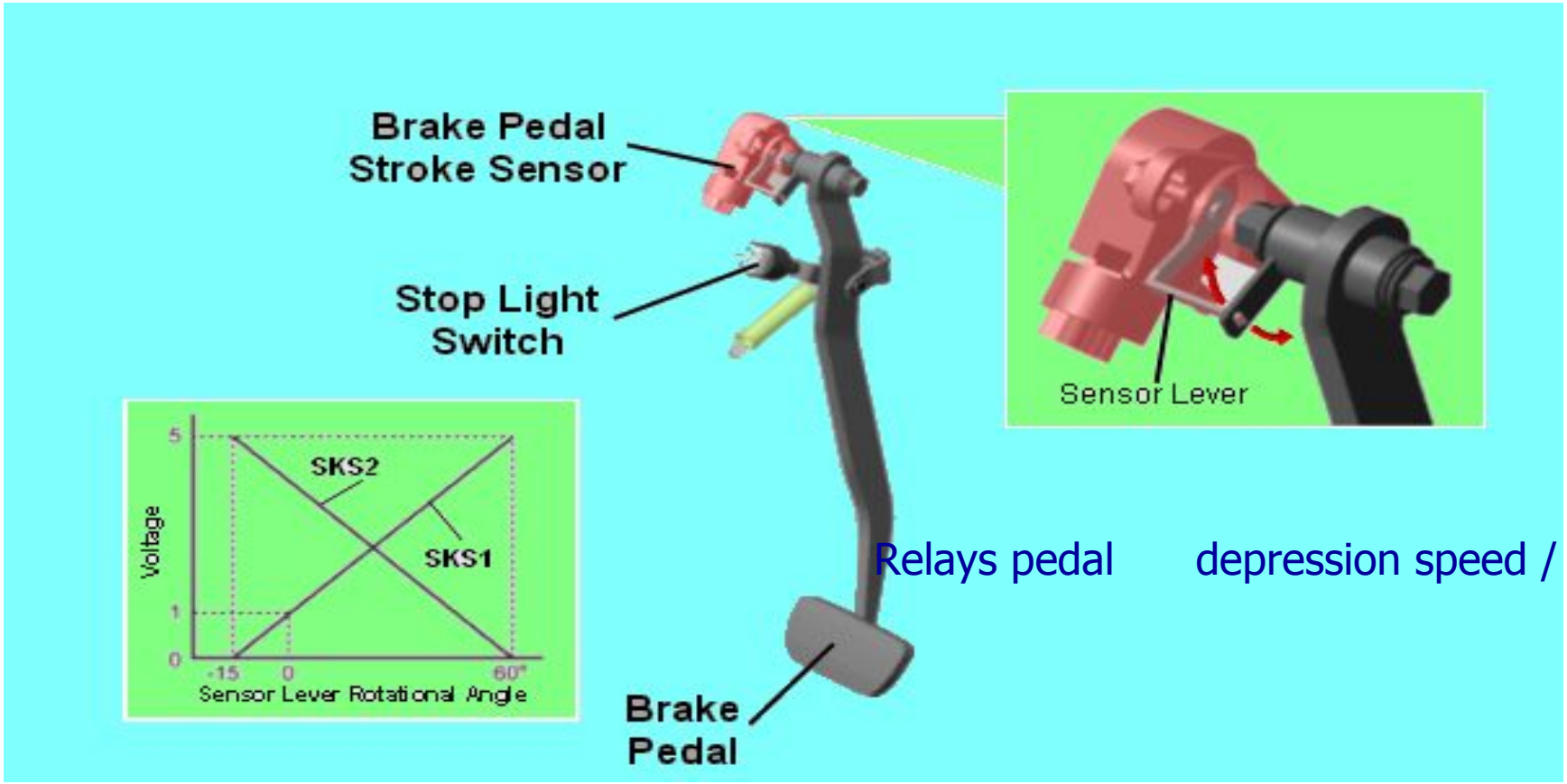

FRONT PRESS 0.0MPa
REGEN RQST TORQ 0N m
Sample: 0.00sec
0
30
Hydraulic Pressure
Normal Stop
Re-Generation Effort

# Panic Stop

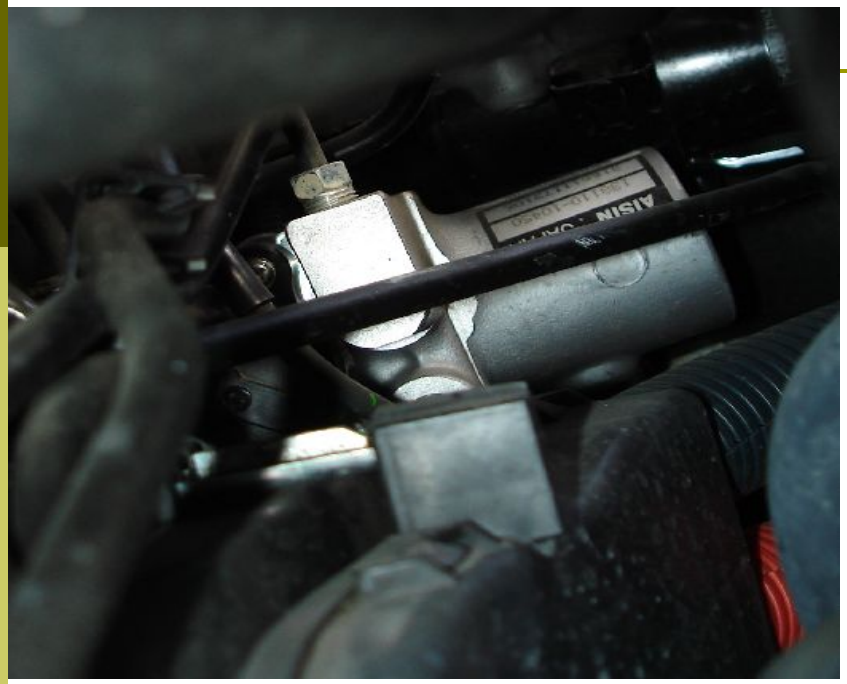

FRONT PRESS 12.1MPa
REGEN RQST TORQ44N·m
Sample: 4.60sec
15
Panic Stop
Hydraulic Pressure
Re-Generation

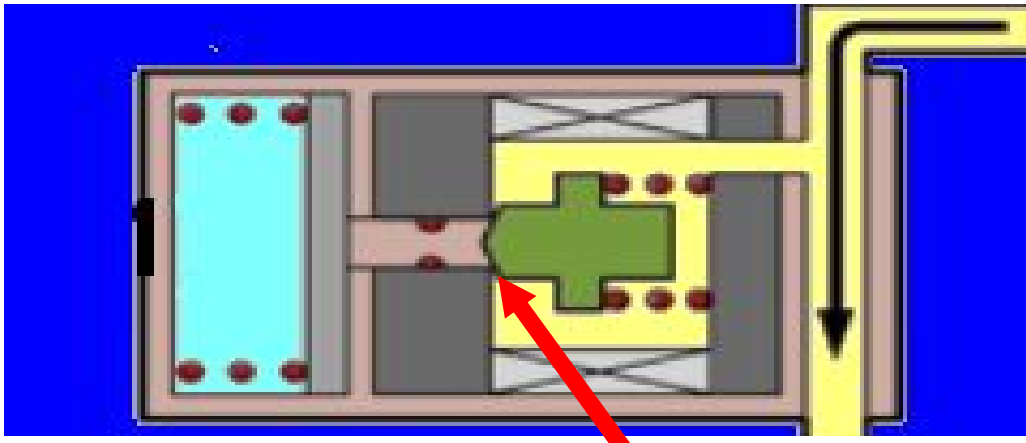

: Electrical Signal
: Fluid Pressure
Brake Pedal Stroke Sensor
Master Cylinder Pressure Sensor
EPS
Skid Control ECU
THS-II
Hydraulic Power Source Portion
Hydraulic Control Portion
Regenerative Brake Force
Hydraulic Brake Force
Brake Force

