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Abstract

Mesa was commissioned 1965-1966 from Gordon Mumma by John Cage as the accompaniment for the Merce Cunningham Dance Company (MCDC) work *Place.* This history of the piece reviews evidence from a variety of published and unpublished sources to identify six iterations of the circuitry used to perform the work. As an early work of live electronic music, *Mesa* crystallizes this communal, practice-based tradition of electroacoustic music, acting as a miniature of these dynamics.

1) Introduction: composing inside electronics

"...somewhat like a recipe for a pizza, but without the minute details of the individual ingredients…" Gordon Mumma describing *Mesa*, email from November 10th, 2019, cited with permission

In this essay, I argue that *Mesa* is recognizably Mumma's composition, and at the same time, has always been firmly outside of his individual grasp at both the circuit and performance level. As such, *Mesa* has always been a communal, distributed project. Like many works of electroacoustic music, performing it requires more than simply learning the idioms of its design(s), it also asks the performer(s) to reinvent these for themselves. Musicologist Jonathan Goldman writes that *Mesa* "exhausts itself in its own apparatus," (2020, 735) echoing Nic Collins' earlier and more general statement that, in live electronic, "the circuit—whether built from scratch, a customized commercial device, or store-bought and scrutinized to death—became the score." (2004, 1) As they both make clear in their own ways, this should not be read to mean that the piece is fully determined by its circuitry. Rather, understanding (and preserving) *Mesa* is found in the making-accessible of the circuitry via a documentation of its relationship to past and future performers.

Although I did not have access to the surviving circuits (the majority or all of which are kept with the Tudor instruments of Wesleyan University's World Instruments Collection), other researchers (especially Jonathan Goldman, Francis Lecavalier, You Nakai, and Michael Johnsen) pointed me to the scattered variety of information available on *Mesa*. In preparation for future publications, like Johnsen's circuit analysis of *Mesa*'s circuitry, this essay summarizes the history of the six iterations of the piece I was able to identify.

This project comes from a decade of study of live electronic music, which began with initial interviews with Nicolas Collins for my master's thesis (Teboul 2015). A personal conversation with John Driscoll at the 2016 Wesleyan University event *Over, Under, Around, and Through the Music of David Tudor* highlighted that live electronic music was best preserved via practice. To that end, this history includes some insights into my own attempt at building a digital system for the performance of something inspired by *Mesa* in the Pure Data audio programming environment.

In technology studies terms, learning CIE works implies a level of willful self-*enrolment* (Callon and Law 1982) through which the tacit knowledge inherent to the implied, idiosyncratic systems and performance practices can be communicated and experienced (Collins 2001). In what follows, I trade roles as a musicologist, technical systems designer, reverse engineer, and archivist, as I discuss materials which were shared with me in a non-linear and ad-hoc way. I have done my best to fit these erratic overlapping experiments, social relations, and nebulous apparatus in the linear shape of the scholarly essay, but the reader should be fully aware that that form is hardly the best suited one through which to appreciate and begin to intuit *Mesa*. Nothing replaces playing something you think might be *Mesa*. Hopefully, the below contributes to a larger project dedicated to giving performers a good idea of what doing that implies, exactly.

2) Reverse engineering as a practice-based, mixed methods approach

Like other practice-based studies of electroacoustic music (Teboul 2020, Jackson 2024) this work can be situated in a longer tradition of historically-informed music studies and performance (Scott 2014, Pérez 2018, Bowan 2019). However, this project is more closely related to Nakai's *forensic* approaches to musicologies with electronics (Teboul 2022). Nakai's work (e.g. 2021) is both unassailably committed to the sounds produced by assemblages of human and electronic instruments, and simultaneously rarely focused on what would generally be discussed as musical events: notes, rhythms, timbres, movements and pitches. Like Trevor Pinch (2002, 11) or Kyle Devine (2019, 18), I join a growing array of music scholarship which take technique and technology as the starting point of composition rather than a means to an end.

To study *Mesa* I relied on a number of contextual insights. Most of my materials are unpublished, archival documents. They were usually obtained via other scholars, artists and engineers because of travel and access limitations: oral histories and participant observation are central to live electronic music as a memory project (Bertolani et al. 2020). Emails with Gordon Mumma, but also John Driscoll, Michael Johnsen, You Nakai, Mimi Johson, Barbara Lloyd Dilley, the Merce Cunningham Trust, and others informed the discussion below to either open new lines of inquiry, support interpretations, or identify dead ends. The project evolved inconsistently from 2022 to today because various resources became available unexpectedly, drawing a more accurate picture of *Mesa* and its various instances. In many ways, my study of *Mesa* mirrors its own communal, unstable, and mediated development. In line with Driscoll's above comment that Tudor and CIE's music was best understood and preserved by playing it, I developed digital emulations of *Mesa*'s analog circuitry complement various aspects of my analysis.

3) *Mesa*'s chronology

The context of *Mesa* has been discussed several times, including in essays by Mumma (1967 & 1971—reprinted 2015; 1997), musicological studies of live electronic music (Hartman 2019, 21-23), first hand listeners (Brown 2007, 475-477 see also numerous other passages on *Place* in this reference) or for projects concerned with Mumma's and Tudor's instruments (Goldman 2012, 2020, Goldman et al. 2020, Nakai 2021, 230-231, 344). Those concerned with the musicological or art historical study of *Mesa* should consult those for completeness, but such completeness is out of the scope of this present essay.

