flows into the chamber **30** and the chamber **30** is allowed to pressurize and expand the Braille dot **20**. In this the Braille dot **20** is formed by distorting the top surface **46** attached to the frame **24** (which may be part of the housing **22** module **18** and is not shown in FIG. **5**A or **5**B). The Braille dot **20**, is just a dimple in the top surface **46**. Referring now to FIG. **5**B, voltage is applied to electrode **281***a* and the slide element **28** is attracted to it closing the passage to the plenum **32** and opening the passage to the vent **33** and allowing the pressure to vent out of the chamber **30**. Without the pressure, the Braille dot **20** contracts, flattening out the Braille dot in the top surface **46**. The voltage to the electrodes **281***a*, **281***b* is controlled by either the microcontroller **40** through lines **44** or the module microcontroller **45** through lines **44** allowing independent extension and retraction of the Braille dots **20**.

Referring now to FIG. **6** there is shown a schematic representation of the Braille dots **20** electronic addressing scheme. The Braille dots **20** are actuated based upon a row and column scanning mechanism. Although, only 4 rows and 5 columns are shown on FIG. **6**, the scanning mechanism can be applied to any number of rows and columns. If at any time "t" both the row and column are at open electrode voltage (signified by "0") the MEMS device is open and the Braille dot **20** is extended. If either the row or the column is at close electrode voltage (signified by "1"), the MEMS device **16** is closed and the Braille dot **20** is retracted. In this manner, at any time "t" a specific Braille dot **20** based upon its row and column location can be operated. For example, at t_1 row **1** has open electrode voltage and column **1** has open electrode voltage. The Braille dot **20** is extended as shown by the X on the actuation scheme.

Referring now to FIG. **7**, there is shown an internal elevation of the housing **22**. In this FIG. **7**, the modules **18** are mounted to the inside of the housing **22** near its top. The top surface **46** attaches to the top of the housing **22**. The top surface **46** is constructed of a single sheet of polymer material stretched over the top of the housing **22**. The top surface **46** presents a continuous surface which provides both environmental protection to the MEMS devices **16** (not shown in FIG. **7**) and other electronic hardware as well as providing a tactile surface with no discrete holes, seams, gaps or voids. In the present invention a low modulus elastomer with a thickness of approximately 0.004" is used for the top surface **46**. Two commercially available elastomer films can be used; a medium modulus latex polymer mix, or a blend of Natural Rubber, Neoprene and Nitrile. The top surface **46** is sealed to the modules **18** and/or housing **22** using either a suitable epoxy or adhesive or a vacuum seal. This provides a continuous uninterrupted tactile reading surface for the user eliminating any interference with reading of Braille characters **14**. This modular design allows different size Braille displays **2** to be assembled from a different number of individual modules **18**.

Referring now to FIGS. **8**A and **8**B there are shown detail views of a Braille dot **20** with a MEMS device **16** extended and retracted, respectively. The actuators are a pair of MEMS microvalves **284***a*, **284***b* which open or close. The MEMS microvalves **284***a*, **284***b* can be actuated electrostatically, piezoelectrically or using thin film shape-memory alloys. In FIG. **8**A, the MEMS microvalve **284***a* is open allowing pressurized air from the plenum **32** into the chamber **30**, while the MEMS microvalve **284***b* is closed blocking the pressurized air from leaving the chamber **30**. The pressurized air in the chamber **30** expands the Braille dot **20**. In this the Braille dot **20** is formed by distorting the surface covering **45** attached to the frame **24** (which may be part of the housing **22** module **18** and is not shown in FIG. **8**A or **8**B). The Braille dot **20**, is just a dimple in the top surface **46**. Referring now to FIG. **8**B, the MEMS microvalve **284***a* is now closed blocking the flow of pressurized air from the plenum **32** and the MEMS microvalve **284***b* is now opened allowing the air to evacuate from the chamber **30** to the vent **33**. With the pressure vented, the Braille dot **20** contracts, flattening out the dimple on the top surface **46**. The voltage to the two the MEMS microvalves **284***a*, **284***b* are controlled either directly by the microcontroller **40** or by the module microcontroller **45** to extend and retract Braille dots **20** independent of other Braille dots **20**.

Referring now to FIGS. **9**A and **9**B there is shown a detail view of a Braille dot **20** and MEMS device **16** which uses a thin film shape memory alloy ("SMA") element **282** as the actuator. A thin film SMA based microelectromechanical actuator is significantly different then traditional bulk shape memory alloy actuators in size, fabrication techniques, and operation. The mechanical properties of a thin film SMA can be precisely tailored by changing the alloy ratios during fabrication while a macro sized bulk SMA actuator may have regions where the alloy ratio changes within the bulk material of the actuator, these regions will increase power consumption, reduce fatigue resistance and limit life. Thin film SMA actuators have greater fatigue life and improved phase transition characteristics then traditional bulk SMA actuators. The thin film SMA also has faster response and lower power consumption then traditional bulk SMA actuators due to their reduced volume and large surface area which allows the actuator to change from one phase state to another faster then the larger bulk SMA actuators. The rapid response of the thin-film SMA actuators allows a user to quickly scroll through a document without having the refreshable Braille display lag behind. The lower power consumption of a thin film SMA actuator reduces the amount of heat that needs to be dissipated from the actuators during operation and can permit battery operation for use with portable electronic devices.

FIGS. **9**A and **9**B also show the application of a direct actuation of the Braille dot **20** without the need of a pneumatic force. Shape Memory Alloys (SMA's) are a unique class of alloys which have the ability to form two different crystalline phases, defined as martensite and austenite, in response to temperature and strain. SMA's are produced by equiatomically combining at least two component metals into a desired shape which is then annealed. When produced, the SMA is in the austenite phase, having a certain shape and characterized by low ductility, high Young's modulus and high yield stress. Upon cooling the SMA changes to the martensite phase characterized by high ductility, a low Young's modulus and low yield stress. In the martensite phase, the SMA is easily deformed and can take on a different shape from its austenite or original shape by applying an external strain. The SMA will retain this different shape until it is heated to its austenitic transformation temperature. When the SMA is heated to its austenitic transformation temperature the SMA transitions to its austenite phase and transforms back to its original shape.

In FIG. **9**A the thin film SMA element **282** is in its martensite phase with the Braille dot **20** retracted. Since the martensite phase is characterized by high ductility, low Young's modulus and low yield stress, the thin film SMA element **282** is easily deformed by external stresses like biasing means **283**, shown as a spring in FIG. **9**. When heated to its austenitic transfer temperature, the thin film SMA element **282** transitions from its martensite phase to its