# Brake Pedal Stroke Sensor

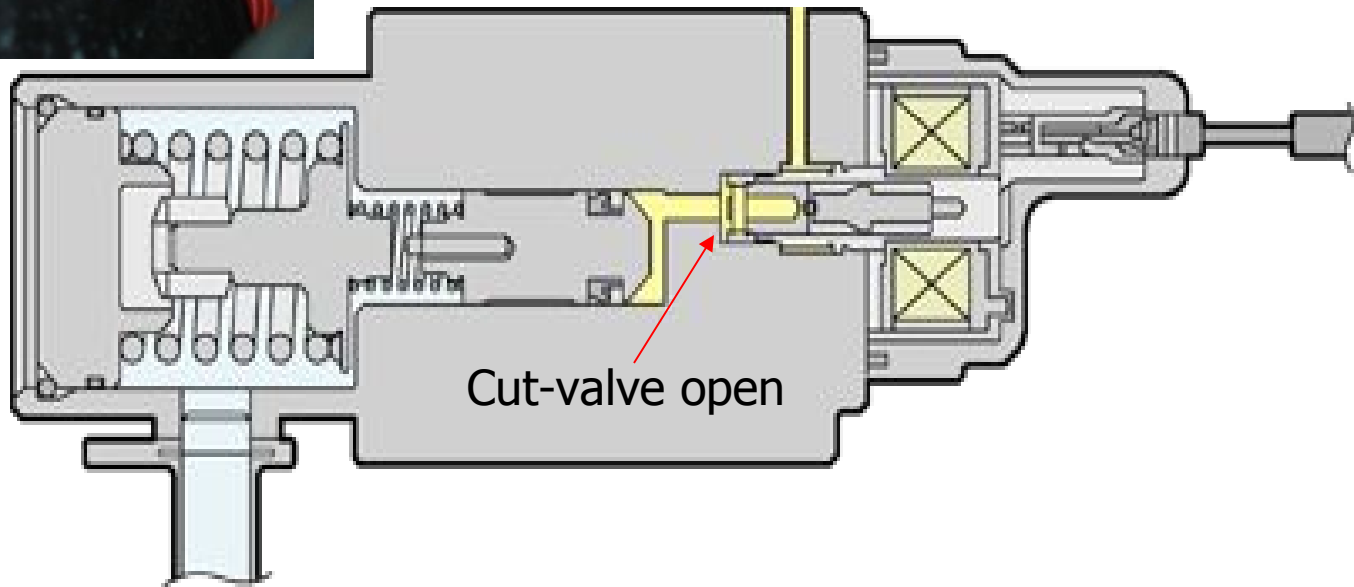


# Stroke Simulator



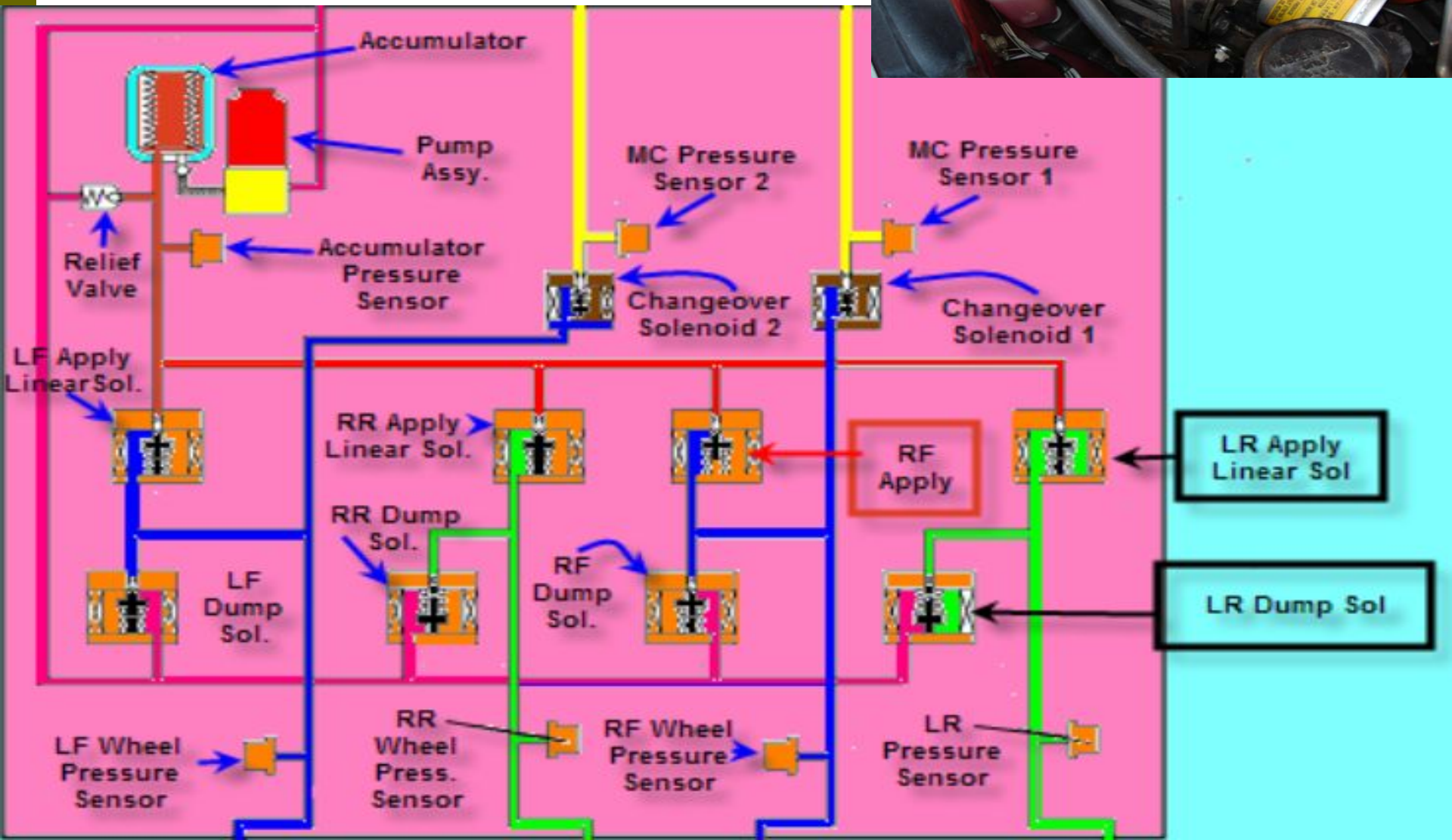


Cut Valve Closed

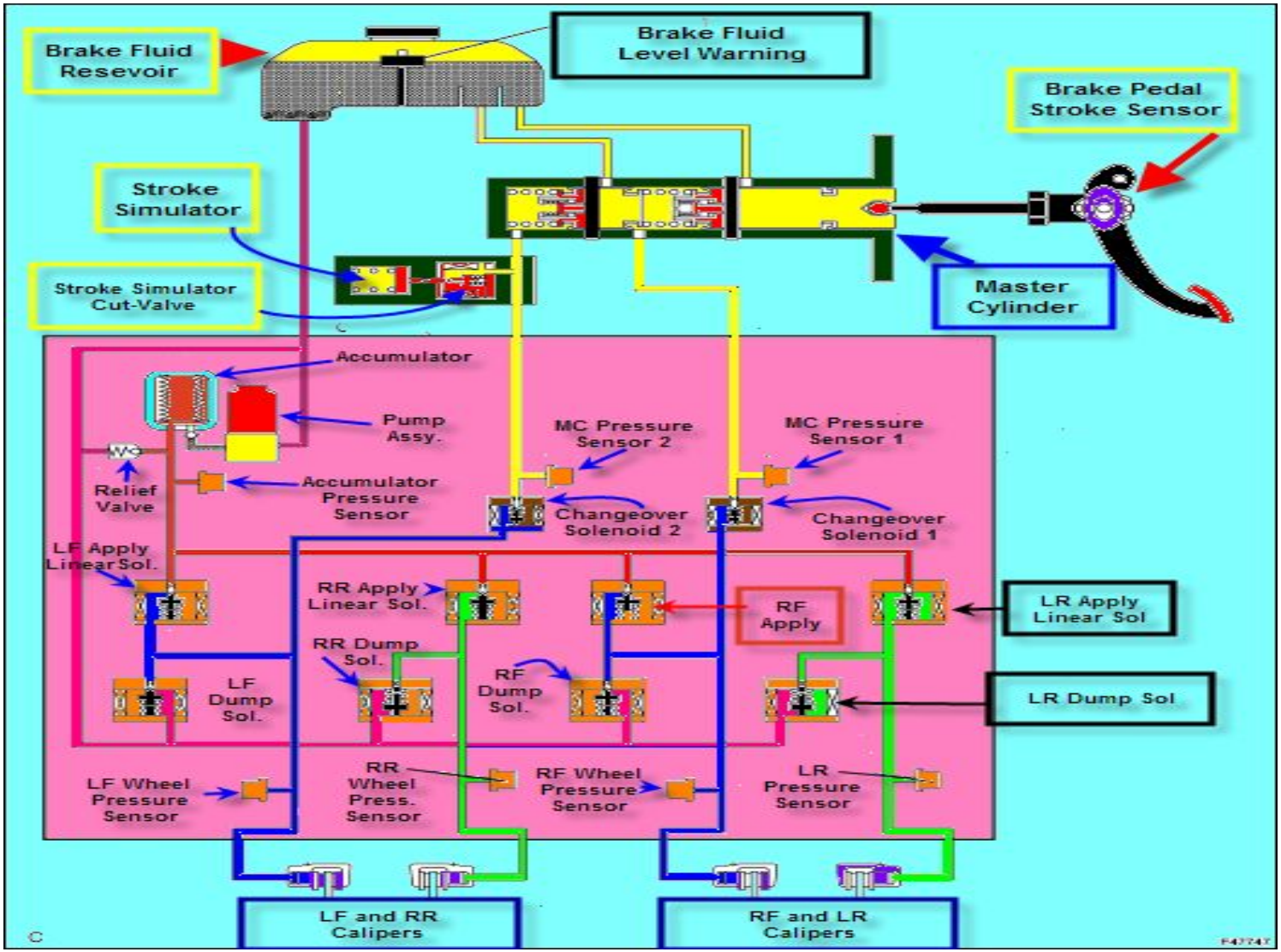


Cut-valve open

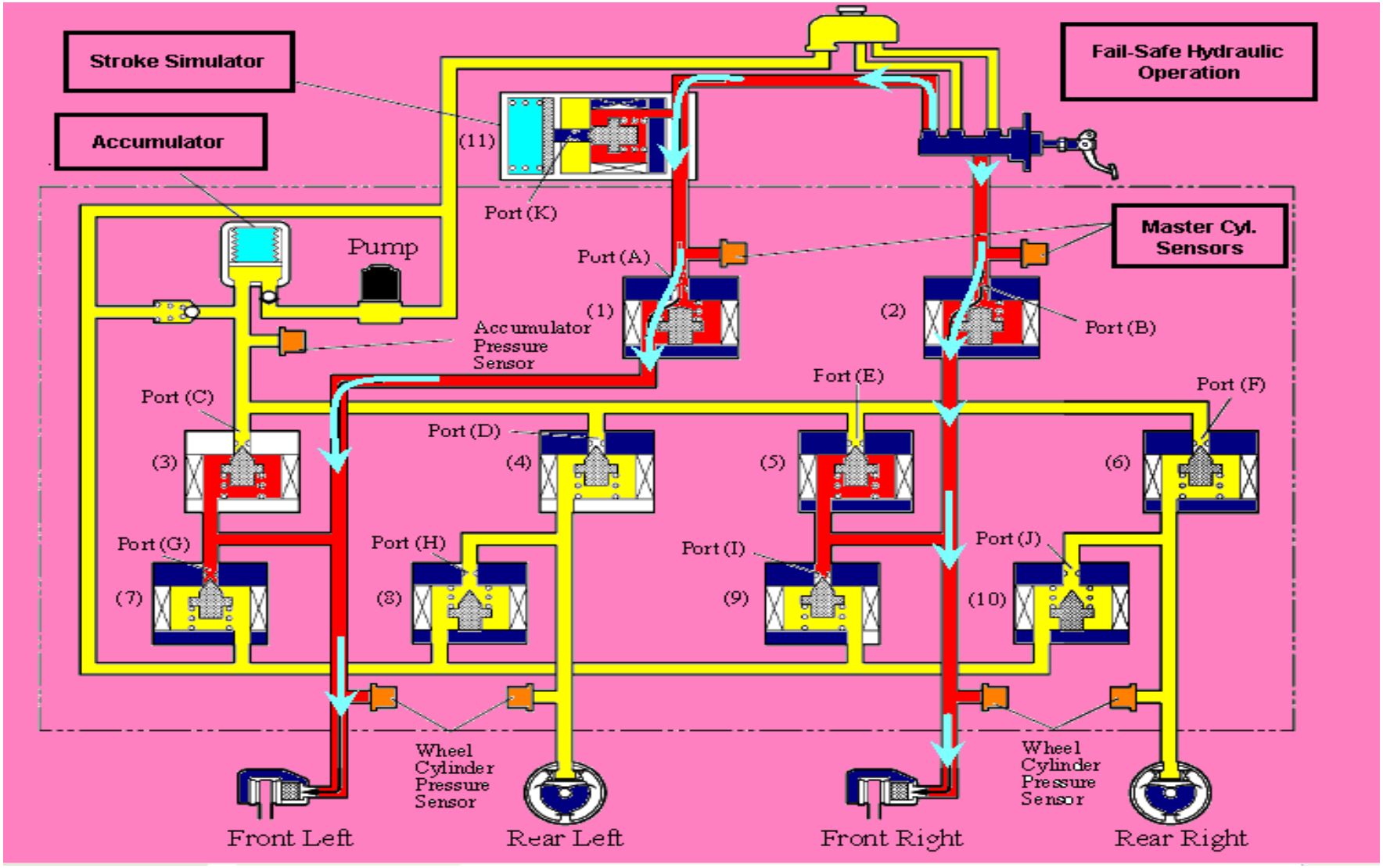
# Brake Actuator



# Normal Mode: Fluid Movement



# Fail-Safe Mode



# Brake Bleeding Steps

Cautions:

- Scanner is needed for most procedures.
- Remove pump motor relays 1& 2 until told to install or in some operations they will instruct you to remove and re-install, but you do not want the pump running while servicing.
- When removing any part of the system, remove relays and bleed pressure off before removing any lines.

