Motion-compensation 100Hz TV eliminates flickers and judders

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Abstract
First introduced in the early 1990s, 100Hz is a major Philips innovation in high-end television, using a digital memory technology to create flicker-free viewing. Incredible Motion ensures perfect natural movement of objects in television screen by eliminating the juddering sometimes seen in such sets. Nowadays, all major brands have adopted the 100 Hz Philips innovations in their high-end TV ranges.

None of the standard definition TV broadcast systems in use around the world is perfect, with each having its own advantages and disadvantages. For example, despite its poor color rendering and 525-line vertical resolution, the NTSC system uses an interlaced display that is updated at a refresh rate (field rate) of 60 Hz – high enough to significantly reduce large area flicker (70Hz is the ideal minimum refresh rate to eliminate this effect but 60 Hz is close enough). Although the 625-line interlaced display PAL system is better at producing accurate colors and provides better vertical resolution, its 50 Hz refresh rate results in a picture with more perceptible large area flicker.

The key to reducing this large area flicker is to increase the refresh rate from 50 Hz to 70 Hz or higher. Philips Semiconductors 100Hz technology simply double every ordinal field so that the TV refresh rate raises up to 100Hz from ordinal 50Hz rate in PAL system. The glowing and fading phenomenon of phosphors in CRT are no longer perceived by HVS (Human Visual System) and flickers do no longer exist in pictures.

Based on vast experience in analog TV and world-beating picture enhancement technologies, Philips Semiconductors offers 'Incredible Motion' techniques to eliminate blur and judders to provide extremely clear pictures and deliver outstanding image quality. Our unique 'Movie Mode' ensures DVD and Video CD playback is ultra-smooth, even during high action sequences.

Philips Semiconductors 100Hz chipsets are simple, scalable solutions. These chipsets are pin-to-pin compatible, so the same design can be used for low-, mid- and high-end sets. The 100Hz display technology removes large area flicker from screen of current standard definition TV system so that watching a TV becomes a relaxation of your eyes. Philips Semiconductors has now available a number of scan converter modules differing in range of functions and intended application environment. The technology now has been widely adopted and designed in major TV manufacturers over the world.

Simple 100Hz TV system
In a 100Hz TV set, each image field is repeated a second time (e.g. AA-BB, with A and B being two individual fields) simply to increase field rate from 50Hz to 100Hz by utilizing a converter that is SAA4979 in Philips Semiconductors 100Hz TV solution. The simply generated 100Hz fields in this mode are simply compensated using median filters technology. The filter smoothen motions in these fields at a basic level.

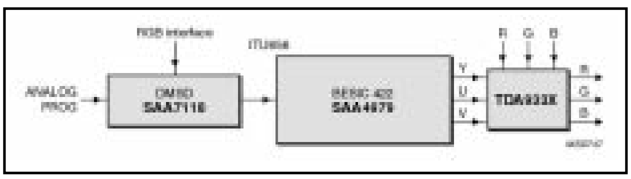

Figure 1. Entry level 100Hz TV System

Incredible motion 100Hz TV system
In a Philips 100Hz set with Incredible Motion technology, the fields are alternated - A-B-A-B - to further eliminate flicker and provide a totally stable picture. To eliminate any juddering which may occur when moving objects are in the picture, Incredible Motion uses a digital memory to

estimate motion of objects in a field and creates new frames to insert between existing frames with corrected motion positions of moving objects.

The new, inserted fields are computed from motion information - the position of the moving object in time - coming from three fields - the current (A), the next (B) and the previous (Z). By comparing these fields, Incredible Motion creates a smoother movement.

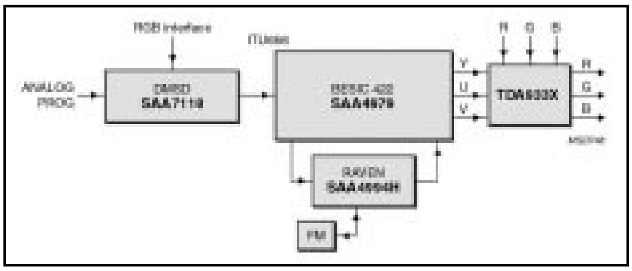

Figure 2. Mid-end motion enhanced 100Hz TV System solution

When there is motion in the picture, the newly created field will locate the moving object(s) in the correct motion position, which makes the movement of objects appear smooth. The power behind this process is the Philips Falconic chip, which is capable of detecting fast-moving objects and it can handle rapid multi-directional movements at the same time.

