The evolution of load/unload technology

M. Suk, T. R. Albrecht

Abstract Load/unload (L/UL) has recently replaced contact start-stop (CSS) technology in major segments of the hard disk-drive (HDD) industry. Although L/UL has existed since the earliest HDDs, recent implementations use fixed ramp L/UL systems, which are considerably simpler than earlier versions. L/UL offers multiple advantages over CSS, including practically unlimited start-stop cycles and improved shock robustness. However, disk damage can occur in L/UL drives due to head-disk contacts, and a variety of parameters including vertical L/UL speed and slider corner radius should be optimized to minimize damage. Tight control of key tolerances is essential to maximize available disk real estate and minimize the required disk spacing to accommodate L/UL. Power-off retract systems for L/UL must produce higher retract torque than those for CSS designs, leading to new retract circuit designs.

1 Introduction
During the mid-1990’s, all major manufacturers were using contact start-stop (CSS) technology in non-removable hard disk drives. However, it was a technology ripe for replacement. The inherent difficulty in designing CSS drives is well known throughout the industry: stiction and start-stop wear durability design points demand two opposing sets of requirements. The continual need for smoother disks that meet the challenging demands of stiction and wear durability requirements, compounded by limited understanding and control of the tribology of the slider/lubricant/disk interface, has driven the transition from CSS to load/unload (L/UL) technology. L/UL eliminates stationary contact between heads and disks, and thereby eliminates the difficult tradeoffs inherent in CSS design. However, dynamic contacts between the heads and spinning disks may still occur during the L/UL process under some conditions, leading potentially to disk damage and data loss. Hence, it is critical that L/UL drives be designed to minimize contact events and manage the consequences of any damage that occurs.

Current L/UL drives (Fig. 1) employ a set of fixed ramps located at the outer diameter (OD) of the disks. For this reason, the technology is often referred to as “Ramp Load/Unload”. During non-operation, the slider-carrying suspensions rest on the ramps and the sliders are completely off the disk surface. When the drive is started, the suspension slides along the ramp and loads the slider onto the disk after the disk has reached some designed speed. Conversely, when the drive is turned off, the suspension moves off the disk and onto the ramps before the disk comes to a full stop.

Technical advantages of L/UL include a relaxation of the durability requirements for carbon overcoats, which can allow thinner overcoats and reduced magnetic spacing, elimination of texture effects on disk signal-to-noise ratio (for the case of full-disk texture), and simplification of air bearing flying height profiles (no need to invoke special flying height requirements in the CSS zone). Non-operating shock robustness of a drive can be substantially better with L/UL. In mobile drives, L/UL enables reduced power consumption, both via the more aggressive application of power saving modes, which shut down the spindle (and would result in more start-stop cycles than CSS drives can be designed to handle), and via the creation of a new mode in the power management hierarchy, in which the spindle is spinning but the heads are parked on the ramp. L/UL simplifies the product development cycle for new disk drives, since extensive L/UL cycle testing can be completed in far less time (a few days) than normally required for CSS testing (weeks to months).

From a cost/complexity point of view, the choice between L/UL and CSS involves a variety of tradeoffs. L/UL requires the addition of the ramp structure, along with circuitry to handle L/UL functions (including power-off retract). Another factor that may increase the
cost of L/UL drives is the use of highly reliable latches (e.g. bi-directional inertia latches) to fully take advantage of the increased shock robustness that L/UL offers. While L/UL drives can be designed with either glass or AlMg disk substrates, manufacturers often choose the more expensive glass substrates, because of the ability of L/UL drives to take advantage of their reduced weight to improve the drive’s shock robustness, the possibility of smoother surface finishes (which today is less of a distinction between the two) and the more benign nature of disk damage caused by L/UL. On the other hand, adopting L/UL eliminates costs and negative yield factors associated with disk texture, and manufacturing capital costs and complexity are reduced by the simplified merge and demerge procedures that L/UL offers. Furthermore, most CSS drive manufacturers apply anti-wetting agent (AWA) to the sliders to avoid the so called “fly-stiction” problem [1]. Load/Unload drives do not need AWA.

2 Converging technology?
L/UL technology has existed since the time of the very first disk drive, the IBM RAMAC 350 introduced in 1956 (Fig. 2). Figure 3 shows a close up picture of the RAMAC’s disk stack and the actuator arm. To minimize head costs in this 50-disk design, a single pair of heads was used to access all disks. To change the disk being accessed, the sliders were “unloaded” from disk surfaces and the actuator arm was moved up or down vertically aligning itself with the target disk. Once positioned, the actuator moved inward and the sliders were “loaded” onto the disk surfaces.

CSS technology was introduced in the early 1960’s as a means to simplify drives by eliminating the complex cam and lever systems used in L/UL implementations [2]. From this time through the 1980’s, L/UL went into and out of fashion in large form factor drives, ending with the IBM 3390 series, the last of the major large form factor drives, which used L/UL. With the re-introduction of L/UL in IBM 3390 series, research activities increased at universities involved in magnetic recording technology (mainly at the University of California at Berkeley (UCB) [3–7] and University of California at San Diego [8, 9]). Not many publications from the industry can be found from this time except for a couple by researchers associated with NEC [10, 11].

In small form factor drives, L/UL was first introduced (using a moving cam system) by LaPine in the mid 1980’s. Later, PrairieTek introduced fixed ramp L/UL technology [12] for the first time in its 2.5” drives followed later by Integral [13] in its 1.8” and 2.5” drives. Although these small companies introduced the version of L/UL that has now become pervasive, it was not until IBM introduced L/UL in its 2.5” drives in 1997 that a major shift in the thinking of the entire industry occurred. Today, all manufacturers of mobile drives (2.5” and smaller) use L/UL exclusively, and L/UL is making inroads in desktop and server drives as well. It appears that manufacturers are finally converging on L/UL as the preferred technology, although stiction-free sliders remain viable for now as an alternative [14]. The latest innovation to occur in L/UL design is a ramp L/UL design in which the ramp is located at the inner diameter of the disk (Fig. 4) [15]. This design, which is best applied to single-surface drives, takes advantage of the today’s market tendency toward fewer heads per drive.