

BUBBLE MEMORY RESYNCHRONIZATION MECHANISM

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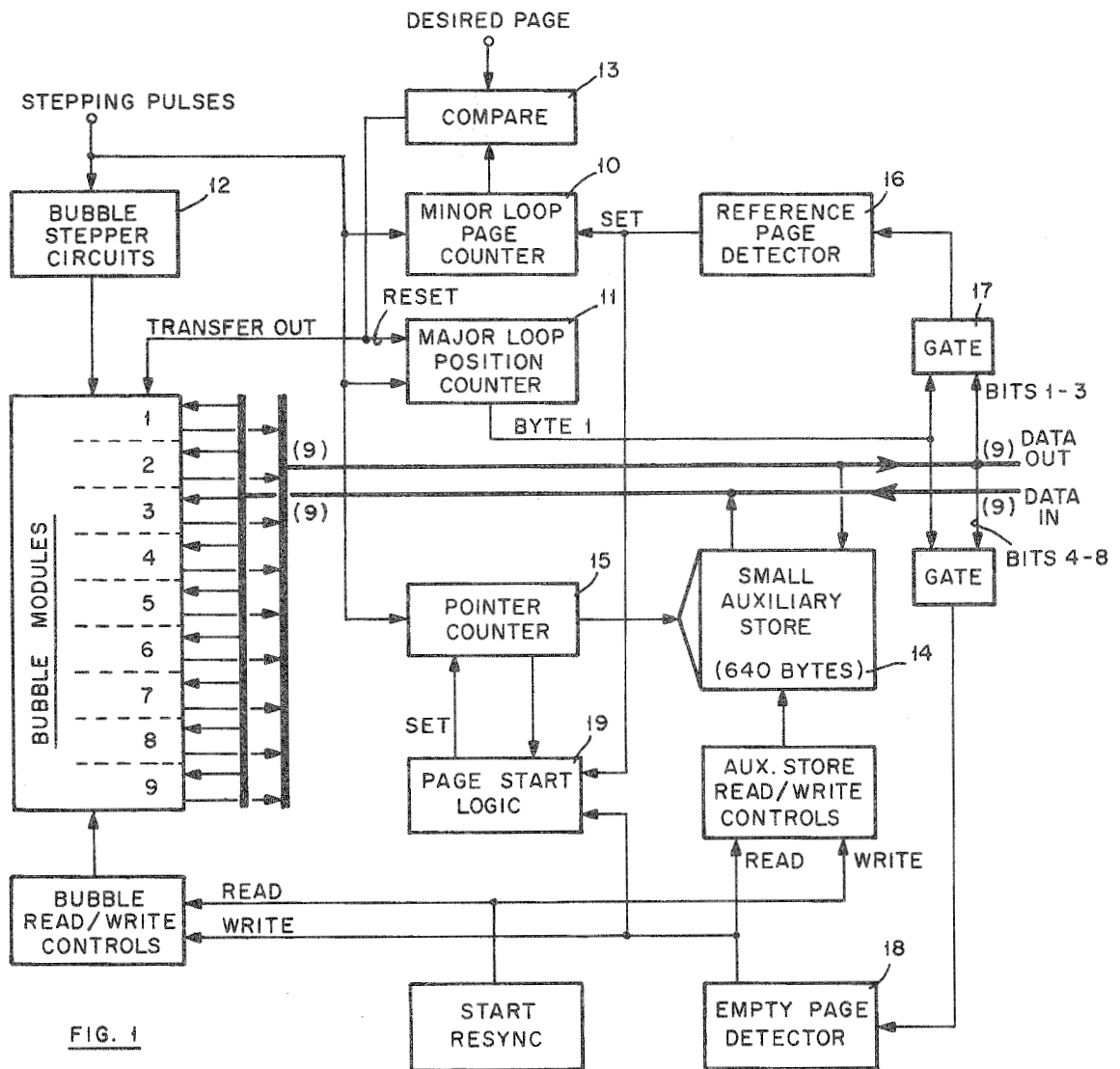


FIG. 1

Since a magnetic bubble memory is nonvolatile, a power failure does not affect the data stored in the memory. It does, however, destroy the count in the bubble position counters associated with the memory. Thus, when power is restored, you do not know where the various blocks of data are inside the memory. The present technique provides an efficient, reliable and economical way of resynchronizing the bubble memory counters after correction of a power failure.

