

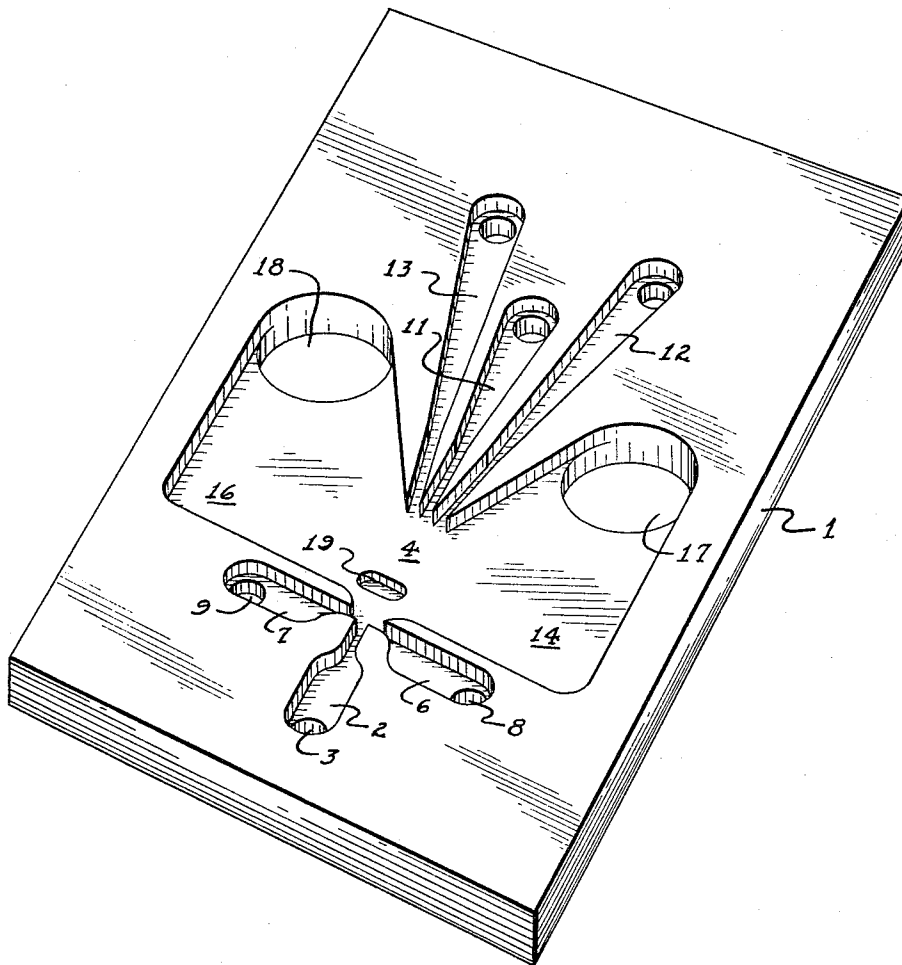
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ANALOG AMPLIFIER CROSS VENT

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## ANALOG AMPLIFIER CROSS VENT

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The present invention relates to pure fluid amplifiers and more particularly to an analog amplifier having a cross vent in the interaction region to reduce noise and increase the gain of the unit over that which is realized when a cross vent is not employed.

Pure fluid amplifiers of the type with which the present invention is concerned are a relatively recent development in the fluids field. In these devices amplification of an input signal is effected by producing an interaction between a so-called "power" stream of fluid and a control signal to deflect the jet in such a manner as to vary the proportions of fluid received or applied to two or more downstream receiving or output passages. Deflection of the jet may be effected by momentum interchange between the power jet and one or more control streams of fluid, the interaction between the two or more streams taking place in a region where the power stream is confined to its plane of deflection. In consequence of the confinement of the power and control streams, a momentum interchange occurs between the control stream and the power stream since the two streams cannot flow around one another but are required to impact against one another. The resultant direction of the combined stream after interaction lies along the direction which is a function of the relative momenta of the two streams.

It has been found that noise is introduced into such a system as a result of local random variations in static pressure on the two sides of the stream. The random pressure variations create local pressure differentials across the stream which produce unwanted and uncontrolled minor deflections of the stream. Further, variations in static pressures on two sides of the stream tend to reduce the gain thereof since otherwise useful signal energy now appears as noise energy.