Rather, I focus select evidence which points to multiple versions of the work, and I elaborate on the implied differences and progression of the piece through this chronology to support the technical decisions subtending my development of a Pure Data performance system inspired by *Mesa* and which was premiered at Casa del Popolo, in Montréal, on January 6th 2026, with Stuart Jackson on uilleann pipes taking the role of Tudor and his bandoneon.[1] Because of the nonlinear nature of artistic and academic publishing, I have arranged events, rather than developments of discourse about *Mesa,* chronologically.

a) 1965-1971

John Cage's 1969 book *Notations* contains a circuit diagram for *Mesa* (199, the manuscript is reproduced in figure 1), which lists September 1965 and Ann Arbor as the beginnings of the project. In an essay about his work with the MCDC (1975, republished 2015), Mumma summarizes the genesis of *Mesa* as stemming from a 1965 invitation by Tudor to compose a piece for him and his bandoneon (110).[2] In a 2008 interview with Goldman, Mumma would recall a parking rooftop conversation with Tudor about the piece that September of 1965, highlighting how his electronics would take advantage of the bandoneon's unique capacity for producing drones of varying intensity (Goldman 2012, 46-48). In May 1966, a letter from Mumma to Tudor (Getty Research Institute, Tudor Papers, box 57, folder 3) points to a preliminary work using tape sources alongside Tudor's bandoneon, and an initial apparatus which appears completed, if not final. From the very beginning, *Mesa* served multiple masters (Tudor and Cunningham), involved multiple performers (Tudor and Mumma), and a variety of sound sources (oscillator, tape and bandoneon) for at least three speakers. Two of these early tape versions of *Mesa* are diagramed in the Tudor Papers (box 41, folder 6).

[1] An audience recording of the performance is available here.
[2] An undated essay by Mumma, titled "Why Modern Music Looks So Strange", originally published in a magazine called *Bandwagon*, a photocopy of which I found in the uncatalogued Columbia Princeton Electronic Music Center archives (box 167, folder "Gordon Mumma"), reads in part:

> All written music is a set of instructions, compressed to save time and space. The same instructions, could be written out, and in fact U.S. patent applications are both written out and diagrammed. But that is tedious, as patent applications reveal. Graphic symbols are more efficient. In the case of music they are efficient enough to guide a performer through an acceptable rendition even at first reading.

With regards to patent applications, Mumma implied in part circuit schematics. The *Notations* book is historically notable for the way it introduced circuit scores for musical works to a wider audience (with the *Mesa* diagram discussed below, and another diagram by Max Neuhaus for *Max-Feed*, two pages later).