# Brake Bleeding Steps

1. Connect hand-held tester & select diagnostic menu (ABS/VSC air bleeding)
2. List:
    1. Usual
    2. Actuator
    3. Master Cylinder or Stroke Simulator

Hint: A "FAILED" message will appear in any mode of bleeding if the system believes there is still air present Simply return to MENU, repeat procedure.

3. Fill reservoir (DOT 3) with brake fluid.

# Brake Bleeding Steps

4. To bleed the front/rear brakes select “USUAL” and follow on screen prompts to “turn off ignition, remove motor relays 1&2, turn ignition on then press enter.

5. An “Operations” screen will appear and allow the front brakes to be bleed in the normal fashion.

6. Press enter and a screen will appear saying turn ignition off, install relays, and turn ignition on. Press enter.

7. A screen will appear saying hold brake pedal down and bleed air from left rear wheel.

(The actuator pump motor will run while pedal is depressed.)

# Brake Bleeding Steps

8. The next screen will allow for bleeding in the same manner for the right rear.

9. Pressing enter a screen should come up to say Complete. If not, repeat.

10. Bleeding the Actuator is much the same. Follow on screen prompts to bleed at the wheels in a defined order.

# Brake Bleeding Steps

11. Option is available to bleed the air from the stroke simulator line. Screen will come up wanting the pedal depressed 20 times in 20 seconds/ hold pedal on last ($20^{th}$) stroke to bleed.

12. Bleeding the Master Cylinder/ Stroke Simulator requires following the screen prompts, first performing the USUAL procedure for front wheels as before.

**DO NOT FORGET TO CLEAR THE DTCs.**

# Brake Pedal Adjustment

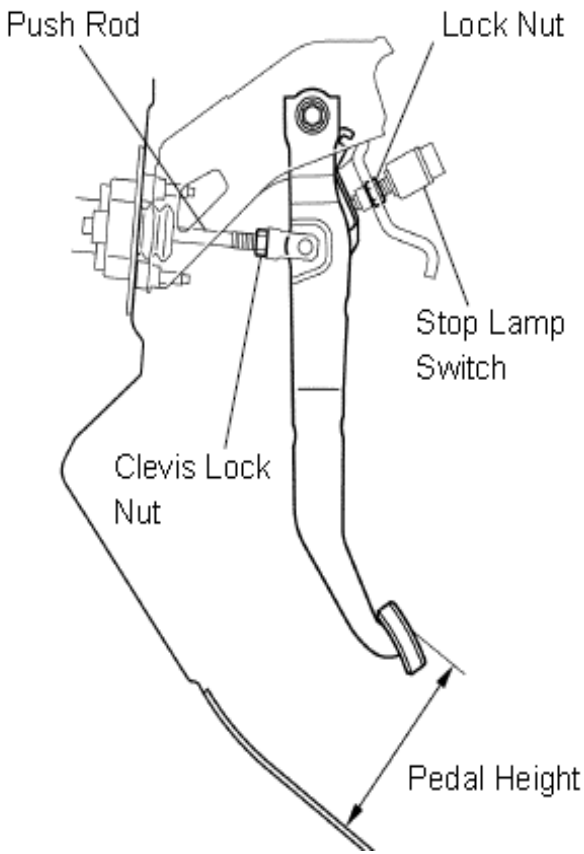
1. Inspect brake pedal height.
   **Pedal to top of the asphalt sheet:**
   **138 to 148 mm (5.433 to 5.827 in.)**

2. Back off stop light switch.

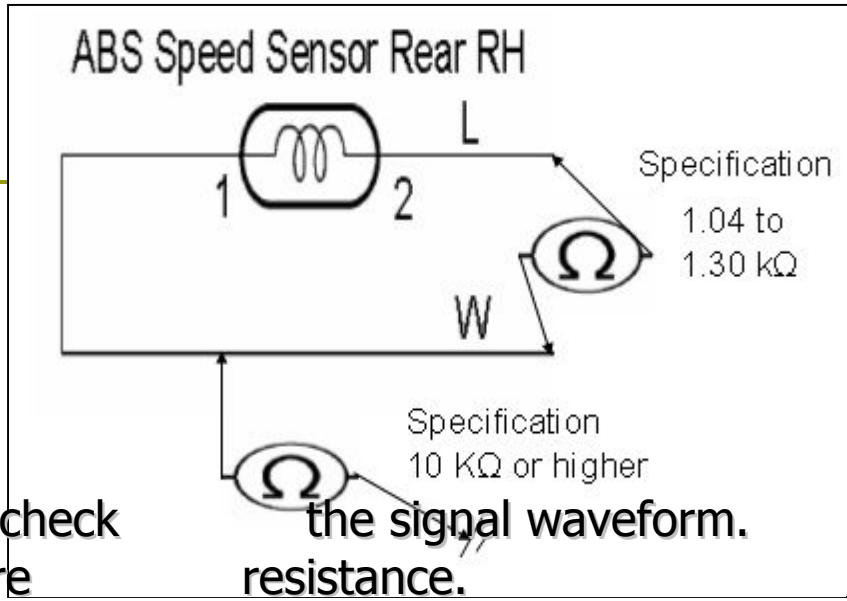
3. Loosen the clevis lock nut. Turn the push rod to adjust the pedal height.

4. Tighten the clevis lock nut.
   **Torque: 26 Nm (265 kgfcm, 19 ft.lb)**

5. Adjust Stop light switch to obtain .5-2.4mm (.02-.095”) between the threaded portion of switch and pedal.



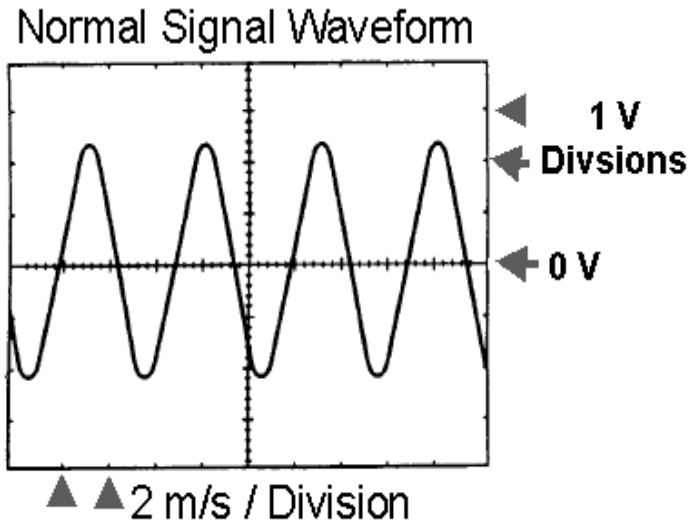
# Wheel Speed Sensors



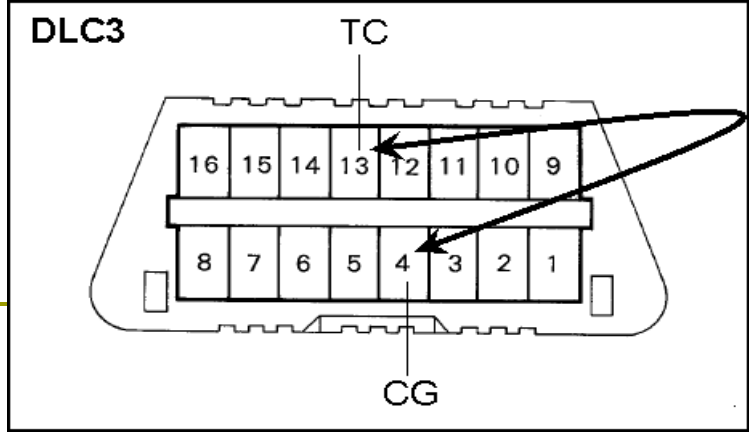

Diagnostics

ct sensor & Speedometer. (± 10%)

als + & -
d Control ECU. Drive 19 mph (30 km/h), and check the signal waveform.
pect sensor connector at the wheel and measure resistance.
or damage to wire or terminals.
od signal and erase DTCs.



# Reading Codes

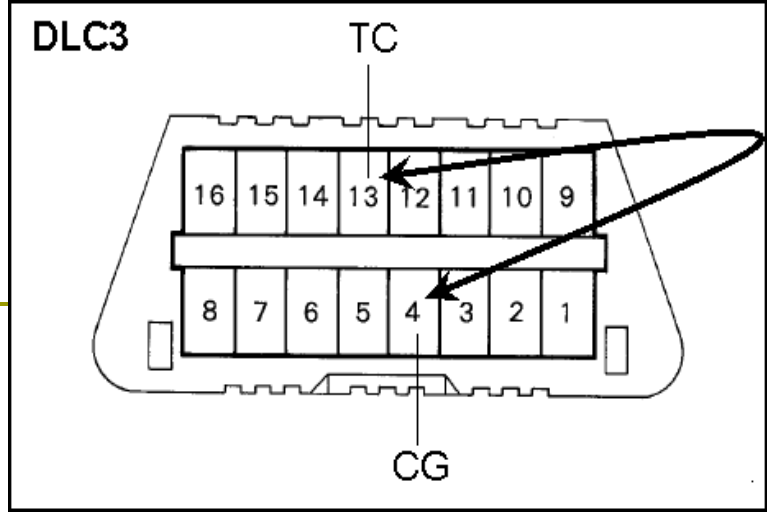



- Jumper terminals TC to CG in Data Link Connector 3 (DLC3).
- Turn ignition "on" (Smart Key & push button)
- Read Brake Control, ABS, & VSC warning lights in instrument panel's combination meter. If there is a stored DTC, the light pertaining to that area will flash on, 4 sec. pause, add each .5 sec. flash to get first digit, a 2.5 sec. pause indicates the second digit of the 2 digit code, and add again. Similar to the way GM's OBD I flashed a code.

  (If 2 or more codes are detected, the lowest number will flash first then 2.5 sec. later it will start to flash the next code.)
- Remove jumper.

*Normal: steady blinking light at 1/4 second intervals*.