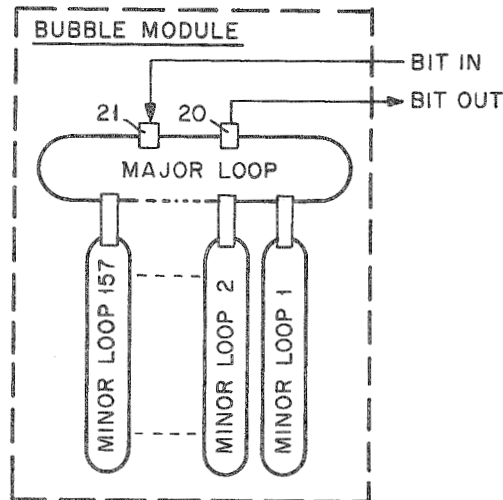


FIG. 2

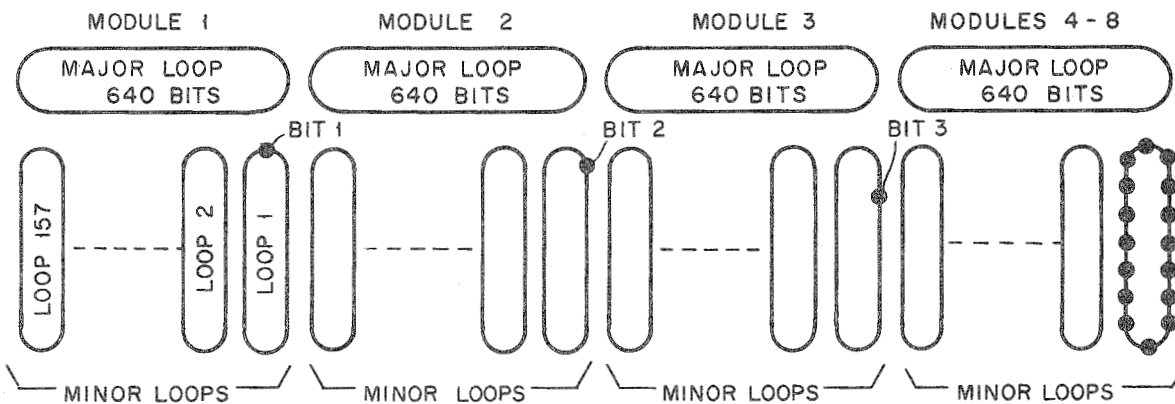


FIG. 3

A typical application of the technique is shown in Figs. 1 and 2. As indicated in Fig. 1, nine separate magnetic bubble modules are operated in unison to provide a bubble memory having a one byte readout and write-in capability. Each module has the form shown in Fig. 2, and includes a major loop having a magnetic bubble detector/replicator station 20 and a magnetic bubble generator station 21. Some 157 minor loops are coupled to the major loop. Each minor loop has 641-bit or bubble positions. For sake of example, each of these bubble modules is assumed to be a Texas Instruments 0103 magnetic bubble module. Bubble module 9 of Fig. 1 provides parity bits for the data from the other 8 modules.

When data is to be read, a simultaneous transfer of 157 bits occurs from the set of 157 minor loops to the major loop (1 bit from each minor loop) in each of the nine modules. This total simultaneous transfer of

data to the major loops ($157 \times 9 = 1413$ bits) is called a "page" of data. The bits transferred to each major loop are stepped around the major loop and are read out in a serial manner via the detector/replicator station 20 in the major loop. The 9 bits read out of the nine modules at any given instant constitute a byte of data. Thus, there are 157 bytes per page.

A minor loop page counter 10 is associated with the bubble memory for keeping track of the pages as they circulate around the minor loops. In particular, the page counter 10 shows the number of the page which is at that moment in the minor loop to major loop transfer position. A major loop position counter 11 is also associated with the bubble memory for keeping track of the beginning of the page in the major loop as it circulates around the major loop. This major loop position counter 11 is reset to zero at the same moment that a new page is transferred out from the minor loops to the major loops. The counting range of the page counter 10 is equal to the number of bubble positions in a minor loop, and the counting range of the major loop position counter 11 is equal to the number of bubble positions in a major loop. Both of these counters are driven by the same stepping pulses which are applied to the bubble stepper circuits 12 associated with the bubble memory.

The normal accessing of the bubble memory is accomplished by supplying the number of the desired page to a compare circuit 13 which also receives the count from the page counter 10. When the actual page indicated by the page counter 10 is equal to the desired page, the compare circuit 13 generates a transfer out pulse which is sent to the bubble memory to cause a transfer of a page from the minor loops to the major loops. This pulse also resets the major loop position counter 11.

The first minor loop in each module (hence the first byte in each 157-byte page) is reserved for control and resynchronization purposes. As shown in Fig. 3, the first minor loops in modules 1-3 contain single "one bits" which are used for locating or identifying any one of pages 1, 2 or 3 as they circulate around the minor loops. All other bubble positions in each of these three minor loops contain a zero value (no bubble). As will be seen, these first minor loops of modules 1-3 are used by the resynchronization mechanism for purposes of resetting or resynchronizing the minor loop page counter 10 during power up following a power failure.

The first minor loops in modules 4-8 are used to locate the minor loop position of the page (if any) which was resident in the major loops at the moment of the power failure. When first used, the bubble memory is initialized so that all positions around the first minor loop in each of modules 4-8 contain a "one" value (a bubble). When a page is transferred from the minor loops to the major loops, its minor loop positions lose their bubbles. Thus, the presence of zeros in the first minor loops of modules 4-8 marks the location of the empty page position in the minor loops.