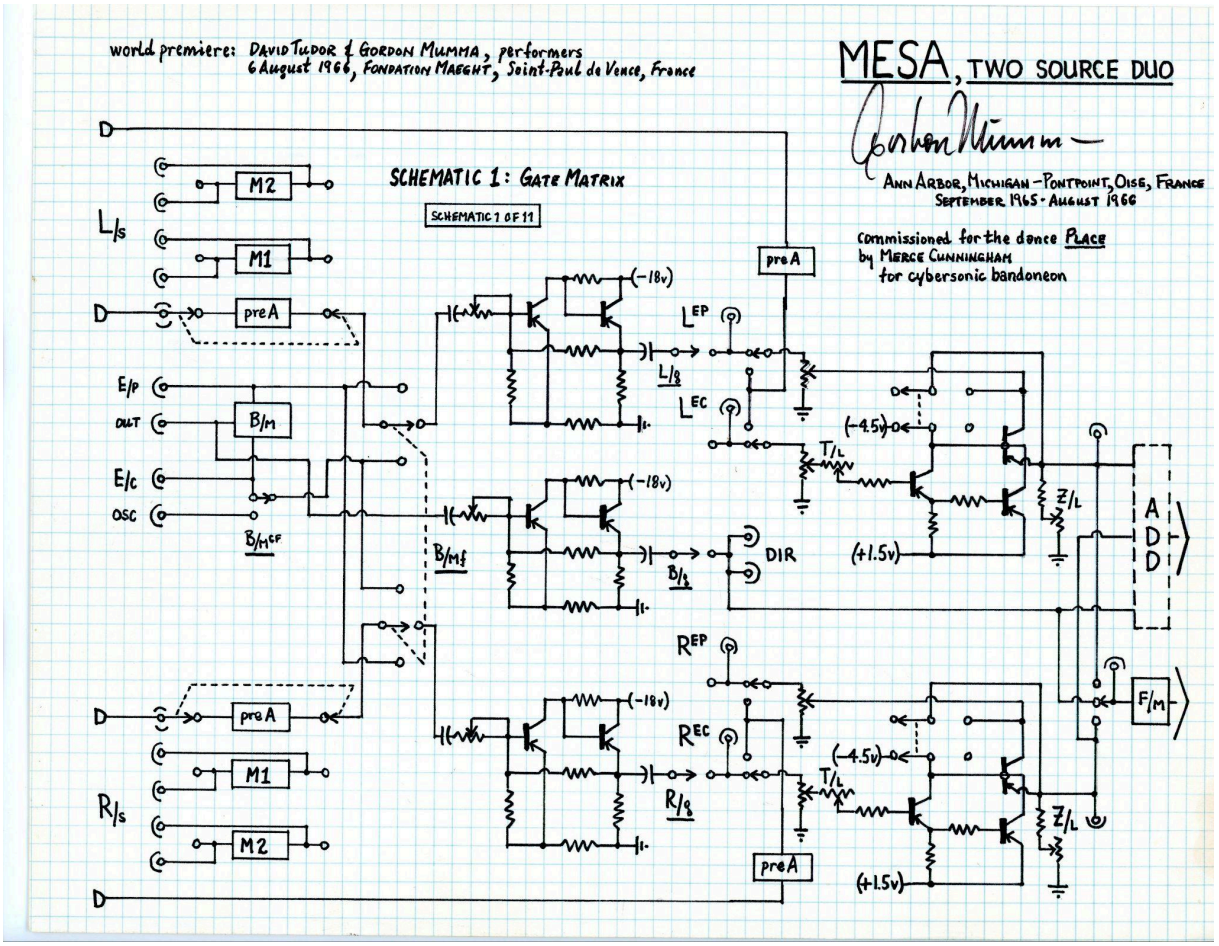


Figure 1: the original, drawn on graph paper, for the partial score of *Mesa* sent to John Cage for inclusion in the *Notations* collection. Note the absence of component values, and the title of the fragment, "Schematic 1: Gate Matrix" followed by the remark "schematic 1 of 11". From the Northwestern University Archives, John Cage *Notations* project collection, Gordon Mumma manuscripts folder. Used with permission of the John Cage Trust.

In June 1966, John Cage invited Mumma to join the MCDC for their summer European tour, and a week after, Cage extended Mumma's duties to the provision of a piece which would be premiered in August of that same summer (Mumma 2015, 109). According to the opening remarks of a 1968 broadcast of *Place* performed at the State College at Buffalo, *Place* was at least in part funded by a National Endowment for the Arts grant (Englander 1968). To meet the deadline, Mumma decided to combine Tudor's and Cunningham-via-Cage's commissions, a decision likely made easy by Tudor's established presence within the MCDC touring roster, and their shared preparation time in Stony Point, N.Y. in the summer of 1966 (Mumma 2015, 110, 153).

These two early schematics featuring tape inputs from the Tudor Papers at the Getty are enough to build something which might have been these setups, but not doing so with certainty. The under-determination of *Mesa* by any of its canonical document sources *requires* the reverse engineer to show creativity in going from these archival sketches to a performable system. This is not surprising,

much of the same can be said and has been said of various swaths of CIE-style *live electronic music* and diy electronic music (Teboul 2015, 2020).

In his essay on *Mesa*, Jonathan Goldman writes that *Mesa* "exhausts itself in its own apparatus" and that the work is "ontologically-unstable and seemingly inscrutable" (2020, 735). Although the majority of the essay uses documentation for *Mesa* derived from conversations with Mumma, and Mumma's canonical essay on the work (1967, republished 2015—discussed below), we can already see how the fragmented, combinatory nature of *Mesa* early development shaped the *co-constructive*[3] development of such an apparatus in these unstable and inscrutable directions.

Box 37 folder 6 of the Tudor Papers include 6 pages of undated instructions for the installation, testing, and troubleshooting processes related to an intermediate version of *Mesa*. These are on MCDC letterhead, and, presumably, are written by Mumma around the time of the premiere or shortly after. Once again, these instructions are not sufficient to assemble the corresponding apparatus without some creative authorship from the side of the technician, but the margin of error is much smaller than in the above diagrams. This is for two reasons: the instructions point to a much smaller array of devices (two "Sound Units" and a power supply, in addition to Tudor's bandoneon), and because these "Sound Units" survive within the Wesleyan University World Instrument Collection. From these instructions, we can draw a possible block diagram of this third version of *Mesa* (figure 1). These high-level technical descriptions of *Mesa* are not functionally very effective for a reimplementation of the underlying circuitry in hardware or software because they do not include a clear description of what the Sound Units contain. It is unclear when any of these 3 versions of *Mesa* / *Place* were performed, if they were performed at all.

[3] That is, constituting of both the people and the systems at hand, where the genesis of the technical objects mirrors the genesis of their makers as artists and circuit designers / users. See Simondon 2017 (1958), 40, and Pinch and Oudshoorn 2007, 3.