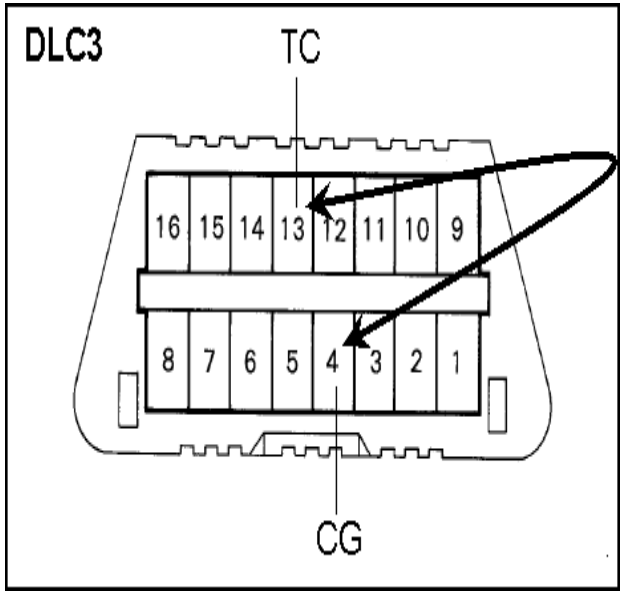
# Clearing Codes




- Turn ignition off
- Jumper terminals TC to CG again.
- Turn ignition on.
- Depress brake pedal 8 times in 5 seconds.
- Check for normal code flashing. (repeat if necessary or codes are present)
- Remove jumper.

# SKID CONTROL INITIALIZATION

- 2 ways to "Initialize" the SC ECU:
- Scanner and Follow Prompts
- Using a Jumper Wire or SST check wire.



# Jumper Wire

Step 1. Clearing stored values of previous linear solenoids and calibration values.

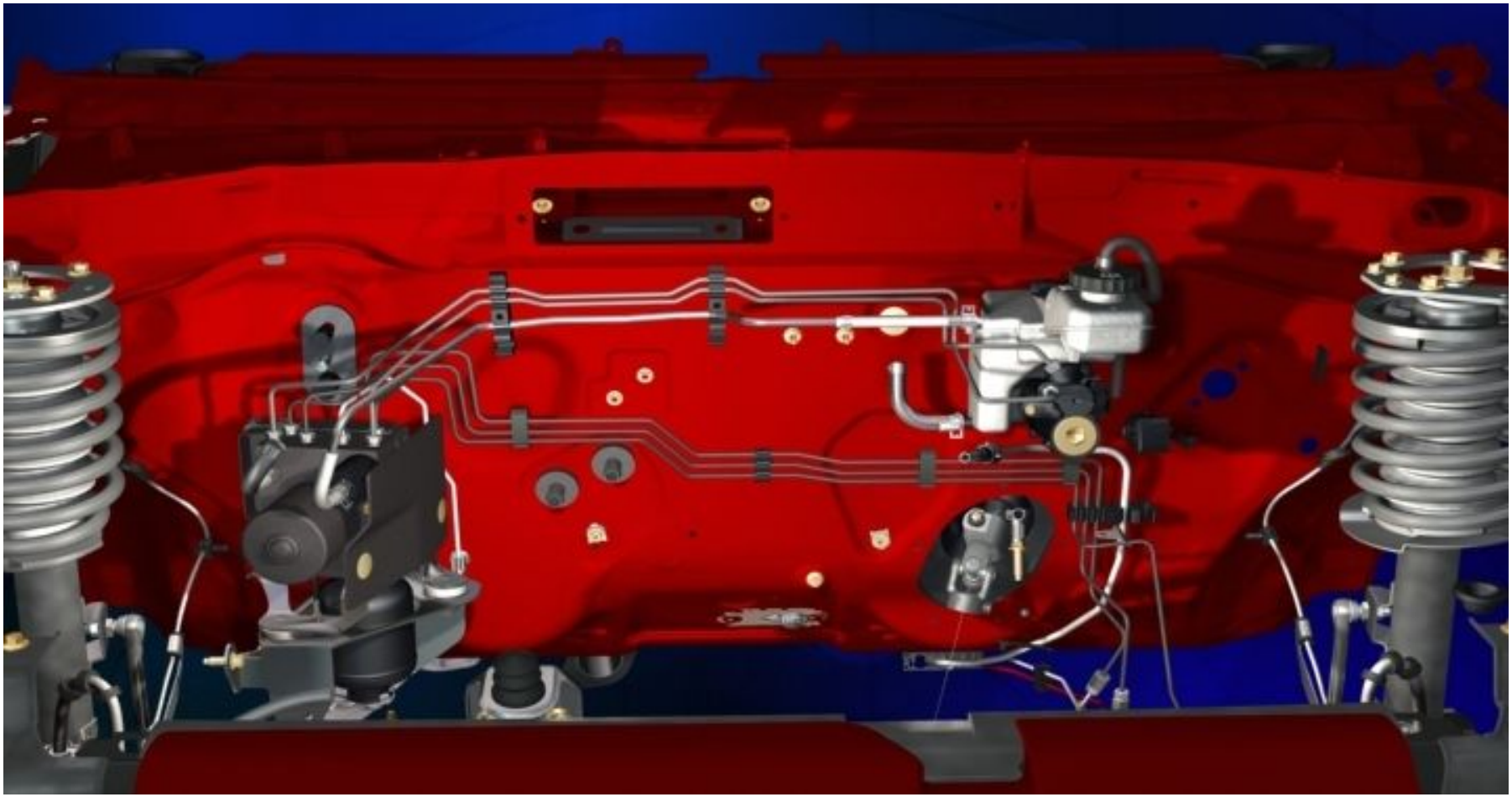
- Shift into park, turn ignition on, and brake pedal released.
- Connect and disconnect terminals TS/CG of the DLC3 (4 times)  within 8 seconds.
- Leave wire across terminals and check for a code 42 from the ABS light, code 45 from VSC light, or code 48, 66, or 95 from Electronically Controlled Brake light. They will flash at 1/2 second intervals with a 1 ½ second between digits. Any other codes represent a problem. Try again.
- Remove wire.

# Jumper Wire

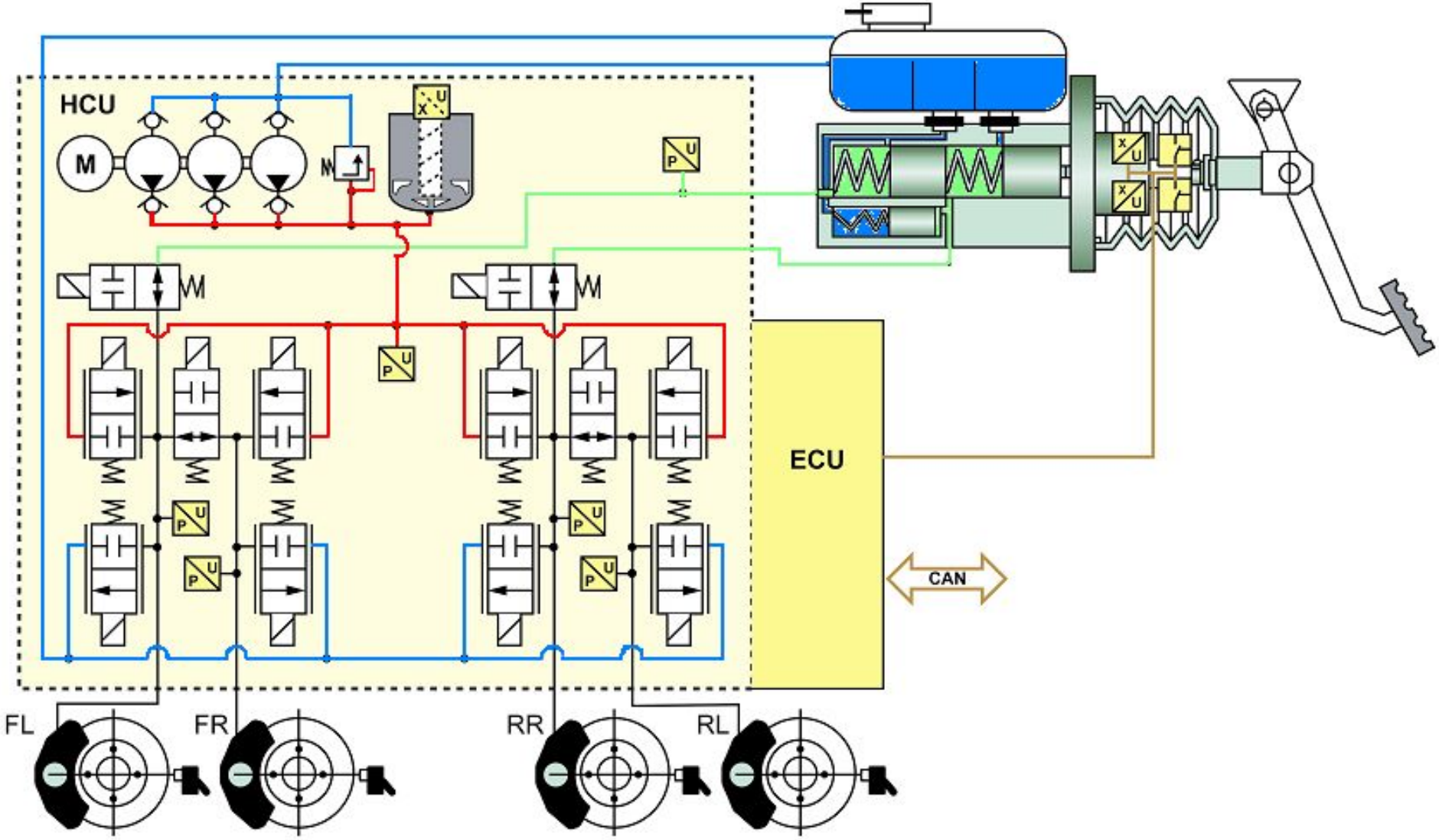
Step 2. Initialization Procedure:

- Connect wire as before.
- In park, ignition on, & brake pedal released.
- Leave the vehicle stationary without depressing the brake pedal for 1 or 2 minutes.
- Check that the interval between blinks of the brake control warning light changes from 1 second to 0.25 seconds
- No DTC C1345/66 present.
- Turn off ignition and remove wire.