Field scan rate conversion

The SAA4979 is a stand-alone IC for 4:2:2 video scan conversion from 50/60 Hz to 100/120 Hz. The main characteristic is that all digital functions including a 3.5 MBit field memory are placed inside one IC.

The IC supports two digital ITU-656 video input data streams to allow picture-in-picture processing. It provides picture improvement features and non-linear horizontal picture compression or expansion and has analog YUV outputs for a display. The on-chip memory is used for scan conversion as well as for field-based noise reduction. The SAA4979 is designed especially for an economy 100 Hz applications and allows one-chip 100Hz conversion. For mid- and high-end applications it also offers an expansion port for vector based motion estimation and compensation ICs like the SAA4993/4 (FALCONIC).

Field memory

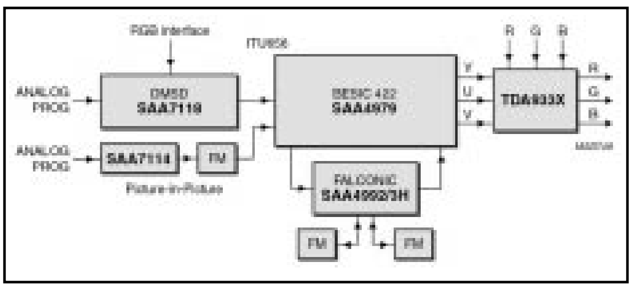

Figure 3. Incredible Motion- Complete 100Hz TV System solution with motion compensation and picture-in-picture features

The SAA4979 has a built-in scan conversion memory. The write address pointer is reset by the RSTW pulse which is derived from the 50 Hz vertical sync pulse V656_1, the read address pointer is reset by the RSTR pulse which occurs in the vicinity of the vertical 100 Hz sync pulse VD. Whenever WE is active, data is written to the memory, and whenever RE is active, data is read from the memory. WE and RE are generated by the acquisition control part within the SAA4979. Fig. 4 shows the basic timing of the scan conversion memory. (RSTW, V656_1, WE and RE are chip internal signals).

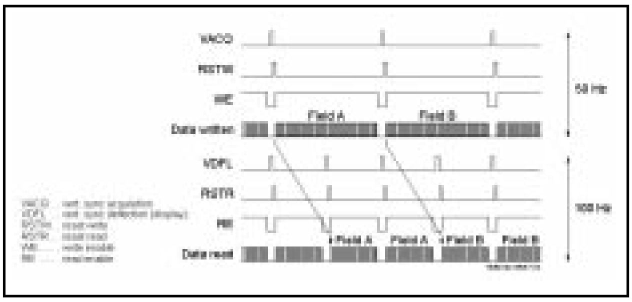

Figure 4. Basic timing of the scan conversion memory

Digital noise reduction

The dynamic noise reduction circuit in the SAA4979 is based on a recursive signal filtering in which an actual and a previous (field delayed) signal are mixed. The level of the noise reduction is dynamically controlled depending on movement, i. e. depending on differences between pictures. The circuit therefore is closely related to the IC's field memory. This memory has two output ports: one is used for double scan rate and the second one is a 50/60 Hz output and is used for the noise reduction loop. Fig. 5 shows the block diagram of the noise reduction circuit.

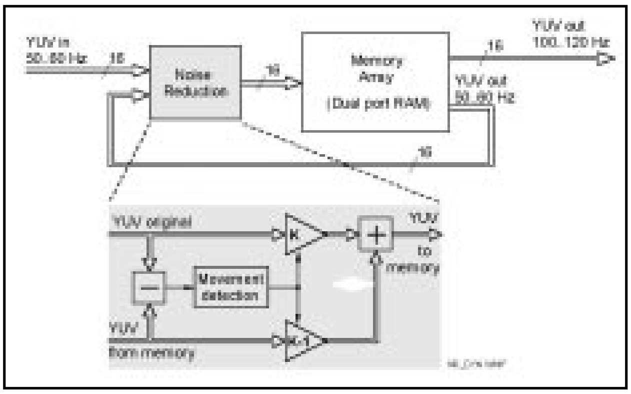

Figure 5. Basic block diagram of the DNR circuit

Problems in motion portrayal with picture rate conversion

The simplest approach to double the scan rate is to display each field twice. This eliminates large area flicker effectively but still has the problem of blurring or contouring of moving edges. This artifact is depicted in Fig. 6. For a moving object it can be seen that its position is incorrectly represented in every second field. If the viewer tracks the object it is perceived double, as its location in every second field is not at the expected position.

