

## **UP SHIFTING A MODERN AUTOMATIC TRANSMISSION**

A step-ratio automatic transmission system in a vehicle utilizes multiple friction elements for automatic gear ratio shifting. Broadly speaking, these friction elements may be described as torque establishing elements although more commonly they are referred to as clutches or brakes. The friction elements function to establish power flow paths from an internal combustion engine to vehicle traction wheels. During acceleration of the vehicle, the overall speed ratio, which is the ratio of a transmission input shaft speed to a transmission output shaft speed, is reduced during a ratio upshift as vehicle speed increases for a given engine throttle setting. A downshift to achieve a higher speed ratio occurs as an engine throttle setting increases for any given vehicle speed, or when the vehicle speed decreases as the engine throttle setting is decreased.

Various planetary gear configurations are found in modern automatic transmissions. However the basic principle of shift kinematics remains similar. Shifting a step-ratio automatic transmission having multiple planetary gear-sets is accompanied by applying and/or releasing friction elements to change speed and torque relationships by altering the torque path through the planetary gear-sets. Friction elements are usually actuated either hydraulically or mechanically.

In the case of a synchronous friction element-to-friction element upshift, a first pressure actuated torque establishing element, referred to as an off-going friction element, is released while a second pressure actuated torque establishing element, referred to as an on-coming friction element, engages in order to lower a transmission gear ratio. A typical upshift event is divided into preparatory, torque, and inertia phases. During the preparatory phase, an on-coming friction element piston is stroked to prepare for its engagement while an off-going friction element torque-holding capacity is reduced as a step toward its release. During the torque phase, which may be referred to as a torque transfer phase, the on-coming friction element torque is raised while the off-going friction element is still engaged. The output shaft torque of the automatic transmission typically drops during the torque phase, creating a so-called torque hole. When the on-coming friction element develops enough torque, the off-going friction element is released, marking the end of the torque phase and the beginning of the inertia phase. During the inertia phase, the on-coming friction element torque is adjusted to reduce its slip speed toward zero. When the on-coming friction element slip speed reaches zero, the shift event is completed.

In a synchronous shift, the timing of the off-going friction element release must be synchronized with the on-coming friction element torque level to deliver a consistent shift feel. A premature release leads to engine speed flare and a deeper torque hole, causing perceptible shift shock for a vehicle occupant. A delayed release causes a tie-up of gear elements, also resulting in a deep and wide torque hole for inconsistent shift feel. A conventional shift control relies on speed measurements of the powertrain components, such as an engine and a transmission input shaft, to control the off-going friction element release process during the torque phase. A conventional torque phase control method releases the off-going friction element from its locked state through an open-loop control based on a pre-calibrated timing, following a pre-determined off-going friction element actuator force profile. This conventional method

does not ensure optimal off-going friction element release timing and therefore results in inconsistent shift feel.

Alternatively, a controller may utilize speed signals to gauge off-going friction element release timing. That is, the off-going friction element is released if the controller detects a sign of gear tie-up, which may be manifested as a measurable drop in input shaft speed. When a release of the off-going friction element is initiated prematurely before the on-coming friction element develops enough torque, engine speed or automatic transmission input shaft speed may rise rapidly in an uncontrolled manner. If this so-called engine speed flair is detected, the controller may increase off-going friction element control force to quickly bring down automatic transmission input speed or off-going friction element slip speed. This speed-based or slip-based approach often results in a hunting behavior between gear tie-up and engine flair, leading to inconsistent shift feel. Furthermore, off-going friction element slip control is extremely difficult because of its high sensitivity to slip conditions and a discontinuity between static and dynamic frictional forces. A failure to achieve a seamless slip control during the torque phase leads to undesirable shift shock.

In the case of a non-synchronous automatic transmission, the upshifting event involves engagement control of only an on-coming friction element, while a companion clutching component, typically a one-way coupling, automatically disengages to reduce the speed ratio. The non-synchronous upshift event can also be divided into three phases, which may also be referred to as a preparatory phase, a torque phase, and an inertia phase. The preparatory phase for the non-synchronous upshift is a time period prior to the torque phase. The torque phase for the non-synchronous shift is a time period when the on-coming friction element torque is purposely raised for its engagement until the one-way coupling starts slipping or overrunning. This definition differs from that for the synchronous shift because the non-synchronous shift does not involve active control of a one-way coupling or the off-going friction element. The inertia phase for the non-synchronous upshift is a time period when the one-way coupling starts to slip, following the torque phase. According to a conventional upshift control, during the torque phase of the upshifting event for a non-synchronous automatic transmission, the torque transmitted through the oncoming friction element increases as it begins to engage. A kinematic structure of a non-synchronous upshift automatic transmission is designed in such a way that torque transmitted through the one-way coupling automatically decreases in response to increasing oncoming friction element torque. As a result of this interaction, the automatic transmission output shaft torque drops during the torque phase, which again creates a so-called "torque hole." Before the one-way coupling disengages, as in the case previously described, a large torque hole can be perceived by a vehicle occupant as an unpleasant shift shock.