# Ford Escape Hybrid Braking System



# Ford Escape Hybrid Braking System



# Ford Escape Hybrid Braking System

**Pressure Units Conversion Chart**

| psi | atms. | "$H_2O$ | mm $H_2O$ | cm $H_2O$ | oz/in² | Kg/cm² | "Hg | mm Hg (Torr) | cm Hg | mbar | bar | Pa (N/m²) | kPa | MPa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0681 | 27.71 | 703.8 | 70.38 | 16 | 0.0704 | 2.036 | 51.715 | 5.17 | 68.95 | 0.0689 | 6,895 | 6.895 | 0.0069 |
| 14.7 | 1 | 407.2 | 10,343 | 1,034.3 | 235.1 | 1.033 | 29.92 | 760 | 76 | 1013 | 1.013 | 101,325 | 101.3 | 0.1013 |
| 0.0361 | 0.00246 | 1 | 25.4 | 2.54 | 0.5775 | 0.00254 | 0.0735 | 1.866 | 0.187 | 2.488 | 0.00249 | 248.8 | 0.249 | 0.00025 |
| 0.001421 | 0.000097 | 0.0394 | 1 | 0.1 | 0.0227 | 0.0001 | 0.00289 | 0.0735 | 0.00735 | 0.098 | 0.000098 | 9.8 | 0.0098 | 0.00001 |
| 0.01421 | 0.000967 | 0.3937 | 10 | 1 | 0.227 | 0.001 | 0.0289 | 0.735 | 0.0735 | 0.98 | 0.00098 | 98 | 0.098 | 0.0001 |
| 0.0625 | 0.00425 | 1.732 | 43.986 | 4.40 | 1 | 0.0044 | 0.1273 | 3.232 | 0.3232 | 4.31 | 0.00431 | 431 | 0.431 | 0.00043 |
| 14.22 | 0.968 | 394.1 | 100,010 | 1,001 | 227.6 | 1 | 28.96 | 735.6 | 73.56 | 980.7 | 0.981 | 98,067 | 98.07 | 0.0981 |
| 0.4912 | 0.03342 | 13.61 | 345.7 | 34.57 | 7.858 | 0.0345 | 1 | 25.4 | 2.54 | 33.86 | 0.0339 | 3,386 | 3.386 | 0.00339 |
| 0.01934 | 0.001316 | 0.536 | 13.61 | 1.361 | 0.310 | 0.00136 | 0.0394 | 1 | 0.1 | 1.333 | 0.001333 | 133.3 | 0.1333 | 0.000133 |
| 0.1934 | 0.01316 | 5.358 | 136.1 | 13.61 | 3.10 | 0.0136 | 0.394 | 10 | 1 | 13.33 | 0.01333 | 1,333 | 1.333 | 0.00133 |
| 0.0145 | 0.000987 | 0.4012 | 10.21 | 1.021 | 0.2321 | 0.00102 | 0.0295 | 0.75 | 0.075 | 1 | 0.001 | 100 | 0.1 | 0.0001 |
| 14.504 | 0.987 | 401.9 | 10,210 | 1021 | 232.1 | 1.02 | 29.53 | 750 | 75 | 1,000 | 1 | 100,000 | 100 | 0.1 |
| 0.000145 | 0.00001 | 0.00402 | 0.102 | 0.0102 | 0.00232 | 0.00001 | 0.000295 | 0.0075 | 0.00075 | 0.01 | 0.00001 | 1 | 0.001 | 0.000001 |
| 0.14504 | 0.00987 | 4.019 | 102.07 | 10.207 | 2.321 | 0.0102 | 0.295 | 7.5 | 0.75 | 10 | 0.01 | 1,000 | 1 | 0.001 |
| 145.04 | 9.869 | 4019 | 102,074 | 10,207 | 2321 | 10.2 | 295.3 | 7500 | 750 | 10,000 | 10 | 1,000,000 | 1,000 | 1 |

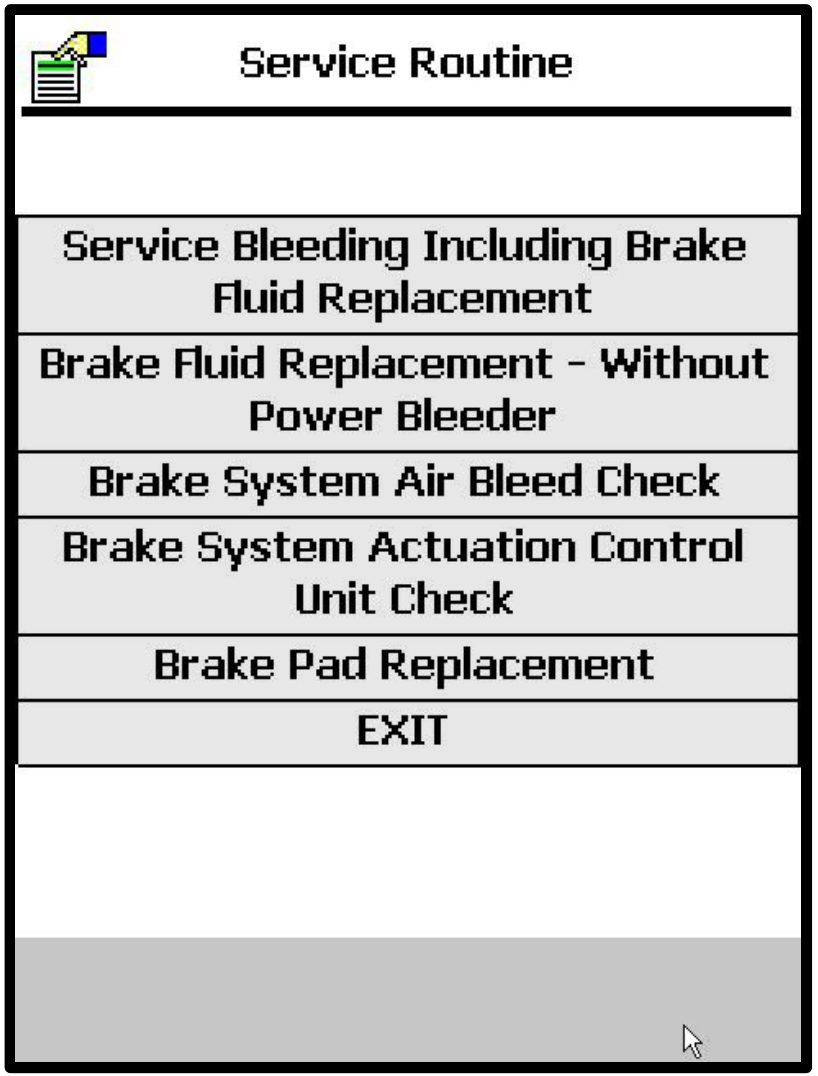
# Pad Service Mode

1. Vehicle in Park
2. Ignition to run
3. Apply and hold the brake pedal
4. Cycle ignition OFF and ON three times (fast) in three seconds
5. Release the brake pedal
6. Brake warning lamp will flash while hydraulic pressure is dumped
7. Brake warning lamp will remain illuminated