Much worse is the display of movie film on a TV set or even in cinema, because motion comes in a rate of only 25 pictures per second. On a 50 Hz TV each motion phase is displayed twice resulting in annoying jerky motion due to a lower picture update rate and therefore a larger position error between expected and displayed object position. In current 100 Hz TV each movie picture is repeated four times which still increases the jerkiness of the motion.

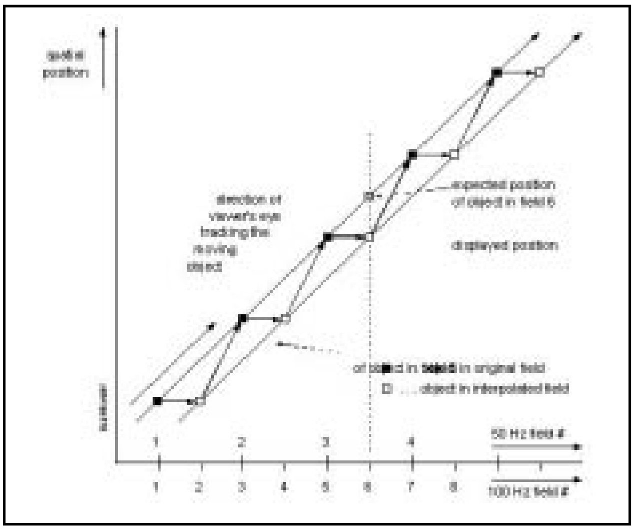

Figure 6. 100Hz field repetition causes blurring at moving edges

Motion estimation and compensation for luminance

In order to overcome above-described problems a motion estimation technique is needed, objects in the interpolated image can then be placed at the position expected by human vision. The technique implemented in the SAA4993/4 is based on a 3-D recursive search block-matching algorithm. Fig. 7 demonstrates the block matching principle.

Motion estimation is performed in the luminance channel only. Motion compensated upconversion is done in the luminance channel while for the chrominance signal upconversion is done by a median filter. The vector range is vertically ± 12 lines, horizontally ± 31.75 pixels (sub-pixel accuracy). The general architecture of the motion estimator and compensator in luminance can be referred to data sheets of SAA4993/4.

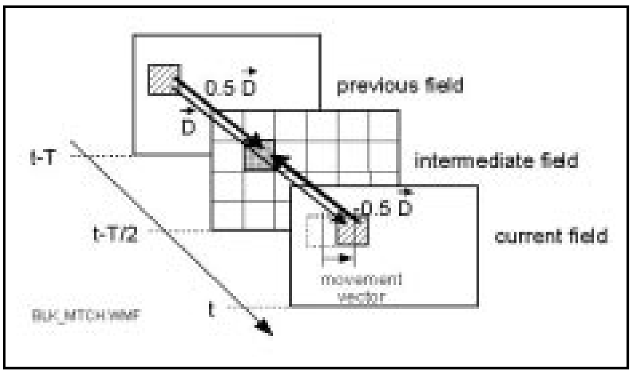

Figure 7. Bloack matching principle

Motion estimator

The motion estimator calculates the motion vector of objects within an incoming video field by comparing the field itself with a previous frame. It reads pixel data from the current field and the previous frame via the local caches or multi port RAMs. Prediction vectors of the current and neighboring blocks that were estimated in the previous field period and stored in the Temporal Prediction Memory (TPM) are used as a basis for new estimations. From this information, it generates a new motion vector, which is again forwarded to the TPM, leading to a temporally recursive motion estimation.

