Holden Hybrid Technology Seminar
Tim Newman
Powertrain

ENGINEERING OBJECTIVES/REQUIREMENTS

The key objective for the Powertrain department was to supply and implement a combustion engine suitable for use in Holden's hybrid vehicle. The Holden powertrain components needed to interface with the electric units supplied by the CSIRO. The complete hybrid powertrain then had to be packaged into the selected vehicle. This involved some significant changes to Holden's conventional powertrain configurations including clutches, cooling system, lubrication and throttle control.

One of the key challenges for our group was to meet these objectives with limited budget and development time. This was achieved by using as many currently designed and validated components as possible. Before any new component was designed we looked to our current product range and local suppliers for individual components or systems.

Today I will review the changes we made to the combustion engine and powertrain components to ensure the Holden engine and transmission worked in the hybrid vehicle.

SOLUTIONS/OPPORTUNITIES

Engine Conditions

There is a considerable difference in the way the combustion engine in this hybrid car operates compared to a normal car. The main difference is that the combustion engine is frequently turned off and back on again. The engine may run for only 20 to 60 seconds before it is turned off for possibly several minutes, depending on vehicle operation. This poses several problems for combustion

engine, including excessive engine wear, high engine friction due to low engine temperature and no inlet manifold vacuum for the brake booster. As well as this cycling mode the engine must be able to run at full load and engine speed when maximum power is requested by the driver. This means that any changes made to solve these issues due to cycling must also work for normal engine operating conditions.

Powertrain Selection

A computer vehicle model developed by the CSIRO was used extensively to select the combustion engine power necessary to meet the performance requirements of the project. This model used the Australian ADR drive cycle and included some extreme events that the vehicle would endure. Engine characteristics such as power, torque and brake specific fuel consumption were fed into the model for a number of potential engines. From the results of this modelling the 2 litre engine was chosen as most closely matching the CSIRO requirement.

Packaging

Although the deletion of accessories assisted in the packaging of the powertrain, the major challenge was to keep the total extended length of the powertrain to 210 mm so as to fit within the hybrid's body. A considerable amount of this space was consumed by the CSIRO electric motors, and we still needed to accommodate a second clutch in the system to decouple the engine from the electric motor. This left approximately 30 mm to fit the additional clutch slave cylinder and flywheel. This constraint required the development of a special flywheel and a compact clutch package that fitted within the electric motor.

Clutches

The hybrid powertrain required two clutches – one to disengage the wheels from the complete powertrain to allow for gear changes of the transmission, and the other to disengage the combustion engine from the electric motor. The standard Vectra clutch was adopted for the interface between the electric motor and transmission, while the second clutch needed to be operated by the

CSIRO energy management computer. This computer control was achieved by developing an electronic clutch.

To make the clutching of the combustion engine and the electric motor as smooth as possible, the combustion engine has to be brought up to the same speed as the electric motor before engaging. The speed of both the electric engine and the combustion engine is measured and fed back into the CSIRO management system.

Base Engine Changes

To aid with the reduction of vehicle mass an aluminium block was made specifically for the engine. This block is very similar to a conventional family two block. It incorporates spun cast iron alloy liners and allows for a significant mass reduction. The overall fuel consumption of the engine was also improved by using floating piston pins for reduced friction, electric water pump and the deletion of accessory loads such as air conditioning compressor and alternator.

Engine Calibration

In order to optimise engine operation within the project timing, and to avoid extensive development effort we decided to use the calibration on the existing Vectra as a foundation, thus minimising base engine mapping. This was achieved by adopting complete systems from the Vectra with minimal modifications for this application. The induction and exhaust systems from the Vectra were used with only slight modifications being made for packaging purposes.

Electronic Throttle Control

The speed and load of the engine needed to be controlled by the energy management computer instead of the accelerator pedal. To achieve control of the engine the throttle body needed to be replaced or modified. To add a new throttle body to the engine would have required months of calibration development work. The solution was to take the existing throttle body and

drive the normal linkages with a small electric motor, thus not changing the throttle body's geometry or idle air control.

Engine Communications

The method of communication used by the Vectra is significantly different to the method used by the Commodore. To allow the combustion engine to communicate with the Commodore vehicle systems the CSIRO energy management computer was used as a translator.