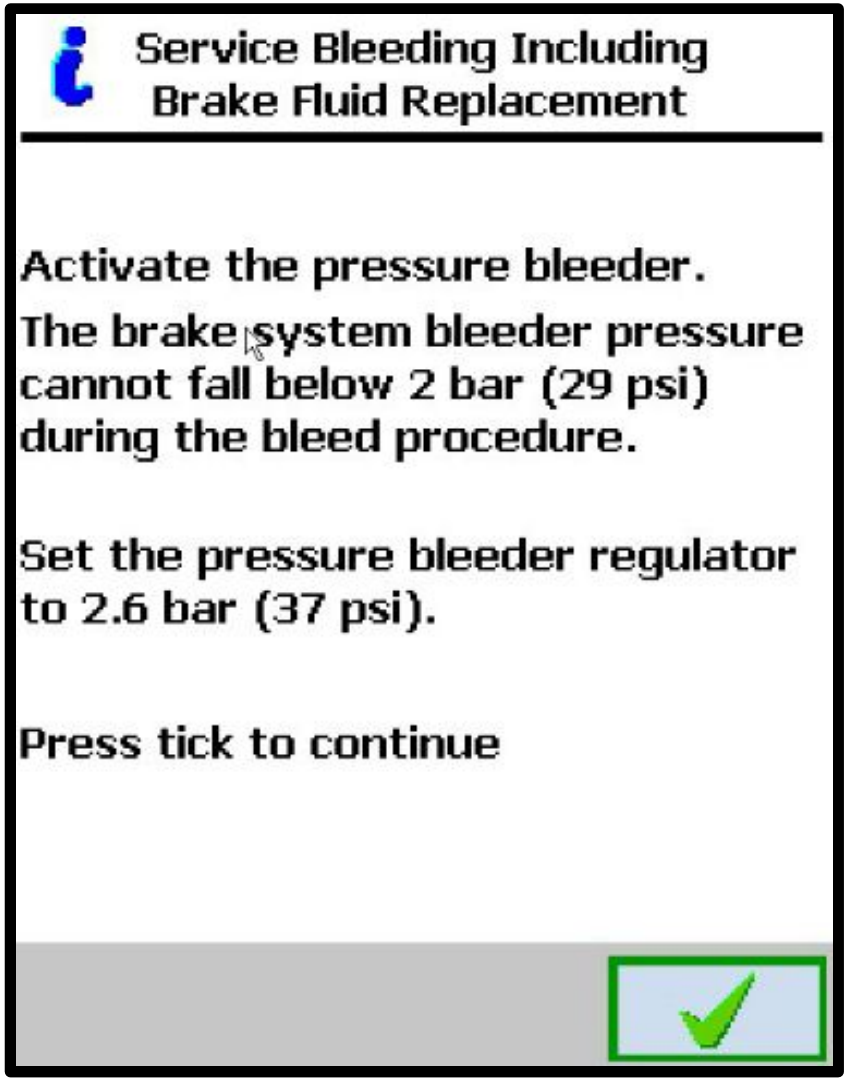
# Exit Pad Service Mode

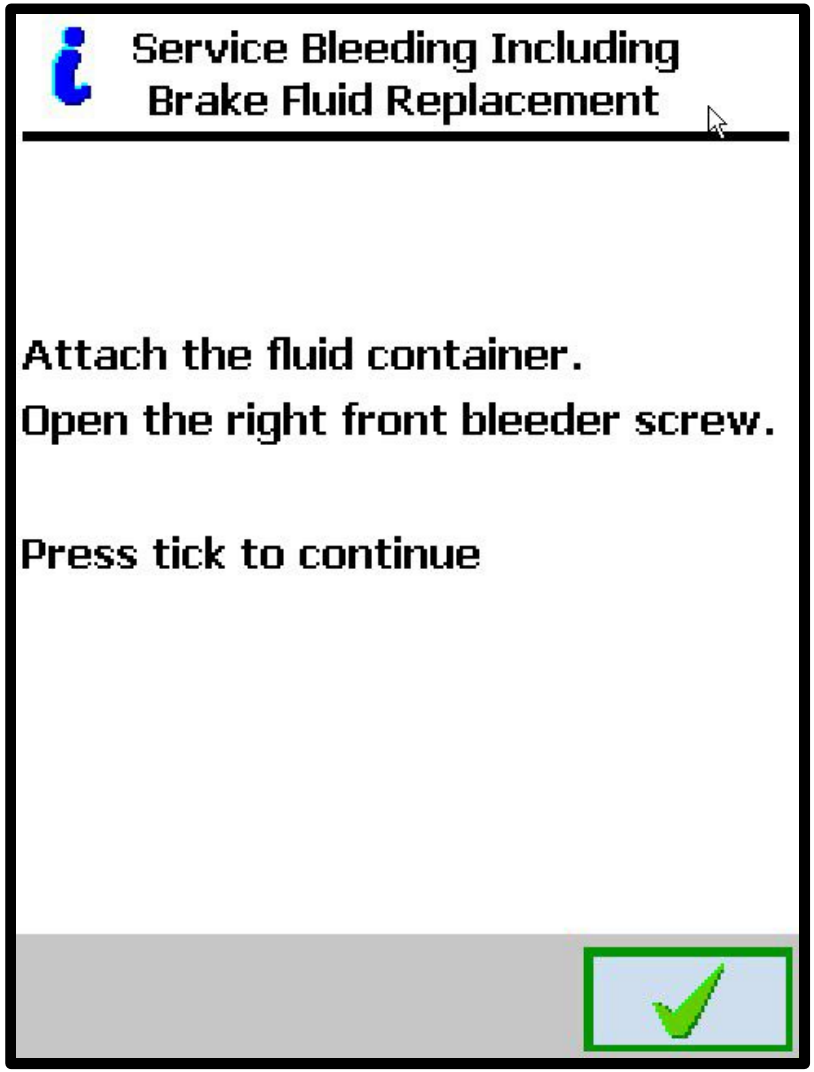
1. Apply the brake pedal
2. Turn the ignition OFF then ON. Pressure will be build in the system, then the brake lamp will shut off
3. Pad Service Mode will also terminated if:
   - Gear selector is moved from the Park position
   - Ignition turned OFF
   - Vehicle moves

# Ford Escape Hybrid Braking System

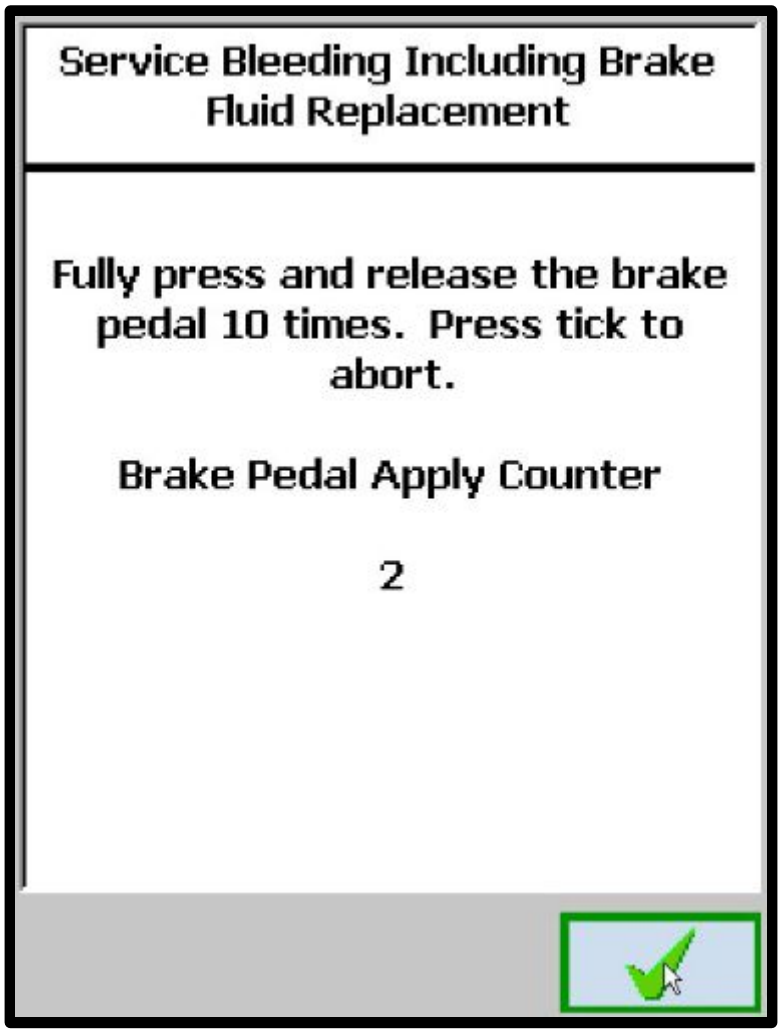



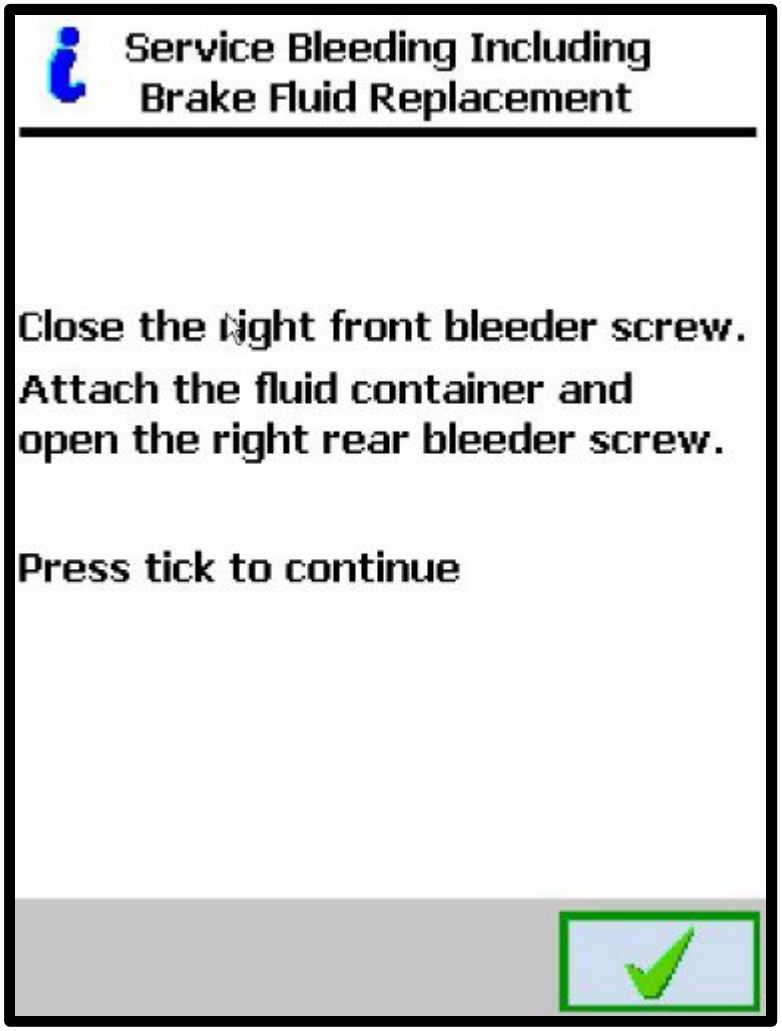
# Ford Escape Hybrid Braking System



# Ford Escape Hybrid Braking System



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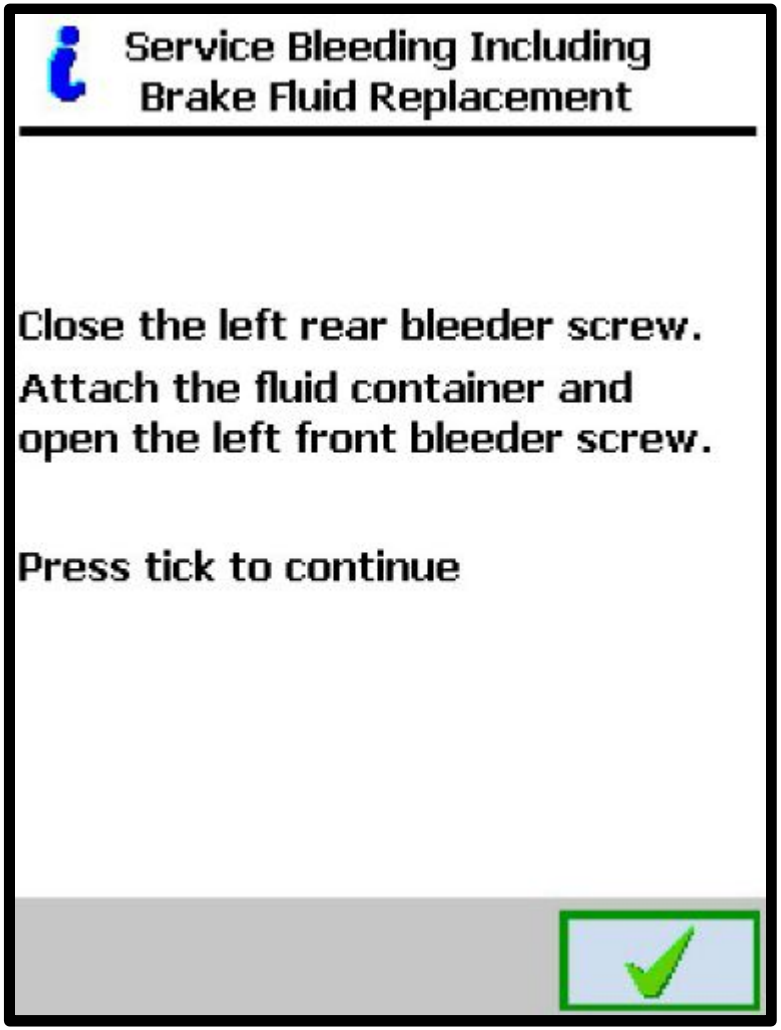