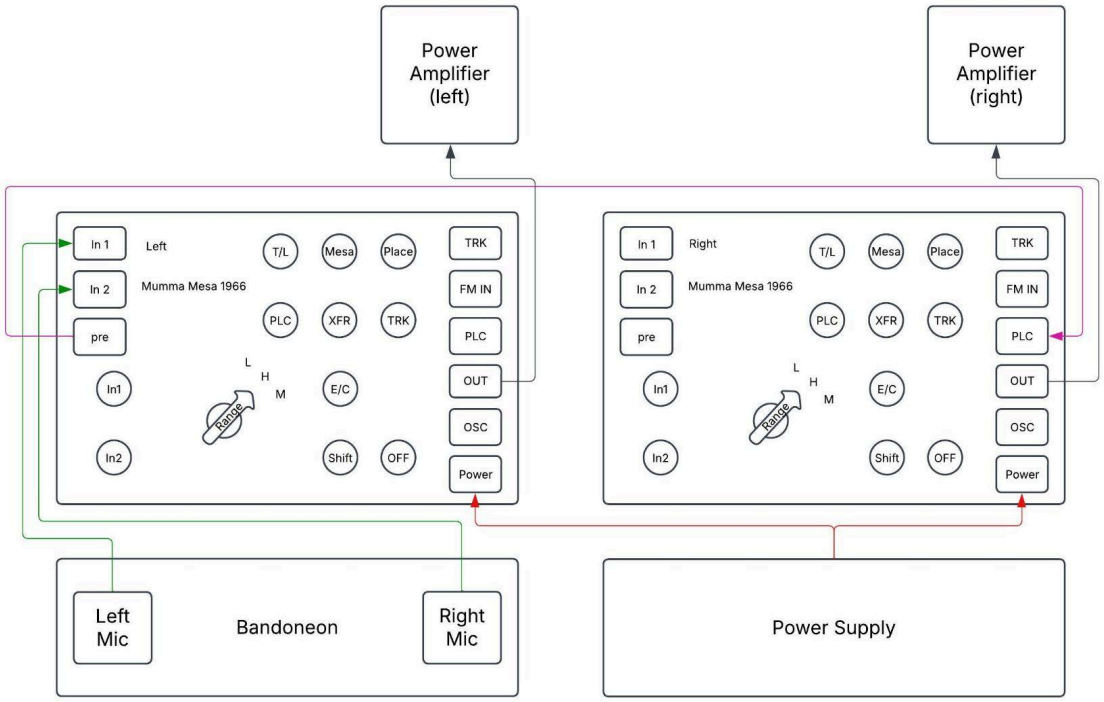


Figure 2: a block diagram of a possible interpretation of the MCDC letterhead instructions, from box 37 folder 6 of the Tudor Papers (Getty Research Institute), informed by the devices found in the Tudor instruments of the Wesleyan World Instruments collection. All diagrams are by the author unless noted.

Mumma and Tudor completed the piece in time for it scheduled premiere at the Fondation Maeght (St. Paul de Vence, France). Travelling from Spain by train the previous day, Mumma recounts the high-stress situation resulting from a customs office closed for a holiday, only getting a portion of the equipment in time after chartering a private plane (Mumma 2015, 181, see also Brown 2007, 472-476). At the premiere, like at most other important stages of *Mesa*, surprises and improvised, inconsistent setups solidified as a trend rather than exceptions. Carolyn Brown, one of the MCDC dancer, would call *Mesa* "menacing." On the premiere for *Place* / *Mesa*, she wrote: "all thoughts of fun and games were erased from our minds as we were propelled into an intense drama—anxiety-ridden and darkly tragic—which we didn't begin to comprehend but viscerally and instantly absorbed." (Brown 2007, 476) At a later performance in London, she assessed that "not unexpectedly, the sound for *Place* (...) was reviled." (483) In November 1966, a performance in Paris, where *Place* acquired a stage set (475) was recorded. The recording was donated to the NYPL by the Cunningham Trust later (NYPL, n.d.) became the basis for the New World Music's inclusion of *Mesa* in the 2010 *Music for Merce* 10 CD set (NWM, n.d.).[4]

[4] November 9th is the information printed in the liner notes from New World Records, which list the source of the recordings as the New York Public Library Performing Arts branch and Mumma as the restoring engineer (NWM, 2, 53). The NYPL's catalog does list a *Mesa* recording, for which the metadata reads "Recorded in performance at the Theatre de Champs Elysees in, Paris, France, 1966." (Rodgers and Hammerstein Archives of Recorded Sound, The New York Public Library, n.d.). However, that NYPL metadata also reads two dates: 11/9 and 11/11. I have emailed the Rodgers and Hammerstein archivists for clarification (Feb. 6th 2025), without response.

In December 1966, Mumma moved to New York City permanently (Fillion in Mumma 2015, xxxi). By the following year, Tudor and Mumma had secured a CBS/Odyssey release for *Mesa* and recording time in July 1967 at CBS Studios on 30th Street in Manhattan with Edward T. "Bud" Graham. These sessions served as the basis for three separate releases (Mumma 2015, 286). Spectrographic analysis points to slight edits and mastering variations:

CBS Odyssey 3216 0157-8 (1967)
co-issued on CBS France S-346 1065 (no year listed)
re-issued on Lovely VR-1093 (1986)
re-issued on Tzadik TZ 7074 (2002)

The Cunningham Trust's notes for *Place* tell potential producers of this piece to use the Tzadik recording as accompaniment, further noting that Mumma was consulted in this matter.[5] With Mumma also likely involved in each re-release process (Lovely Music and Tzadik Records are both operated by people close to Mumma's New York / East Coast social circles. It appears two people took pictures of the sessions at the session: Frederik Plaut, and Barbara Lloyd Dilley. The formers pictures are part of the Frederik and Rose Plaut Papers at Yale University Archives (Box 18, folder 602, negatives R3, R5-6, and S1) and one of Dilley's pictures was used in Mumma's collected essays book, *Cybersonic Arts: Adventures in American New Music* (2015, 118). Although these are not detailed enough to identify exactly how each device is connected to the others, we are nevertheless able to draw a rough sketch of this fourth version of *Mesa* (diagrammed in figure 2). It used:

- two "Sound Units" discussed in the previously mentioned *Mesa* instructions
- two unnamed units
- 302 Transfer, Rogalsky number 0450 in the World Instruments collection
- the "Dual Mesa Gate"
- a Fisher K-10 SpaceXpander vacuum-tube based reverberation unit (not pictured in figure 2)[6]

Remarkably, all of these save for the SpaceXpander reverberation are still held with the Tudor instrument collection at Wesleyan University. Michael Johnsen is developing a case-study of these circuits which includes extensive archival and oral history research—not unlike his prior highly insightful studies of the Mumma-Tudor ring modulator (Nakai and Johnsen 2020) or the cybersonic console (Johnsen 2024).