The motion estimator works on a picture block size of 4 lines x 16 pixels, while a motion vector is assigned to a block size of 4 lines x 8 pixels in a checker board pattern (quincunx block subsampling), this means a subsampling of factor two, only every second block a motion vector is assigned to. For the other blocks the motion vector is interpolated. Fig. 8 shows the principle. The main basis for finding the movement vector of a block is the vectors of the neighboring blocks (spatial pre-diction vectors) and the vectors of the current and neighboring blocks of the previous field (temporal prediction vectors). This situation is depicted in Fig. 9.

For each picture block four candidates will be selected as candidate vectors. The selection of the vectors is programmable; an algorithm example is depicted in Fig. 10. It represents a random update vector that can be applied to any prediction vector.

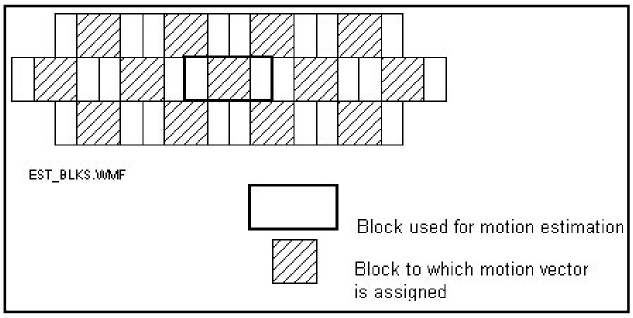

Figure 8. Motion estimator block subsampling

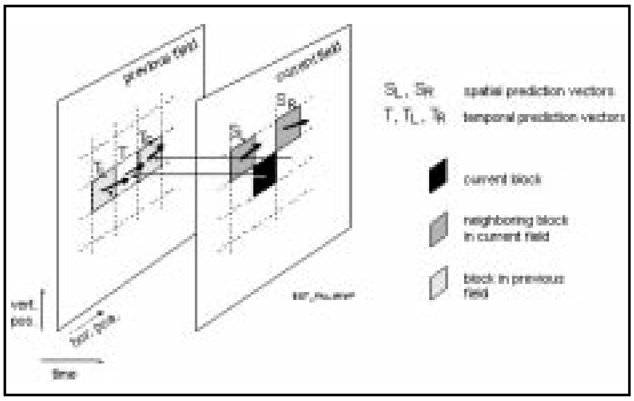

Figure 9. Position of the spatial and temperal prediction vectors in relation to the current processed block

Cmax defines the maximum candidate within a certain area around the current block B. It is found of scanning 5 vectors around B as shown in Fig.11. This maximum vector changes from block to block. So every time Cmax is a candidate the 5 motion vectors are evaluated. This maximum candidate enables fast convergence of motion vectors.

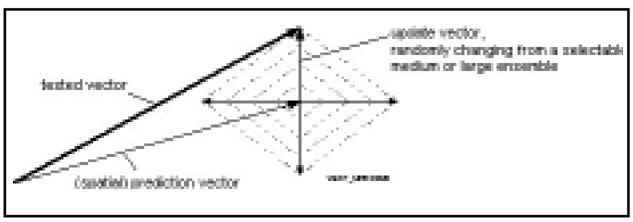

Figure 10. Recursive search trying to find a better vector

Cp is a programmable vector. This candidate is possibly selected when camera panning or zooming is detect-ed. For every input field motion estimation is done twice, but for different candidate sets. The first motion estimation is called left (L), the second is called the right (R), which is the

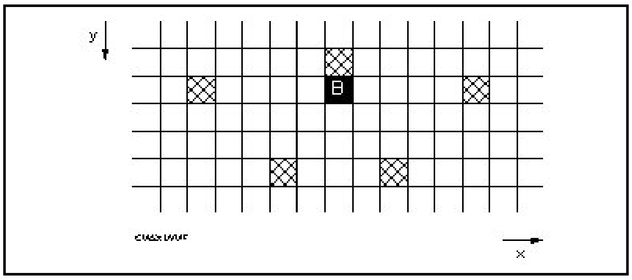

Figure 11. Selection of cmax

column estimator. In hardware only one motion estimator is used, which is multiplexed in time.