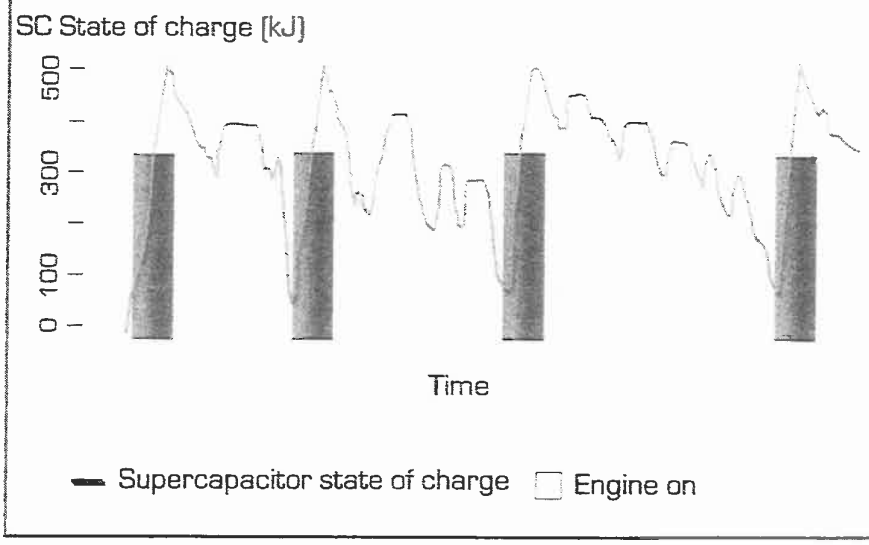
Water Pump

The water pump used on the engine does not need to operate when the engine is cold. The mechanical water pump was deleted from the engine and replaced with an electric pump. This reduces parasitic losses because the pump is only turned on when needed. The electric pump is controlled directly by the energy management computer and runs relative to engine temperature.

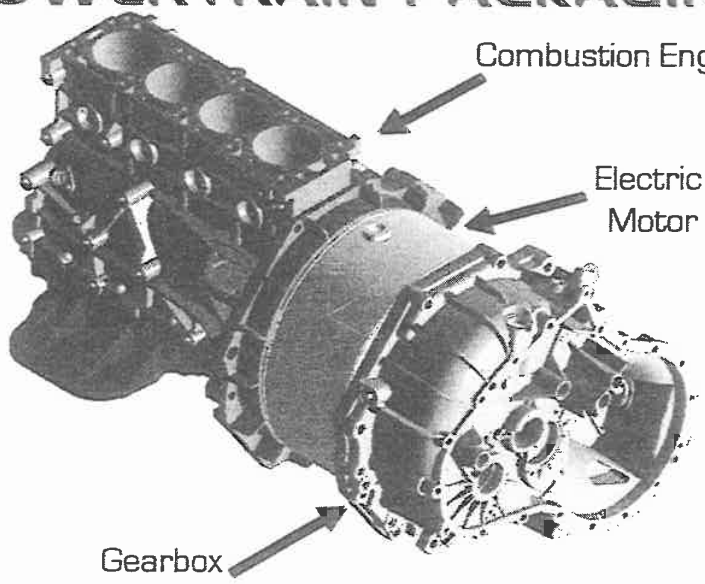
Oil Pump

A significant amount of engine wear occurs during the start-up phase of the engine, due to the lack of oil in the bearings and cylinder bores. This problem was overcome by the inclusion of a secondary electronically driven oil pump. The electric pump pressurises the engine lubrication system before the engine starts. This also provides the benefit of reducing the engine's start-up friction.