[5] Personal communication with the author, email dated March 21st 2025.
[6] Thank you to Sean Williams and Nic Collins for their help identifying this unit.

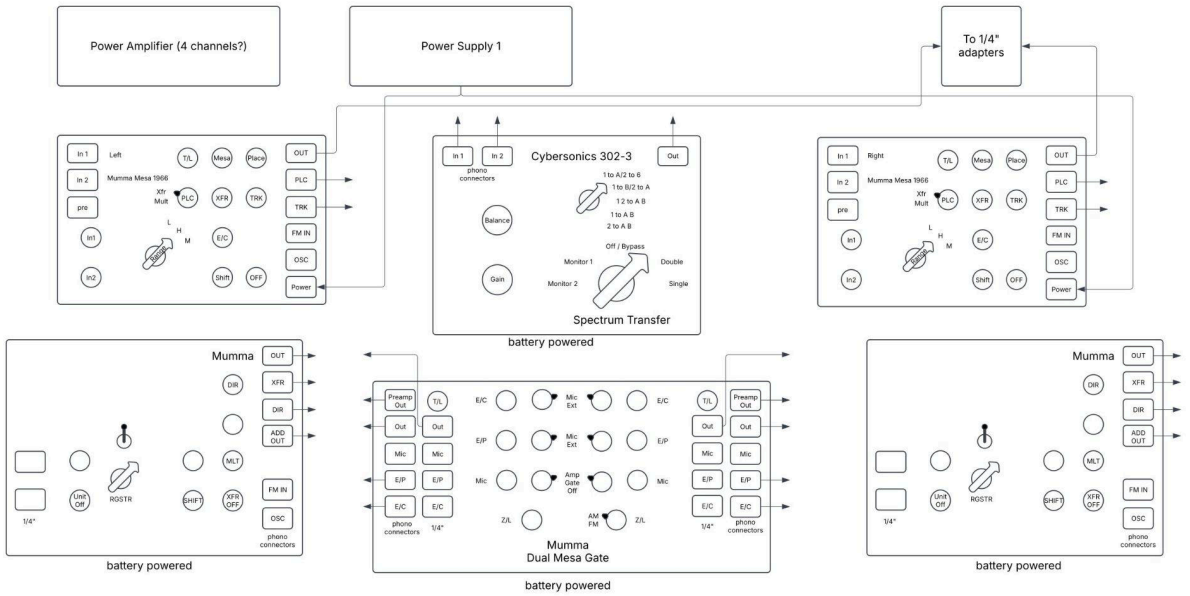


Figure 2: a partial diagram for version 4 of *Mesa*, as recorded and photographed at the CBS Studios in summer 1967. Arrows show where cable end but not their paths.

By October 1967, Mumma would go on to present at the yearly Audio Engineering Society conference. His paper was titled "Creative Aspects of Live-Performance Electronic Music Technology," it remains the most detailed discussion of *Mesa* by its author to date. Surprisingly, the essay is not of central use in Goldman et al.'s 2015-2016 project, with Goldman highlighting how his emails with Mumma were the most helpful resource (2020, 744-745). Like many of the technical descriptions included in his 2015 collection, Mumma's 1967 article is remarkable for simultaneously being deeply evocative and not exactly allowing others to rebuild his systems without significant guessing. For example, two diagrams at the end of the essay, nominally for *Mesa*, are supposed to display high and low-level mechanisms in the *Mesa* system. However, their unclear relationships, and the lack of details pertaining to the functioning of specific subsystems (e.g. frequency modulation, voltage-controlled amplification, or frequency shifting) leaves much to the reader. It is unclear the extent to which the essay was descriptive, or aspirational. What is clear, however, is that the technical setup discussed in these sections of Mumma's 1967 presentation—whatever they are—are not like any of the previous versions discussed in this section. The AES essay represents a fourth, perhaps idealized, version. This further renders *Mesa* "ontologically unstable" and "inscrutable," in Goldman's words (2020, 735). This is compounded by the edits to the essay for its republication in the 2015 collection: although most of the modifications are stylistic, some cuts further complicate the exact relationships between the circuits making the piece possible. Most notably this paragraph is entirely removed in the 2015 edit:

> The logic modules have two basic functions. The FM logic controls the operation of the Spectrum Transfers, determining the amount of program-signal frequency shift by control signals derived from the outrigger VCAs. The Route-Gate Logic modules determine aspects of the sound modification and, in conjunction with the actions of the Bandoneon player, establish the musical continuity. (1967, 7)

That is unfortunate, as it was as close as Mumma ever got to sharing details about this iteration of the *Mesa* logic circuits. These are significant, as control signals within the system are effectively what makes the piece *cybersonic* (Fillion in Mumma 2015, xxi). Mesa remains unstable.