The vector candidates define a translation from field t to t-T. If the intermediate field is the point of reference, the displacement is equivalent to half the motion vector in both directions. Therefore the candidates are split in two parts. In order to prevent that the vectors point to information that is not available (due to interlace or subpixel accuracy), they are 'rounded' to the nearest original data. These split vectors are used to address the pixel data in the current field and in the previous field. The relevant lines of these fields are located in the multi port RAMs (MPR). For every candidate the Sum of Absolute Differences (SAD) is stored in an error memory (ESM). The candidate that delivers the smallest SAD could be considered as the best fitting candidate, and therefore, the best motion vector. But however, in some cases some candidates might be preferred above others. Therefore a (programmable) penalty can be added to each vector. Finally the least error is calculated and the associating vector index (least error index) is determined. The least error index controls that vector will be put forward, via an additional temporal filter, to the temporal prediction memory (TPM).:

Block erosion

In a first step the motion vector block is split into 4 quadrants. The four corresponding motion vectors D00, D01, D10 and D11 are found by median filtering of the block itself and the horizontally and vertically adjacent blocks, this yields a vector for each block of 2 lines by 4 pixels. In a second step the process is repeated further resulting in a block size of 2 (horizontal) pixels, see Fig. 12. Upconverter

The upconverter converts the incoming field frequency to the selected output field frequency, it acts as field and frame rate converter. The quality of field rate conversion improves significantly with motion-compensation techniques. It becomes possible to interpolate new fields at their correct temporal and spatial position. This results in smooth motion portrayal without loss of temporal resolution. However, as motion vectors are not always valid for every pixel or object non-linear filtering is used in order to minimize visible artifacts. The algorithm generally

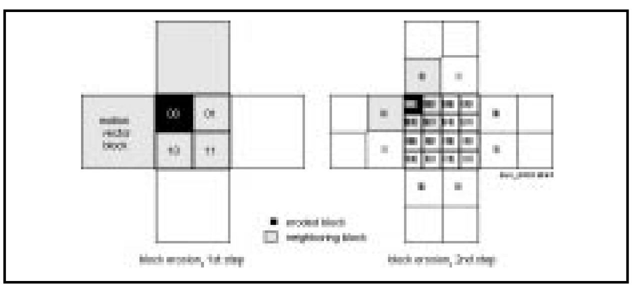

Figure 12. Block erosion

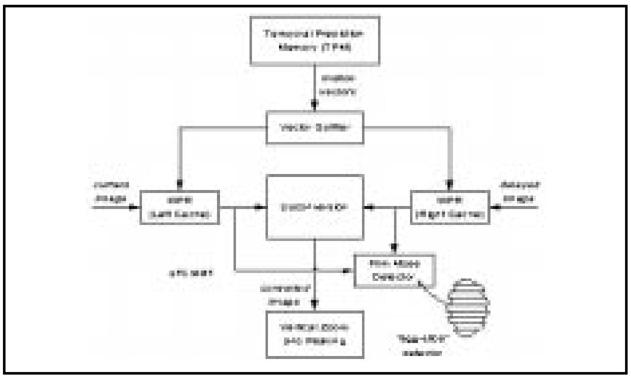

Figure 13. Upconverter block diagram

consists of two steps. First the displacement of objects with-in successive fields of an image sequence must be determined; a motion estimator is needed for this. Secondly, the resulting motion vectors of the first step are used to interpolate new image fields in between existing ones, this is done in the upconverter. Fig. 13 shows the block diagram of the upconverter. The vector splitter gets a motion vector from the temporal prediction memory (TPM), processes it and applies it to the left and right cache (multi port RAM, MPR). The MPR returns the actual pixels as well as the delayed pixels of the requested positions as an array of pixels. These pixels are interpolated with a non-linear filter (cascaded median filter) to form the pixels of a lower and an upper (de-interlaced) line which are output to the zoom circuit. A circuit called "egg-slicer" is used to verify motion detection.

Reference

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Richard Wang is the International Product Manager for Philips Semiconductors and has seven years of engineering experience in video and audio products. In his current position, Wang has submitted competitive solutions and has collaborated with customers in China to define the direction of high-end TV products.

Mr. Wang's professional focus has been largely on analog and digital set-top box technology and modern TV systems. He presently concentrates on reference designs for high-end 100 Hz TV systems and linking them to the digital TV of tomorrow. His knowledge of system-level design also includes the areas of RF, broadband, video, audio, power management, and cable TV scrambling systems.

Mr. Wang holds an M S.C. degree in electrical engineering from Tatung University in Taiwan.