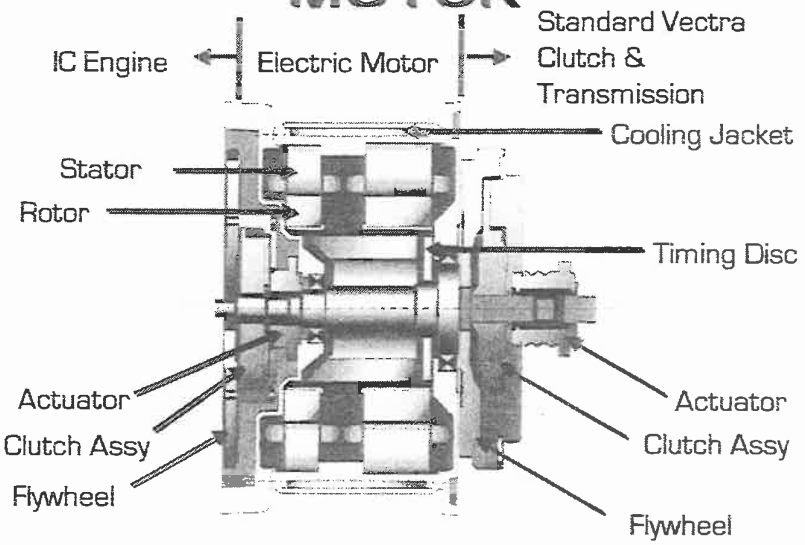
HYBRID ENGINE OPERATIONS



POWERTRAIN PACKAGING



PACKAGING ELECTRIC MOTOR



HOLDEN

CSIRO

Holden has joined forces with Australia's largest scientific research agency, CSIRO, to produce a unique electric hybrid prototype vehicle that showcases Australian ingenuity, provides a test bed for evaluating future technologies, and offers a glimpse into the automotive future.

What Is An Electric Hybrid?

Simply stated, the drive system of an electric hybrid car combines two power sources - a conventional internal combustion engine and an electric motor - to reduce exhaust emissions and maximise fuel economy.

There are two forms of electric hybrid vehicle.

A *parallel hybrid* uses a conventional engine and an electric motor to power the vehicle simultaneously. A *series hybrid* is an electric car which has a small conventional engine driving a generator to charge the batteries, and a separate electric motor to drive the car.

The Holden hybrid is a parallel hybrid vehicle, using a small four-cylinder engine and an electric motor to drive the front wheels. These power sources work in tandem to attain performance levels that are comparable to those of the current Commodore, at the same time achieving dramatic reductions in fuel consumption and hydrocarbon emissions

Parallel Hybrid Components

lements Of Holden Hybrid Technology

Internal Combustion Engine
In most respects, the Holden four-cylinder engine used in this hybrid technology is entirely conventional. Its all-aluminium design makes it more lightweight, and features such as an electric pump for oil circulation assist in reducing internal friction and increasing fuel efficiency.

Electric Motor/Generator
This advanced, CSIRO-developed electric motor incorporates 'switched reluctance' technology. While electric motors are used to power locomotives, none are quite like this one: a compact, low cost, water-cooled unit that is computer-controlled to deliver full torque at low speed, but with a wide speed range capability. Cleverly, the electric motor also doubles as an electricity generator when the hybrid car is being powered by its conventional engine and when the car decelerates.

Batteries
The batteries that power most electric vehicles are enormously heavy, at 500kg, some are half the weight of a small car. Not so with the CSIRO power pack, which combines batteries and supercapacitors and weighs in a less burdensome 200kg. A bank of five batteries has been optimised for use in this hybrid powertrain with the help of creative chemistry and a unique construction. Unlike some exotic batteries that have been developed for electric vehicles, these batteries are affordable and long-lasting.

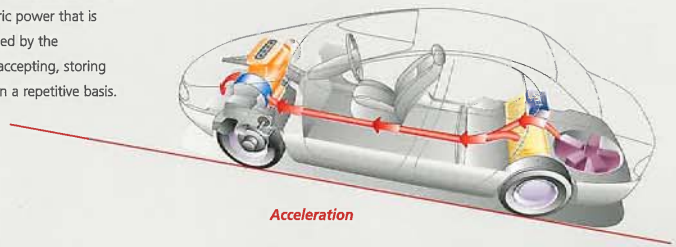
Supercapacitors
Capacitors have long been used to store energy in electronic devices such as computers, much like small batteries. The supercapacitors developed by CSIRO are the first to be given an automotive application. They are larger than a car battery and able to store larger amounts of energy. Advantages over batteries include their low mass, and an ability to absorb and deliver energy very quickly. The role of the supercapacitors is to combine with the batteries to provide a burst of power to the electric motor - during overtaking, for instance - when plenty of acceleration is required.

