Error-Correcting Codes for TLC Flash

Researcher:  **Eitan Yaakobi**, Postdoc, CMRR Dept.
Advisors:  **Paul H. Siegel**, Professor, CMRR & ECE Dept.
          **Jack K. Wolf**, Professor, CMRR & ECE Dept.
          **Alexander Vardy**, Professor, CMRR & ECE Dept.

The topic of asymmetric error-correcting codes over non-binary alphabets has attracted considerable attention in the past few years, largely due to its relevance in the context of multi-level flash memories. Flash memories are comprised of floating gate cells. The charge stored in a cell, also called the cell’s level, is used to represent data. While it is possible to increase a cell level by injecting charge to the cell, reducing its level is not possible unless its entire containing block is first erased. One of the dominant error mechanisms of flash memory cells results from over-programming the cells. These errors cannot be physically corrected unless the entire containing block is erased and thus it is crucial to design error-correcting codes that correct asymmetric errors of limited-magnitude. Furthermore, the ability to correct such errors can enable the programming of the cells to be less accurate and thus faster.

With such an error model in mind, in [1] Cassuto et al. recently developed bounds and constructions for codes correcting \( t \) asymmetric errors with magnitude no more than \( l \). Since then several more research works were presented by Dolecek, Elarief and Bose, and others. In other works, codes were designed for the correction of unidirectional errors of limited-magnitude, and in another related model it was assumed that programming errors and noise can only reduce the cell level.

These previously proposed codes and bounds for the non-binary case mainly deal with the case of \( t \) asymmetric errors of limited-magnitude \( l \). However, it is likely that only a few cells will suffer from an error of large magnitude and that most of the erroneous cells will suffer from an error of a smaller magnitude [2]. In this work, we study such an error model, in which at most \( t_1 \) errors of maximum magnitude \( l_1 \) and at most \( t_2 \) errors of maximum magnitude \( l_2 \), with \( l_1 < l_2 \), can occur. We adapt the analysis and code construction of Cassuto, et al. for the refined error model and assess the relative efficiency of the new codes. We then consider in more detail specific constructions for the case where \( t_1 = t_2 = 1, l_1 = 1, \) and \( l_2 > 1 \).