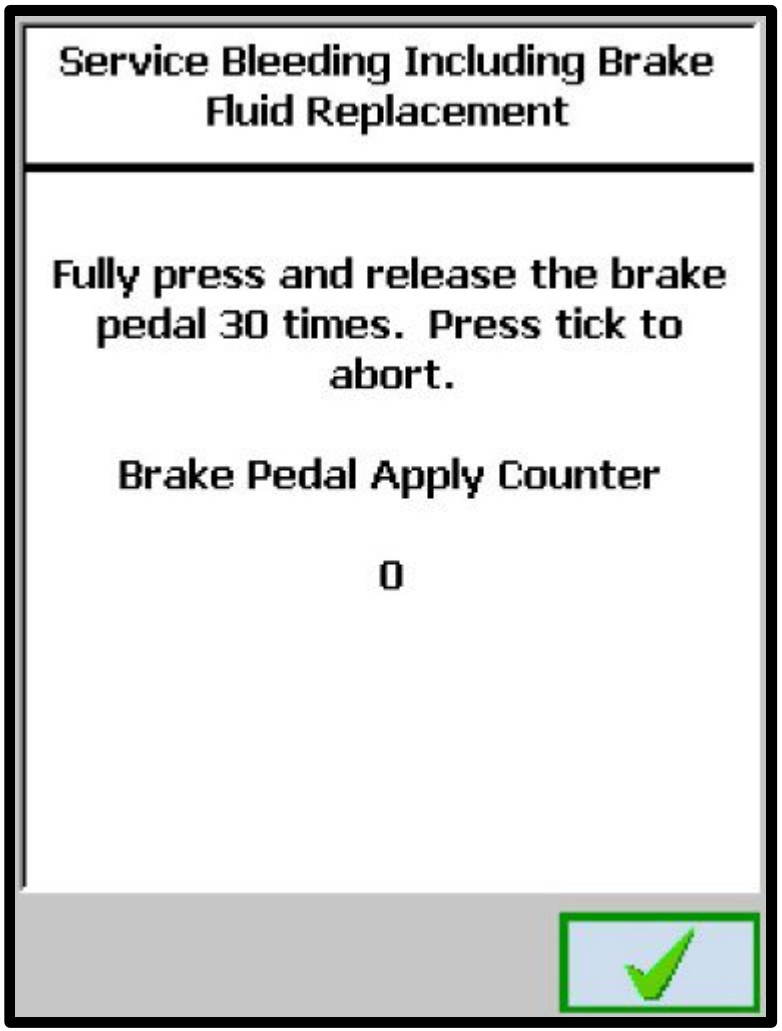

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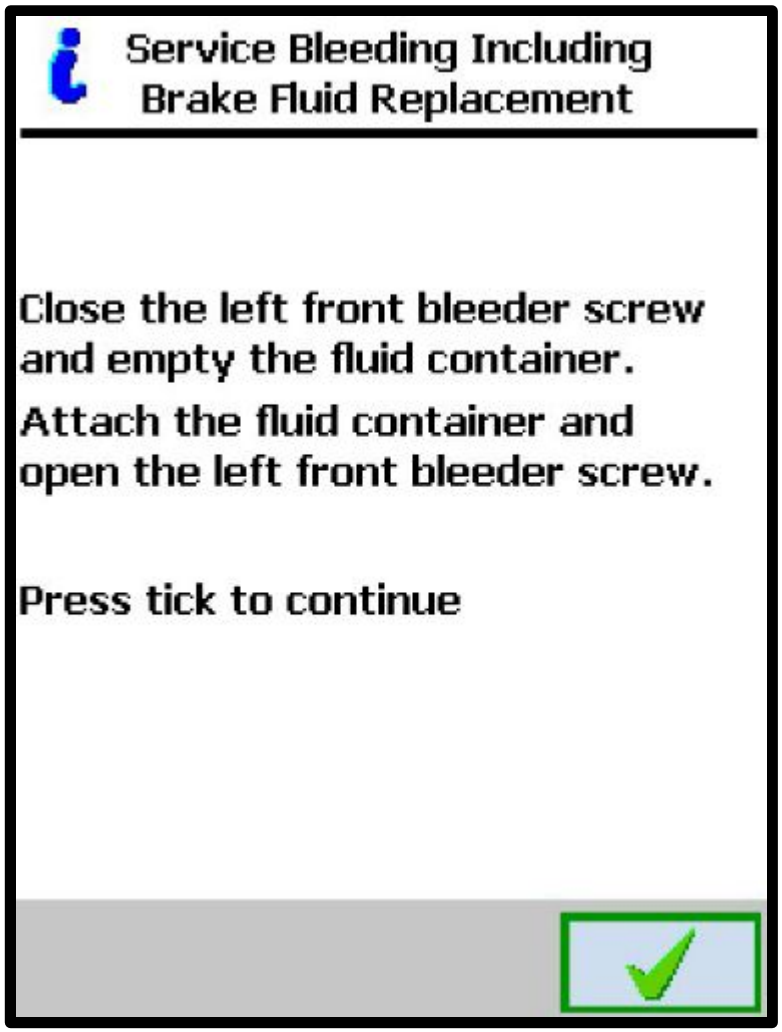