Energy Management Computer
The Energy Management Computer (EMC) is the supercomputer brain behind Holden hybrid technology. It plays a major co-ordination role, deciding when the car should be powered by electricity, petrol or both. It ensures the conventional engine and the electric motor work together as a team, combining smoothly to power the vehicle with maximum efficiency.

How A Parallel Electric Hybrid Works

With parallel hybrid technology, the internal combustion engine and electric motor are both capable of driving the vehicle - either simultaneously or one at a time. Decisions about when to use the conventional engine and the electric motor, individually or together, are made by the EMC and are based on the driving mode.

Acceleration During acceleration, the electric motor joins with the conventional engine to provide high performance. The initial burst of electric power that is required for rapid acceleration is supplied by the supercapacitors, which are capable of accepting, storing and imparting short spurts of energy on a repetitive basis.



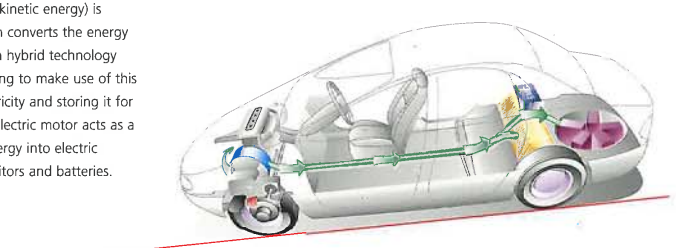
Acceleration

Batteries Charged *Batteries Low*

Cruising

Cruising When the car is cruising and the batteries are charged, the vehicle is powered by the electric motor. As the battery charge drains, the conventional engine takes over from the electric motor. While the conventional engine is driving the car, the electric motor acts as a generator, charging the batteries and supercapacitors for later use.

Regenerative Braking In order to stop a normal car, the energy due to motion (kinetic energy) is dissipated by the brakes. Brake friction converts the energy to heat, and the energy is lost. Holden hybrid technology uses a system called regenerative braking to make use of this kinetic energy by converting it to electricity and storing it for later use. As the car decelerates, the electric motor acts as a generator by converting the kinetic energy into electric power and storing it in the supercapacitors and batteries.



Regenerative Braking

What Would It Feel Like To Drive An Electric Hybrid Car?

Driving a hybrid vehicle would feel remarkably like driving a conventional car – except that when the car is driven by electric power alone, it operates almost silently.

The driver does not have to decide when to switch to electric power, or when to charge the batteries, or when to use the petrol engine. The EMC makes all those judgements, deciding in a split second what the car's performance requirements are and what forms of power are needed to satisfy them. Want to overtake that slow-moving truck? Depress the accelerator and the car will respond as you expect it to. The extra burst of power happens to be electrically generated, but you won't notice the difference.

Similarly, when you are bringing the car to a stop, the brakes will work just as efficiently. You needn't even be aware of the fact that electricity is being generated during the braking process and stored in the supercapacitors for later use. It's just a bonus.

What Are The Results?

The prototype hybrid powertrain described here has the potential to reduce fuel consumption by up to 50 per cent, simply because the smaller, lighter petrol engine does not power the car at all times. Consequently, hydrocarbon emission levels would be dramatically reduced, making a real contribution to the protection of our environment.

What Does The Future Hold?

The prototype powertrain jointly developed by Holden and CSIRO will serve as a practical learning tool to be utilised by Australian scientists and engineers.

The key word here is practical. Although hybrid technology is being researched and developed worldwide, this technology is unique in that it is designed to power a full-sized family car – the kind most Australians prefer to drive – and to deliver the brisk, accelerative performance we expect of such a car.

While we may not see an Australian production hybrid car on the road tomorrow, this project confirms Holden's continuing commitment to technological leadership today.

