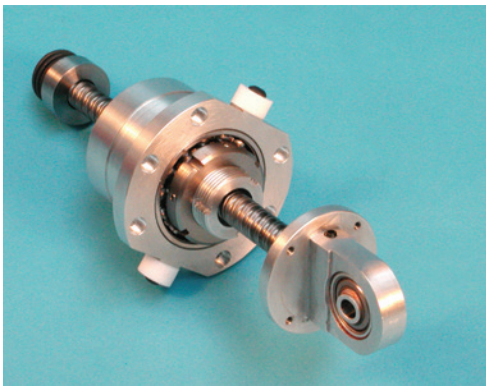
Control for Formula One!

In August 2008, the deployment of a novel mechanical control device in Formula One racing was announced. Developed at the University of Cambridge by Malcolm Smith and colleagues, the device, called an "inerter," was deployed by the McLaren team in 2005 in Barcelona.



A ballscrew inerter (flywheel removed) made at Cambridge University, Department of Engineering, in 2003, designed by N.E. Houghton

What Is an Inerter?

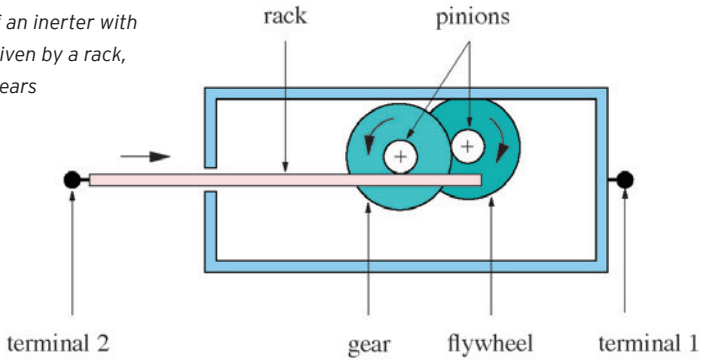
The standard analogy between mechanical and electrical networks relates force to current and velocity to voltage. The following correspondences exist between standard modeling elements:

spring ↔ inductor damper ↔ resistor mass ↔ capacitor

The correspondence is perfect for the spring and damper, but the mass element is analogous to a grounded electrical capacitor and not to a general two-terminal capacitor. Without a two-terminal capacitor equivalent, mechanical systems are unable to provide the same flexibility in dynamic response that electrical systems can. The two-terminal electrical model suite above can be used to produce any "passive impedance" device.

The inerter overcomes this limitation of mechanical systems—this two-terminal element has the property that the applied force at the terminals is proportional to the relative acceleration between them.

Schematic of an inerter with a flywheel driven by a rack, pinion, and gears



Kimi Raikkonen crosses the finish line to take victory for McLaren in the first car to race the inerter. (Photo courtesy of LAT Photographic)

The First Application: Vehicle Suspensions

Malcolm Smith's group at Cambridge University, in attempting to build high-performance mechanical impedances for car suspensions, realized that the lack of a true capacitor equivalent was a fundamental limitation.

After several fruitless efforts to prove that such a device could not exist, they realized it could be built, and in a relatively simple manner. They ultimately developed several prototypes of the device they called the inerter.

Contributor: Malcolm Smith, Cambridge University, UK

From the Laboratory to the Racetrack

Analyses of inerter-based suspensions indicated a potential performance advantage for vehicle suspensions that might be large enough to interest a Formula One team. Cambridge University filed a patent on the device and then approached McLaren in confidence. McLaren signed an agreement with the university for exclusive rights in Formula One for a limited period.

After a rapid development process, the inerter was raced for the first time at the 2005 Spanish Grand Prix by Kimi Raikkonen, who achieved a victory for McLaren.

Stolen Secrets . . . and the Truth Ultimately Comes Out

During development, McLaren invented a decoy name for the inerter (the "J-damper") to keep the technology secret from its competitors for as long as possible. The "J" has no meaning and was just a ruse, and of course the device is not a damper. The idea behind the decoy name was to make it difficult for personnel who might leave McLaren to join another Formula One team to transfer information about the device and in particular to make a connection with the technical literature on the inerter, which Malcolm Smith and his group were continuing to publish.

This strategy succeeded in spectacular fashion during the 2007 Formula One "spy scandal," when a drawing of the McLaren J-damper came into the hands of the Renault engineering team. The FIA World Motor Sport Council considered this matter at a hearing in December 2007. According to the council finding, "[a drawing of McLaren's so-called J-damper] was used by Renault to try to have the system that they thought McLaren was using declared illegal. This failed because Renault had certain fundamental misunderstandings about the operation of the J-damper system." A full transcript of the decision is available on the FIA website: *http://www.fia.com/mediacentre/Press_Releases/FIA_Sport/2007/December/071207-01.html*.

Neither the World Motor Sport Council nor McLaren made public what the J-damper was. Thereafter, speculation increased on Internet sites and blogs about the function and purpose of the device. Finally, the truth was discovered by Craig Scarborough, a motor sport correspondent from *Autosport* magazine. *Autosport* ran an article on May 29, 2008, which revealed the Cambridge connection and that the J-damper was an inerter.

Further Applications

With the truth out, and McLaren's exclusivity expired, Cambridge University entered a license agreement with Penske Racing Shocks USA, enabling Penske to supply inerters to any team in Formula One as well as in other domains of motor sport and elsewhere. The use of inerters in vehicle suspensions has continued to spread. In 2012, inerters were allowed in IndyCar racing for the first time. The Cambridge University research group is working with partners to develop other applications of the inerter. One particular focus is their use in railway vehicle suspensions, where improvements have been found in theory and simulation for ride quality and track wear.

Kimi Raikkonen leading the field in the McLaren-Mercedes MP4-20 at the Spanish Grand Prix, May 8, 2005, Circuit de Catalunya, Barcelona, Spain (photo courtesy of LAT Photographic)

For more information: M.C. Smith, Synthesis of mechanical networks: The inerter, IEEE Transactions on Automatic Control, vol. 47, no. 10, October 2002; http://www.admin.cam.ac.uk/news/dp/2008081906; http://www.eng.cam.ac.uk/news/stories/2008/McLaren.