Hybrid Braking Systems

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Tim Janello
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www.siucautomotive.com

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
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
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

DECELERATION

ACCELERATION

<table>
<thead>
<tr>
<th>Signal</th>
<th>Value</th>
<th>Units</th>
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<tbody>
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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)
- HCU/ABS
- Master Cylinder and Servo w/ECU
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
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

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<th>Control Solenoid Valve</th>
<th>NO</th>
<th>NC</th>
<th>RNO</th>
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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

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<th>Control Solenoid Valve</th>
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</table>
Creep Aid

- Fluid Reservoir
- Master Cylinder
- Servo
- Stroke Simulator
- Accumulator
- Servo Regulator
- Master Cylinder Regulator
- Brake
- Vent
- Pressure Sensor
- Solenoids
Creep Aid
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.

<table>
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<tr>
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</table>
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

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**Description**

Voltage between Battery and IG1

**Reference**

![Diagram](image)
Scan Tool Diagnostics
HDS Pocket Tester
HDS Pocket Tester

Hydraulic Booster CAS Function Test

Brake Pedal Operation: Release
Wheel Status: Locked

ACCUMULATOR PRESSURE TEST

Test Finished

Normal Gas Pressure: 5.0 - 11.0 [MPa]
Presumption Gas Pressure: 6.1 MPa

GAS Pressure: Normal

Pressure recovery target time: 3.0
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.
## Model Year Comparison

<table>
<thead>
<tr>
<th></th>
<th>’01 – ’03 Prius</th>
<th>’04 &amp; later Prius</th>
<th>Highlander Hybrid</th>
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<tr>
<td>Regenerative Brake</td>
<td>Regenerative Brake Cooperative Control</td>
<td>Regenerative Brake Cooperative Control</td>
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<td>Electronically Controlled Braking (ECB)</td>
<td>Electronically Controlled Braking (ECB)</td>
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<td>Booster</td>
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<td><strong>ABS w/ EBD</strong></td>
<td><strong>ABS w/ EBD</strong></td>
<td><strong>ABS w/ EBD</strong></td>
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<td>Brake Assist</td>
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<td>-</td>
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<td><strong>Vehicle Dynamics  Integrated Management</strong></td>
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</table>
Brake Force Proportioning

Driver’s Input

Hydraulic Force

Pedal Applied

Braking Force

Regeneration Force

Vehicle Speed
Improved Regenerative Brake

Brake Pedal Depression

Regenerative Brake

Brake Force

Hydraulic Brake

‘01 – ’03 Prius

ECB Effect

Hydraulic Brake

Expanded Regenerative Range

‘04 & later Prius
Normal Stop

Hydraulic Pressure

Normal Stop

Re-Generation Effort
Panic Stop
Electronically Controlled Braking

- Brake Pedal Stroke Sensor
- Master Cylinder Pressure Sensor
- Skid Control ECU
- Hydraulic Power Source Portion
- Hydraulic Control Portion
- Hydraulic Brake Force
- Regenerative Brake Force
- Brake Force
Brake Pedal Stroke Sensor

Relays pedal depression speed / angle
Stroke Simulator

Cut Valve Closed

Cut-valve open
Brake Actuator
Normal Mode: Fluid Movement
Fail-Safe Mode

Diagram showing the fail-safe mode with various components and ports labeled:

- Stroke Simulator
- Accumulator
- Pump
- Fail-Safe Hydraulic Operation
- Master Cyl. Sensors
- Front Left
- Rear Left
- Front Right
- Rear Right

The diagram includes ports labeled (1) to (11) connecting various hydraulic components in a fail-safe configuration.
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.
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 (20th) 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

1. Use scan tool to compare suspect sensor & Speedometer. (+ 10%)
2. Oscilloscope: Connect to terminals + & - of sensor connections at the Skid Control ECU. Drive 19 mph (30 km/h), and check the signal waveform.
3. Ohm meter: Disconnect the suspect sensor connector at the wheel and measure resistance.
4. Inspect closely for in corrosion or damage to wire or terminals.
5. After replacement-retest for good 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
<table>
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<tr>
<th>psi</th>
<th>atmos.</th>
<th>&quot;H2O</th>
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</table>
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

Escape / Mariner Hybrid
HEV / ATKINSON 4V 2.3L

Systems:--
Modules: ABS

Self Test
DataLogger
Programmable Module Installation
Module Reprogramming
Tests and Calibrations

Service Routine

Service Bleeding Including Brake Fluid Replacement
Brake Fluid Replacement - Without Power Bleeder
Brake System Air Bleed Check
Brake System Actuation Control Unit Check
Brake Pad Replacement
EXIT
Activate the pressure bleeder. The brake system bleeder pressure cannot fall below 2 bar (29 psi) during the bleed procedure.

Set the pressure bleeder regulator to 2.6 bar (37 psi).

Press tick to continue

Attach the fluid container. Open the right front bleeder screw.

Press tick to continue
Ford Escape Hybrid Braking System

Service Bleeding Including Brake Fluid Replacement

Fully press and release the brake pedal 10 times. Press tick to abort.

Brake Pedal Apply Counter

2

Service Bleeding Including Brake Fluid Replacement

Close the right front bleeder screw. Attach the fluid container and open the right rear bleeder screw.

Press tick to continue
Ford Escape Hybrid Braking System

Service Bleeding Including Brake Fluid Replacement

Close the left rear bleeder screw.
Attach the fluid container and open the left front bleeder screw.

Press tick to continue

Service Bleeding Including Brake Fluid Replacement

Fully press and release the brake pedal 30 times. Press tick to abort.

Brake Pedal Apply Counter

0
Ford Escape Hybrid Braking System

Service Bleeding Including Brake Fluid Replacement

Close the left front bleeder screw and empty the fluid container.
Attach the fluid container and open the left front bleeder screw.

Press tick to continue

Service Bleeding Including Brake Fluid Replacement

Attach the fluid container.
Open the right front bleeder screw.

Press tick to continue

Press tick to continue
## Service Bleeding Including Brake Fluid Replacement

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fully depress and release the brake pedal until the brake fluid is clean and free of bubbles.</td>
</tr>
<tr>
<td>2</td>
<td>Press and release the brake pedal 3 additional times.</td>
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</table>

Press tick to continue

## Service Bleeding Including Brake Fluid Replacement

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Turn off the pressure bleeder and allow the pressure to dissipate.</td>
</tr>
<tr>
<td>2</td>
<td>When the pressure is 0 bar, remove the fill hose and bleeder cap.</td>
</tr>
<tr>
<td>3</td>
<td>Adjust the brake fluid in the reservoir to the maximum fluid level and replace the original cap.</td>
</tr>
</tbody>
</table>

Press tick to continue
Communications have been lost. Please check all cable connections are made (as shown above).

Establishing Comms...

Service Bleeding Including Brake Fluid Replacement

Unable to perform test/function

Please verify the following:
• Initial Conditions
• The vehicle is fitted with ABS and the module is communicating properly.
• The ignition is in the RUN position.
• All cables and connections are secured properly.

Communications failure can occur...
Screen you don't want to see

Service Bleeding Including Brake Fluid Replacement

Sub-function Error
(06) The fill pressure is low.
Pressure is equal to 2 bars.

Repair the reported fault before continuing.
Press tick to continue and Retry

On Demand DTC

<table>
<thead>
<tr>
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<th>C1998</th>
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<tbody>
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Continuous Memory DTC

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Cleared CMDTCs

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<th>B1342-E0</th>
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</table>


Description - C1525
Brake System Initialization Incomplete

This feature is not available on PDS, use IDS (Integrated Diagnostic System).