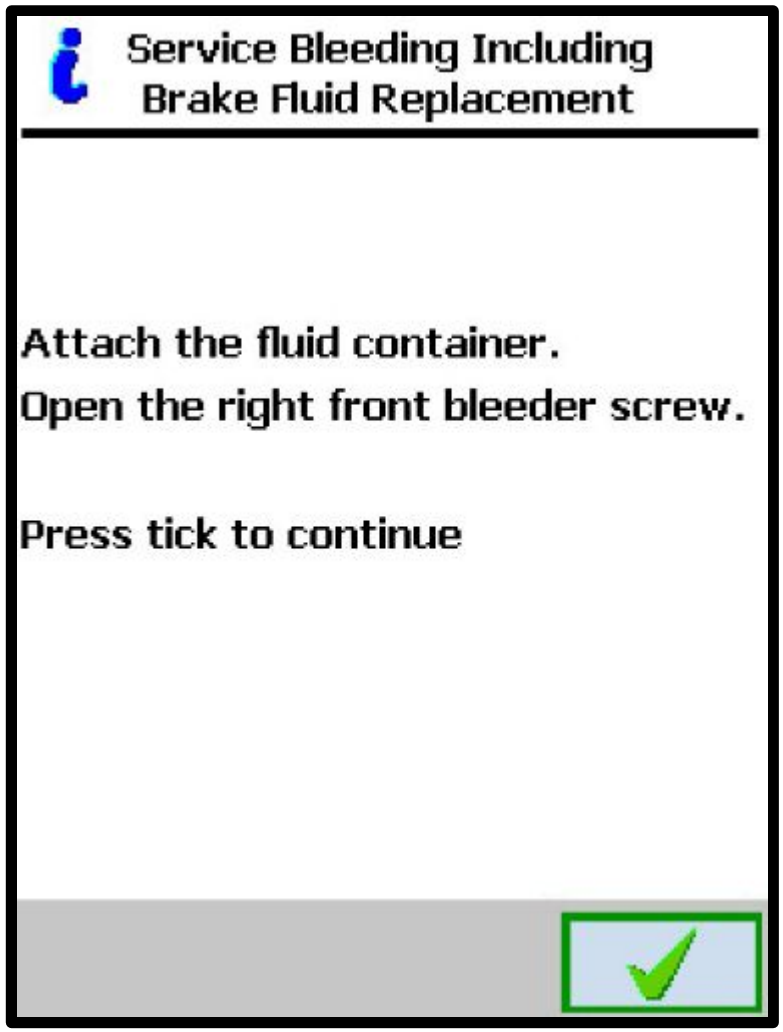

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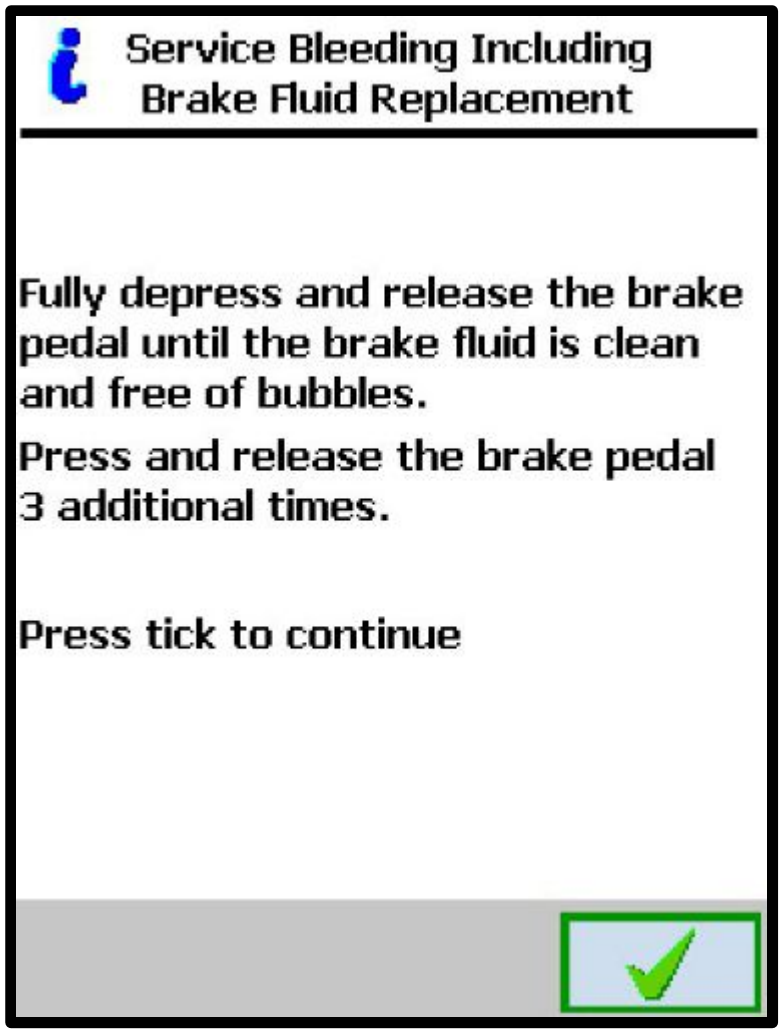
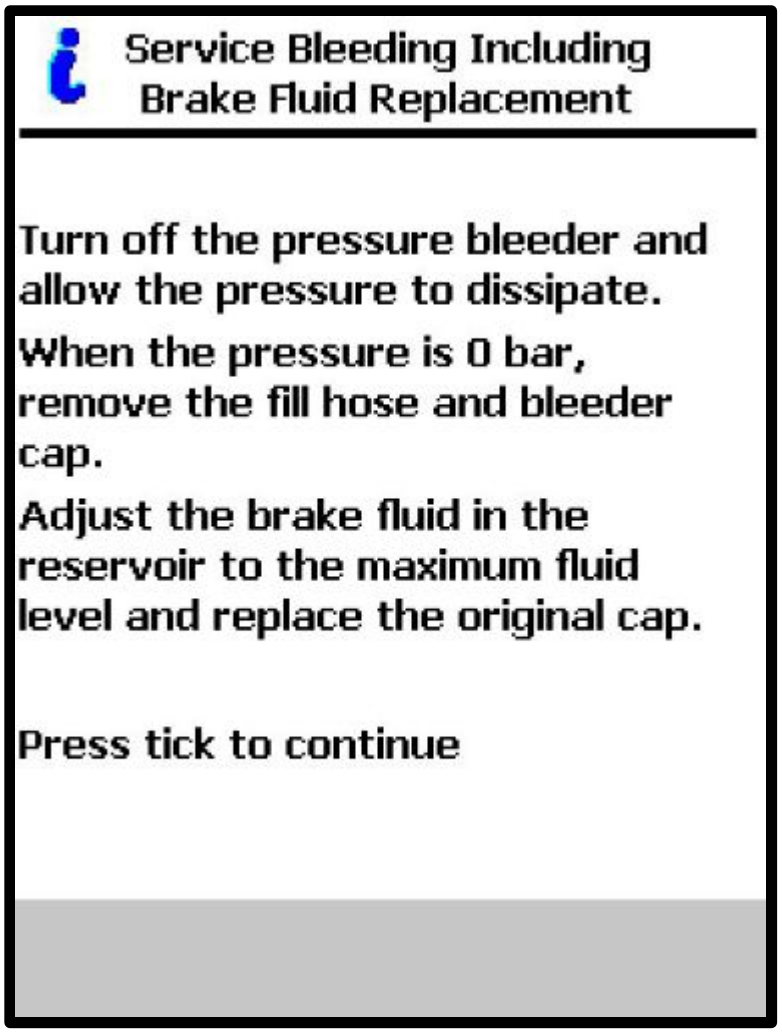
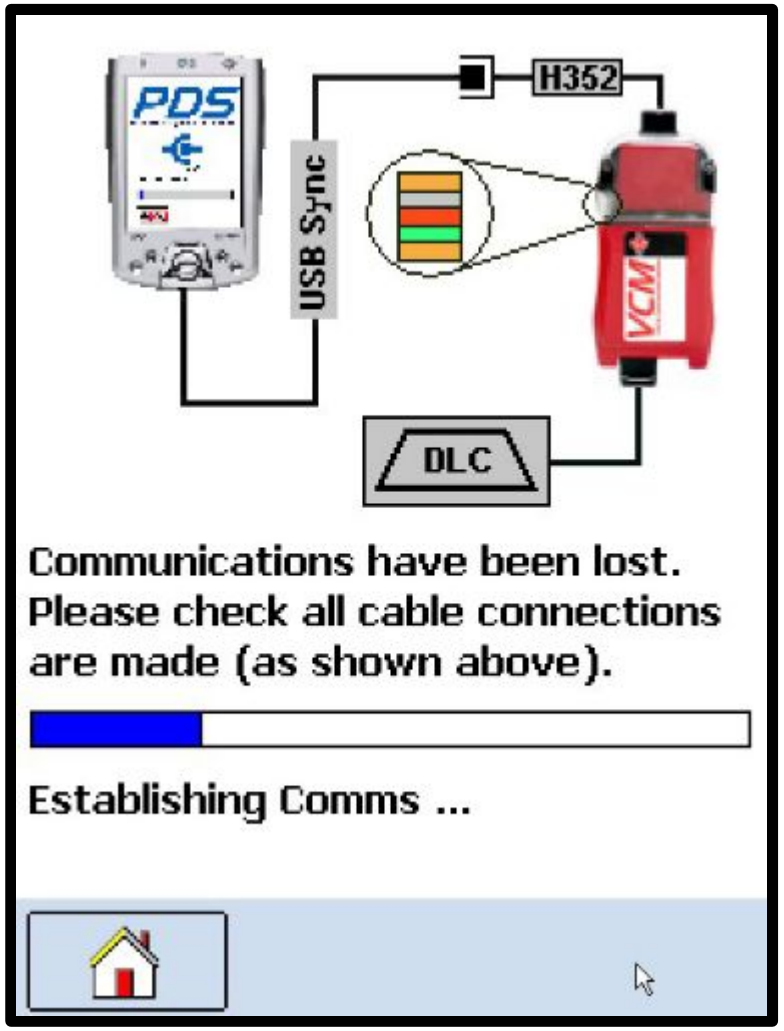
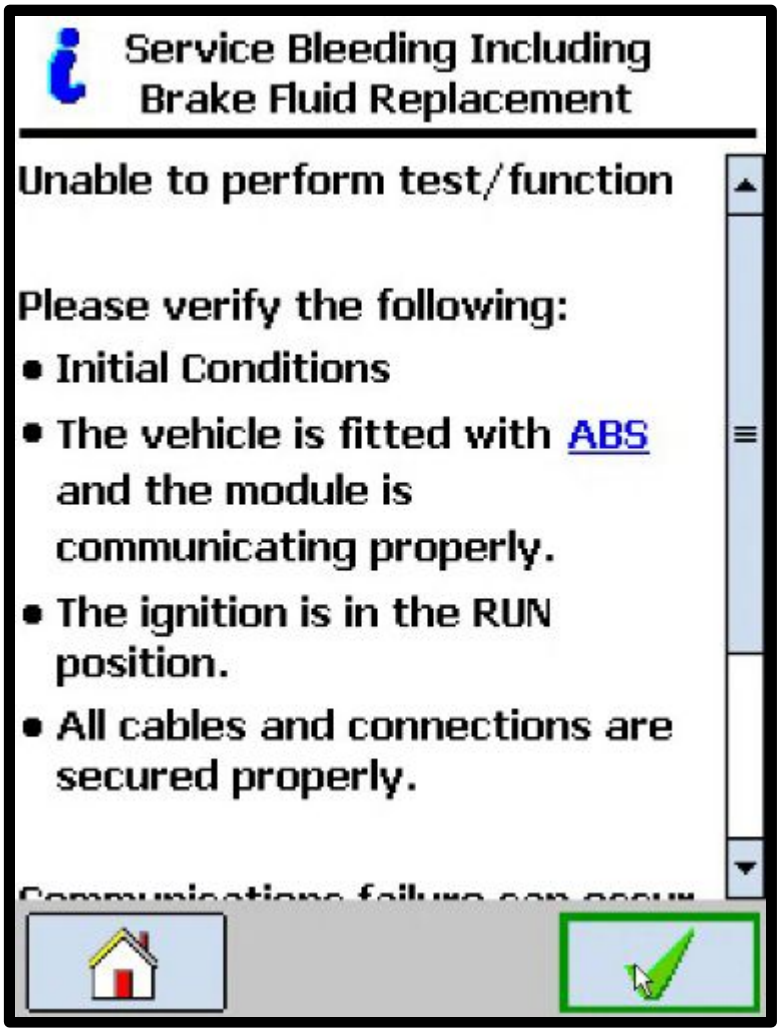


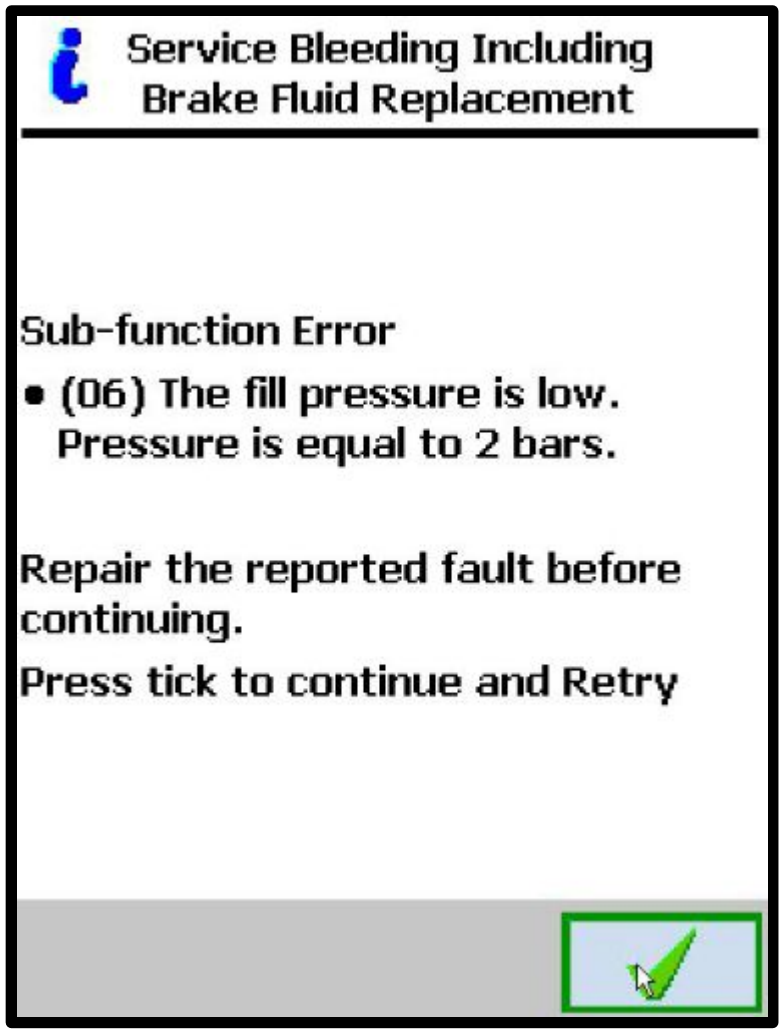



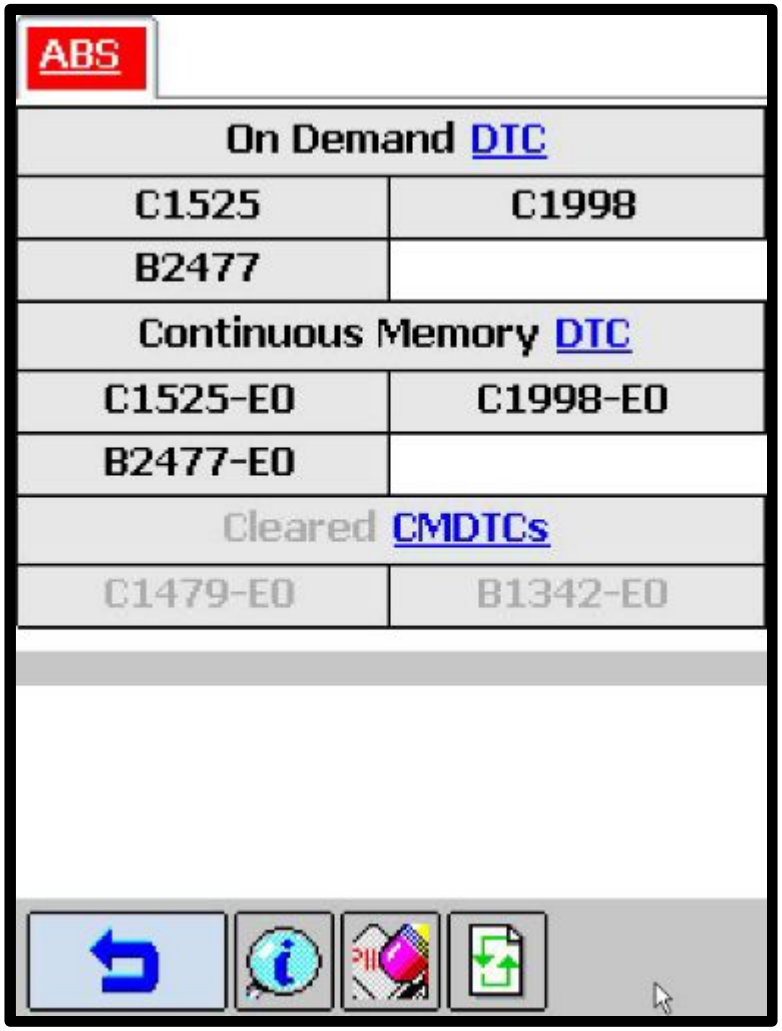
# Screens you don't want to see



# Screens you don't want to see



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