It has been proposed to equalize the static pressures on the two sides of the power stream by undercutting one of the top and bottom walls of the device which walls are normally employed to confine the main stream to its plane of deflection. The prior art proposal contemplated undercutting one of the walls in the entire region starting just downstream of the point of interaction between the streams and terminating at the receiving apertures. The primary purpose of this configuration was to defeat the effects of boundary layer lock-on which tend to increase the gain of the unit non-linearly with deflection. The construction achieved the desired result of defeating boundary layer effects. However, due to spreading of the stream which was permitted by the undercutting of the entire region, the signal-to-noise ratio of the system was not appreciably increased and the gain was somewhat decreased due to loss of energy and pressure as the stream spread in a direction transverse to its direction of deflection.

In accordance with the present invention, it has been found that by providing an undercut region in one of the top or bottom walls of the device which has a small dimension parallel to the direction of the undeflected power stream and only a slightly larger dimension transverse to the direction of the stream, the static pressures on the two sides of the stream are equalized without permitting spreading of the stream transverse to its direction of deflection. It has been found that as a result of this construction boundary layer effects are eliminated, the static pressures on the two sides of the streams are main-

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tained substantially equal (thereby greatly increasing the signal-to-noise ratio of the system) and the gain of the system is up to five times as great as that which is obtained when the entire region between the point of interaction and the receiving apertures is undercut.

It is therefore an object of the present invention to provide a pure fluid, analog amplifier having a large signal-to-noise ratio and a large gain.

It is another object of the present invention to provide an undercut region or cross vent in one of the confining walls of an analog amplifier which cross vent has a length that is small relative to the distance between a power nozzle and receiving apertures of the amplifier and which is only wide enough to maintain the cross venting operation through the maximum design deflection of the power jet.

Still another object of the present invention is to provide a high-gain, low-noise pure fluid amplifier.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawing, wherein:

The single figure of the present invention illustrates a fluid amplifier employing the cross vent of the present invention.

Referring now specifically to FIGURE 1 of the accompanying drawings, the fluid amplifier is formed as channels in a block 1 of suitable material such as plastic, ceramic, metal, etc. The concept of the present invention is applicable to a wide variety of different types of analog amplifiers. The amplifier of FIGURE 1 is exemplary of one such design and is employed for purposes of illustration only. It is not intended to limit, thereby, the invention to use or any specific amplifier design. The apparatus is provided with a power nozzle 2 supplied with operating fluid through a suitable port 3 in the block 1. The power nozzle 2 issues a stream of fluid into and through an interaction region generally designated by the reference numeral 4. Control orifices or nozzles 6 and 7 are provided on opposite sides of the main power nozzle 2, these nozzles being supplied with fluid through suitable inlet ports 8 and 9, respectively.

When fluid is supplied to the power nozzle 2 in the absence of input signals to control nozzles 6 and 7, a stream of fluid passes through the interaction region 4 and into a first receiving aperture 11. A right receiving aperture 12 and left receiving aperture 13 are also provided. The right and left sides of the interaction region 4 are opened up into enlarged regions 14 and 16, respectively, which are vented to the atmosphere or to a suitable source of reference pressure through enlarged apertures 17 and 18, respectively. The regions 14 and 16 and the venting thereof through the apertures 17 and 18 is employed to substantially eliminate boundary layer effects between the main power stream issued by the power nozzle 2 and the walls of the device which define the interaction region 4. If walls were placed in close proximity to the stream issued by the nozzle 2, when the stream was deflected closer to one sidewall than the other, the stream would be more effective in evacuating the fluid between this stream and the closest sidewall thereby producing a further reduction in pressure on that side of the stream. This further, and in this case unwanted, reduction in pressure would produce further deflection of the stream, the operation being a positive feedback operation. If the gain of the feedback provided were greater than one the stream would switch to the sidewall and remain attached thereto until an over-riding control signal were applied. If the gain of the feedback arrangement were less than one then the stream

would be deflected to an extent greater than called for by the control signal but it would not produce complete switching. By equalizing the static pressures on the two sides of the streams, boundary layer effects are defeated and the positive feedback phenomena is not present.

The regions 14 and 16, however, do not prevent local differences in static pressure which may form immediately around the stream due to unwanted and random perturbations in the fluid system. Since these perturbations occur at a rate which is relatively high compared with signal variations, deflections of the stream are produced which appear as noise in the output signal. To the extent that these variations occur, a portion of the energy in the stream is in the form of noise energy and in consequence, the gain of the unit is reduced.