A recording of a performance of *Place* was produced in 1968 by Roger Englander for WNED at the occasion of a performance at the State College at Buffalo, N.Y. (Goldman 2020, 744). According to the Cunningham Trust, it is the only video recording of *Place* from that period.[7] Although the audio was disavowed by Mumma,[8] we see just enough of Tudor and Mumma's setup to unmistakably identify yet another *Mesa* setup, this time with four devices. *Mesa* is seemingly inscrutable once more.

By 1969, the schematic for *Mesa*'s "Gate Matrix" (figure 1) was included by John Cage in *Notations*, a collection edited for Dick Higgins' Somewhere Else press. It notes that this is one of 11 circuit schematics for *Mesa*'s apparatus. The extent to which the schematic reflects the contents of the *Dual Mesa Gate* instrument from the 1967 CBS studio recording setup of figure 2 will have to be determined after Johnsen publishes his study of the corresponding device at Wesleyan. Because Mumma used the same abbreviations as within the instructions from the Sound Units, we can translate some of the abbreviations in figure 1:

- M1, 2: Microphones. The Dual Mesa Gate only has 1 "Mic" connector per side, but with both ¼" and phono connectors.
- PreA: preamplifier
- Out: output
- OSC: oscillator
- DIR: Direct out
- F/M: Frequency Modulation[9]
- T/L: Temperature compensation adjustment
- E/c: Gating Control
- E/p: not translated in available documents, but present in both the schematic and as an output on the Dual Mesa Gate

Commenting on the schematic, Jonathan Goldman adds that "Mumma's principal electronic process in *Mesa* was to have sound from one side of the bandoneon serve as carrier frequency for the ring modulation applied to the sound of the other side" (Goldman 2012, 49). Ring modulation is a process adapted from radio technology into electronic music which multiplies two voltages (Davies 1976, Cowan 1934, Keith 1929). It produces voltages which contain the sum and differences of every frequency present in those two voltages, resulting in the very rich timbral material discussed by Mumma (1967). The Gate Matrix as schematized could enable this, as the F/m selector at the end of the circuit can arbitrarily route the outputs from either side (Left, L/s or Right, R/s) to the frequency modulation stage (F/m) after being processed by the Gate.

[7] personal communication with the Cunningham Trust, March 24th 2025.
[8] personal communication between Mumma and Goldman, 2016, see also Goldman 2020, 744
[9] This particular abbreviation was clarified by Mumma in an email to the author, November 10 2019.

Goldman also writes that transistor-based ring modulation is the basis for *Mesa* (2020, 741). However, he is careful not to locate the ring modulation exactly in this schematic. Indeed, the Gate Matrix does not appear to include any four-quadrant multipliers or other circuits which could replace the traditional transformer-coupled, diode-based modulator—of which Tudor and Mumma built numerous instances (see Johnsen and Nakai in Collins 2020, ch.25). Transistor based multiplication was rudimentary in the mid 1960's, with Gilbert's four quadrant circuit being published only by February 1968. Earlier logarithmic converter or transconductance multiplication (Kester 2008, 2-3), although possibly eventually part of the Cybersonics, Inc. circuits, is not visible in this schematic either. The Cage *Notations* collection at Northwestern University archives include a second, unpublished, partial schematic. As it appears this schematic has not been included in scholarship before, it is included below (figure 3).