HOLDEN HYBRID TECHNOLOGY

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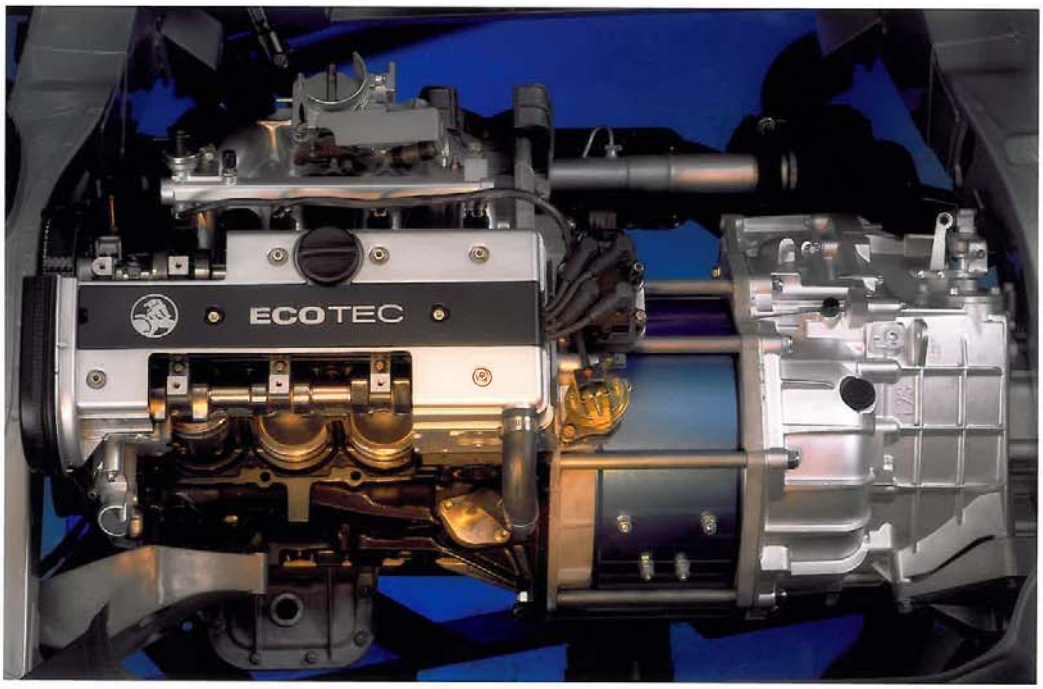

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The Holden hybrid powertrain features a four cylinder engine and manual transmission modified to incorporate a CSIRO electric motor

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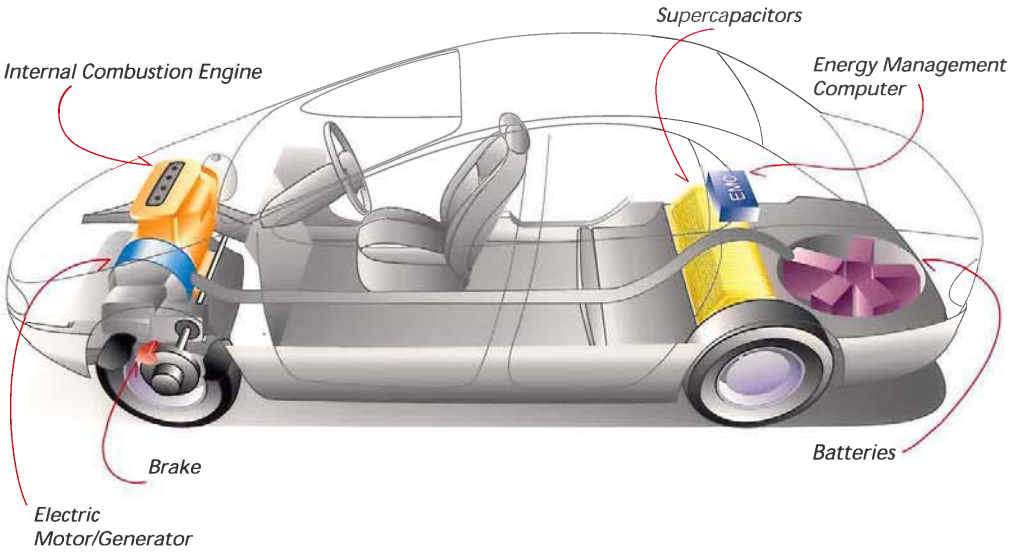

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Controlled by the Energy Management Computer, Holden's parallel hybrid powertrain uses an internal combustion engine, electric motor, batteries and supercapacitors to power the car.

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