Considering now the resynchronizing of the bubble memory after the return of power following a power failure, the first step in the resynchronization process is to offload the page then resident in the major loops and to store it in a small auxiliary store 14 having the same byte capacity as the major loops. This is accomplished by reading out the major loop information from the bubble memory modules and writing it into the auxiliary store 14 one byte at a time. The individual byte locations in the auxiliary store 14 are addressed by means of a pointer counter 15. This pointer counter 15 is driven by the same stepping pulses as are applied to the bubble stepper circuits 12 and advances one count for each stepping pulse. The pointer counter recycles back to zero after each 640 counts, 640 being the number of bubble positions in each major loop. At the start of the resynchronization procedure, that is, before the commencement of the major loop offloading, the pointer counter 15 is reset to zero. Since the first byte of the page which was resident in the major loops at the moment of the power failure may be at some position in the major loops other than the loop readout position, such first byte may, and most likely will, be stored at some location other than the lowest numbered location in the auxiliary store 14.

After the information in the major loops is offloaded to the auxiliary store 14, the next major step in the resynchronization process is to scan the pages in the minor loops to locate any one of pages 1, 2 or 3. Each page is scanned by transferring it to the major loops, stepping it around the major loops to provide a nondestructive readout of the data in such page and then transferring it back to its original position in the minor loops. Since the bubbles in the minor loops complete one rotation at the same time as the bubbles in the major loops, the page is transferred back to the same position in the minor loops as it originally had when it was transferred out to the major loops. Thus, the data is not harmed by this page-scanning procedure.

A reference page detector 16 monitors the page scanning readout from the bubble memory for purposes of detecting the readout of one of pages 1, 2 or 3. In particular, the reference page detector 16 looks at bits 1-3 of the first byte of each page. In this regard, the major loop position counter 11 is reset to zero when a page is transferred to the major loop. Knowing the number of bubble positions between the minor to major loop transfer position and the detector station position, a line from the appropriate stage in the major loop position counter 11 is used to activate a gate 17 for passing bits 1-3 to the reference page detector at the point in time when byte 1 of the page is in the detector station position.

The reference page detector 16 first considers its bit 1 input line to see if it can find the single 1 bit marking the occurrence of page 1 (the single 1 bit originally recorded in bit position 1 of minor loop 1 of module 1). It may not be able to find this page 1 locator bit for two possible reasons. One reason is that page 1 may have been the page that was resident in the major loops at the moment of the power failure.

Another possibility is that a stray extraneous bubble may have wandered into minor loop 1 of module 1. In such case, there would be two 1 bits in minor loop 1, thus making it impossible to tell which marks the location of page 1. If for either reason the reference page detector 16 cannot locate the single 1 bit for minor loop 1 of module 1, then it commences to use the bit 2 input line for purposes of locating the single 1 bit marking the location of page 2. If this fails to succeed, then the reference page detector 16 relies on the bit 3 input line to locate the single 1 bit marking the location of page 3 (the single 1 bit originally recorded at the bit 3 position of minor loop 1 of module 3). This use of three different page locator bits from three different minor loops enables the resynchronization mechanism to recover from multiple power failures and various other possible multiple errors. The odds in favor of being able to determine the location of at least one of pages 1, 2 or 3 are quite large.

In the foregoing manner, the reference page detector 16 detects the readout of one of pages 1, 2 or 3. The reference page detector 16 then resets the minor loop page counter 10 to the page number of the detected page (e.g., reset to 1 if the detected page is page 1). The timing is such that the resetting is done during the same step in which the detected page is transferred back to the minor loop. In other words, the page counter is reset to indicate the minor loop page which is in the major/minor loop transfer position. This establishes synchronization of the minor loop page counter 10.

During the course of the page scanning operation, an empty page detector 18 is used to determine the location of the empty page position (if there is one) in the minor loops. This is accomplished by examining bits 4-8 of the first byte of each page as it is read out of the bubble memory during the page scanning operation. The detection of zeros for these bits 4-8 identifies the readout of the empty page. If no empty page is detected, this means that no minor loop page was resident in the major loops at the time of the power failure. In such case, nothing further need be done for resynchronization purposes, and the bubble memory is ready to resume its normal operation.

If, on the other hand, an empty page is detected, then it is necessary to reset the pointer counter 15 so that it points to the first byte of the page of data stored in the auxiliary store. Note in this regard that a page of data has 157 bytes, whereas the auxiliary store (and the major loops) have 640 storage positions. The proper value to which the pointer counter 15 should be set is determined by page start logic 19 which uses the number of counts needed to detect the reference page and the number of counts needed to detect the empty page to calculate the position in the major loop of the first byte of the page resident in the major loop at the moment of the power failure. This also corresponds to the position of the first byte of such a page in the auxiliary store 14.

After the pointer counter 15 is reset to point to the start of the page in the auxiliary store 14, this page in the auxiliary store 14 is

BUBBLE MEMORY RESYNCHRONIZATION MECHANISM - Continued

then transferred back to the bubble memory major loops. Such page is then stepped around the major loops to bring it into the proper alignment with the major/minor loop transfer positions, at which point the page is transferred back to the minor loops. This completes the resynchronization process, and the bubble memory system is back in business again.