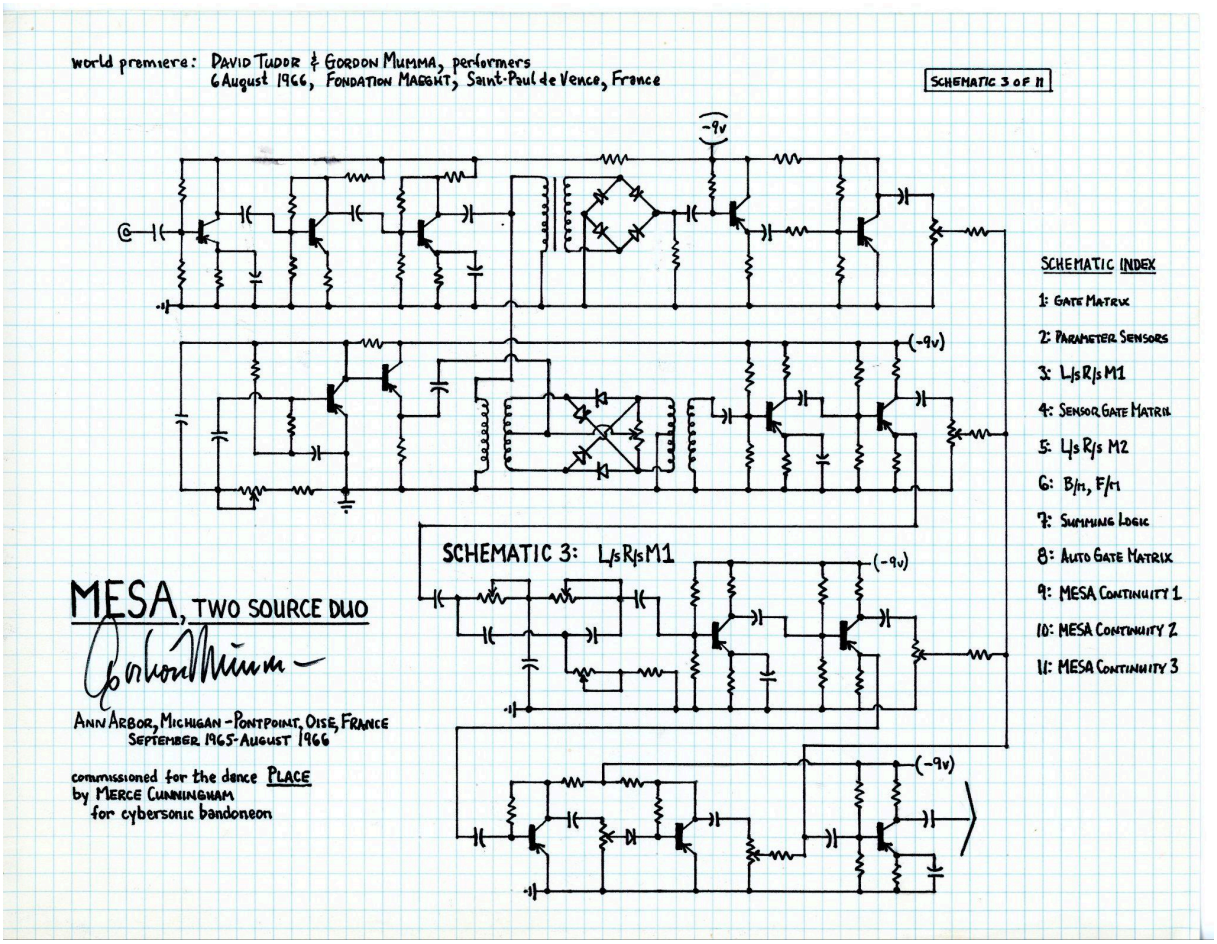


Figure 3: "Schematic 3 of 11" for *Mesa*, an unpublished schematic on graph paper by Gordon Mumma, sent to Cage for consideration for the *Notations* collection but not included in the printed book. It shows two passive ring modular circuits with a common input, followed by some discrete transistor stages. Notice the absence of component values or names, with only symbols for an input (top left) and an output (arrow, bottom right). From the Northwestern University Archives, John Cage *Notations* project collection, Gordon Mumma manuscripts folder. Used with permission of the John Cage Trust.

Although this is clearly not a complete schematic of the *Mesa* system, it does detail more precisely how Mumma was thinking of the design of this particular aspect of the circuitry for the work. Indeed, this schematic shows how one of two ring modulator devices were constructed, and, as one can see, these are the more traditional, passive diode bridge designs. Transistors were certainly essential to *Mesa*, but evidence seems to point to the core circuit of the system—these ring modulator—being the passive diode-based circuit found in other devices by Mumma, as analyzed by Johnsen and Nakai (2020).

This is where comparison of the *Mesa* recordings with ring modulated accordion / bandoneon samples is instructive: using a simple Pure Data patch containing both instrumental and test signal sources (sine, sawtooth, square) a ring modulator, and a reverberation step to replicate the Fisher SpaceXpander unit visible in the Plaut pictures and clearly audible in the published recordings of *Mesa* (listed below), I hear a much stronger resemblance between the sine, square and sawtooth modulators than with the self-modulated variation. Although the bandoneon can produce almost-pure tones, especially if amplified and filtered for that effect, and it can play two separate sounds on either side, I do not believe Mumma's iterations of *Mesa* used both sides of the bandoneon as the two inputs for a ring modulator. Rather, I believe that the side of the bandoneon fed different sides of *Mesa* circuitry, each with separate ring modulating circuits. Control signals from one affected musical parameters in the other, rather than being mixed by a ring modulator.

Place was not performed very long by the MCDC, with roughly 30 performances by 1971 (Mumma 2015, 119). According to Mumma, "for the dancers *Place* was exceedingly strenuous, literally a bone-bruise." (ibid) Michelle Fillion notes that Kagel replaced Mumma on two Sweden dates in 1969. *Mesa* would nevertheless have a life of its own, with Tudor and the Sonic Arts Group, for an unspecified period (305). According to John Driscoll, *Mesa* was not performed by Tudor's *Composers Inside Electronics* ensemble with which Mumma was associated after its founding in 1973.[10] It is possible the reduced frequency of *Mesa* inclusion on programs was due to some of Mumma's devices being stolen over the years (Mumma in Ashley 2000, 108; Mumma 2015, 301 fn.6-1), in addition to *Place*'s toll on dancers.

b) Post-1971 developments

Disparate writing (e.g. Mumma 1997, 2015, Brown 2007), the aforementioned releases and reeditions of *Mesa* on various compilations, and John Driscoll's nods to Mumma in two titles for his own pieces (*Second Mesa*, 1983, and *Cybermesa*, 1993) seem to shift *Mesa* to the historical record after 1971. Only Mumma and Jonathan Goldman's meeting in 2007 as University of Victoria music faculty colleagues puts a reperformance of the work back in the realm of the possible (Goldman 2020, 743). By 2016, Goldman, having moved to the Université de Montréal, sees the project through with two students there: Francis Lecavalier and Ofer Pelz, resulting in a performance with Mumma's approval in 2016. Their writeups (Goldman 2020 and Goldman et al. 2020) are some of the most compact starting points for anyone interested in *Mesa*, extensively shaping the present project. Notably, Goldman obtained a *Mesa* time-map from Mumma, providing interesting insights on how he saw his own work at the time (2020, 745). More importantly, these essays include clear descriptions of

[10] Personal communication with the author, email dated March 28th 2025.

the technical systems used by Goldman, Pelz and Lecavalier. All the signal processing elements at hand are described in common terms, rather than Mumma's poetic yet cryptic cybersonic vocabulary. A diagram drawn by Lecavalier (Goldman et al. 2020) is complete and reproducible (figure 4).