It has been found that by undercutting a wall of the device lying parallel to the plane of the page over a small area, the signal-to-noise ratio of the apparatus may be greatly increased and the gain of the unit increased by up to five over that gain which is obtainable when the device is not so constructed. Specifically, an undercut region 19 is provided just downstream of the region of interaction between the main power stream and the control streams. It is in this region just downstream of where the streams have interacted and where there are small side-walls on opposite sides of the stream, that the major disturbances occur. The cross vent 19, illustrated in the figure, is sufficiently wide to provide communication between the two sides of the stream throughout the range of deflections of the stream for which the device is designed. In the specific design illustrated, the length of the vent 19, along the axis of the nozzle 2, may be as small as  $\frac{1}{16}$  of an inch and may be approximately  $\frac{1}{32}$  of an inch deep. In consequence of this construction, the power stream is maintained confined to its plane of deflection except over a very small portion of its length in the interaction region. Therefore spreading of the stream is substantially prevented and no appreciable dynamic pressure or velocity drop is noted in the stream and the gain of the device is not adversely affected. On the other hand a substantial proportion of the noise is eliminated, and the gain of the device is further increased.

It is not intended to limit the use of the present invention to an analog amplifier having the specific construction illustrated, it having been found that the use of the cross vent is equally applicable to substantially all analog amplifiers regardless of their specific configuration.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. A pure fluid analog amplifier comprising at least one receiving region for a fluid stream, an interaction region, means for issuing a stream of fluid through said interaction region toward said receiving region, means for developing a differential in pressure across said stream of fluid to deflect said stream relative to said receiving region, a pair of walls defining opposed surfaces of said interaction region and confining said stream to its plane of deflection as determined by said differential in pressure, and a cross vent formed in one of said walls, said vent having a longitudinal dimension which is short relative to the distance between said means for issuing and said said receiving region, and having a transverse dimension greater than the range of deflection of said stream of fluid in the region of said cross vent.

2. A pure fluid analog amplifier comprising at least one receiving region for a fluid stream, an interaction region, means for issuing a power stream of fluid through said interaction region toward said receiving region, means for developing a control stream of fluid directed against said power stream of fluid to deflect said power stream

relative to said receiving region, a pair of walls defining opposed surfaces of said interaction region and confining said power stream to its plane of deflection as determined by said control stream, and a cross vent formed in one of said walls downstream of the means for developing a differential in pressure across said stream of fluid, said vent having a longitudinal dimension which is short relative to the distance between said means for issuing and said receiving region, and having a transverse dimension greater than the range of deflection of said power stream of fluid in the region of said cross vent.

3. A pure fluid, analog amplifier comprising at least two fluid receiving regions, an interaction region, means for issuing a power stream of fluid through said interaction region toward said receiving regions, means for directing a control stream of fluid against said power stream in said interaction region, a top and a bottom wall defining two sides of said interaction region, said walls confining said power stream to its plane of deflection as determined by said control stream, a cross vent symmetrical with respect to the undeflected power stream and located adjacent to and downstream of the area of contact between said streams, said cross vent being formed in one of said walls and having a longitudinal dimension which is short relative to the distance between said means for directing and said receiving regions.

4. A low-noise, high-gain, pure fluid analog amplifier comprising a power nozzle for issuing a power stream of fluid, a pair of control orifices for issuing variable control streams of fluid against opposite sides of said power stream so as to deflect said stream, at least two fluid receiving passages positioned downstream of said control orifices in intercepting relationship to said power stream, means for confining said power stream to its plane of deflection as determined by said control streams, a cross vent formed in said means for confining, said cross vent being located downstream of and symmetrical with respect to said power nozzle and having a longitudinal dimension which is small relative to the distance between said power nozzle and said receiving passages, said cross vent having a transverse dimension greater than the range of deflection of said power stream.

5. A pure fluid analog amplifier comprising at least one receiving region for a fluid stream, an interaction region, means for issuing a stream of fluid through said interaction region toward said receiving region, means for developing a differential in pressure across said stream of fluid to deflect said stream relative to said receiving region, a pair of walls defining opposed surfaces of said interaction region and confining said stream to its plane of deflection as determined by said differential in pressure, and means for reducing noise in the amplifier, said means having means for equalizing the pressures on the two sides of the stream of fluid adjacent to and downstream of said means for developing a differential in pressure across said stream of fluid wherein said means for equalizing comprises a recess formed in one of said pair of walls, said recess having a longitudinal dimension small relative to the distance between said means for issuing and said receiving region.

#### References Cited by the Examiner

##### UNITED STATES PATENTS

|           |         |        |          |
|-----------|---------|--------|----------|
| 3,181,545 | 5/1965  | Murphy | 137—81.5 |
| 3,209,774 | 10/1965 | Manion | 137—81.5 |

##### OTHER REFERENCES

Dexter, E. M., *An Analog Pure Fluid Amplifier. Fluid Jet Control Devices*. New York, The American Society of Mechanical Engineers, 1962. Pages 41-49. TJ 935, S95, 1962.

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