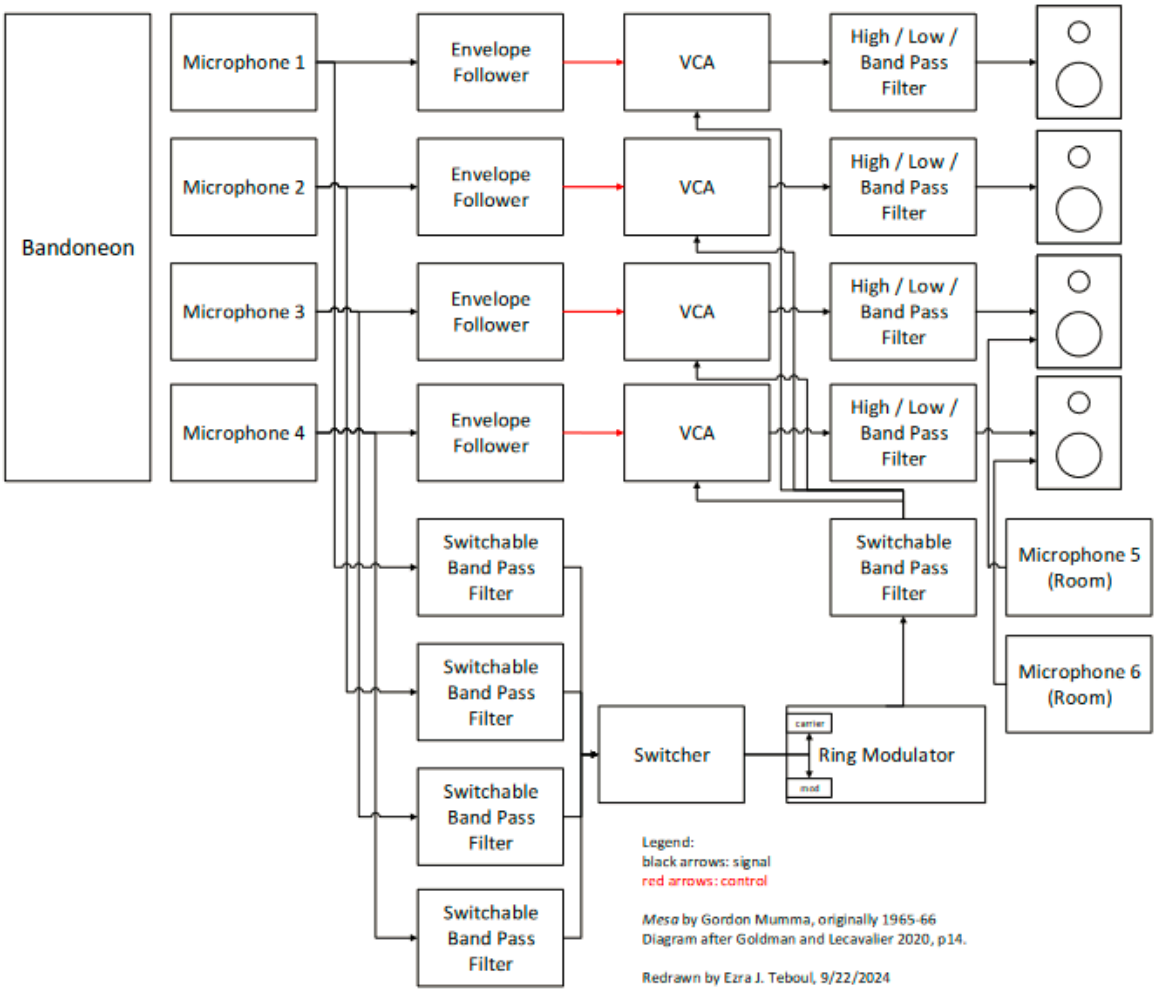


Figure 4: author's redrawing of the diagram by Lecavalier in Goldman et al 2020, 14.

Finally, the entire software emulation is open source and still available on Lecavalier's website (Lecavalier 2018). Although the text does point to modifications between this design version and the performance version, some are included in the discussion. Further communication with Lecavalier identified a few additional modifications not discussed in their 2020 article (Oct 9. 2024). These are summarized in figure 5. Parallels between Mumma's versions of *Mesa* and this one situate Lecavalier's digital system as inspired primarily by the information published on *Mesa*: the 1969 schematic, the vinyl / CD releases, the AES articles, and subsequent private discussions thereof as discussed by Goldman and cited above. This is visible in Lecavalier's setup: there is no recording playback, only one ring modulator, and only one external oscillator / noise source, but there are four outputs and gating / switching logic.

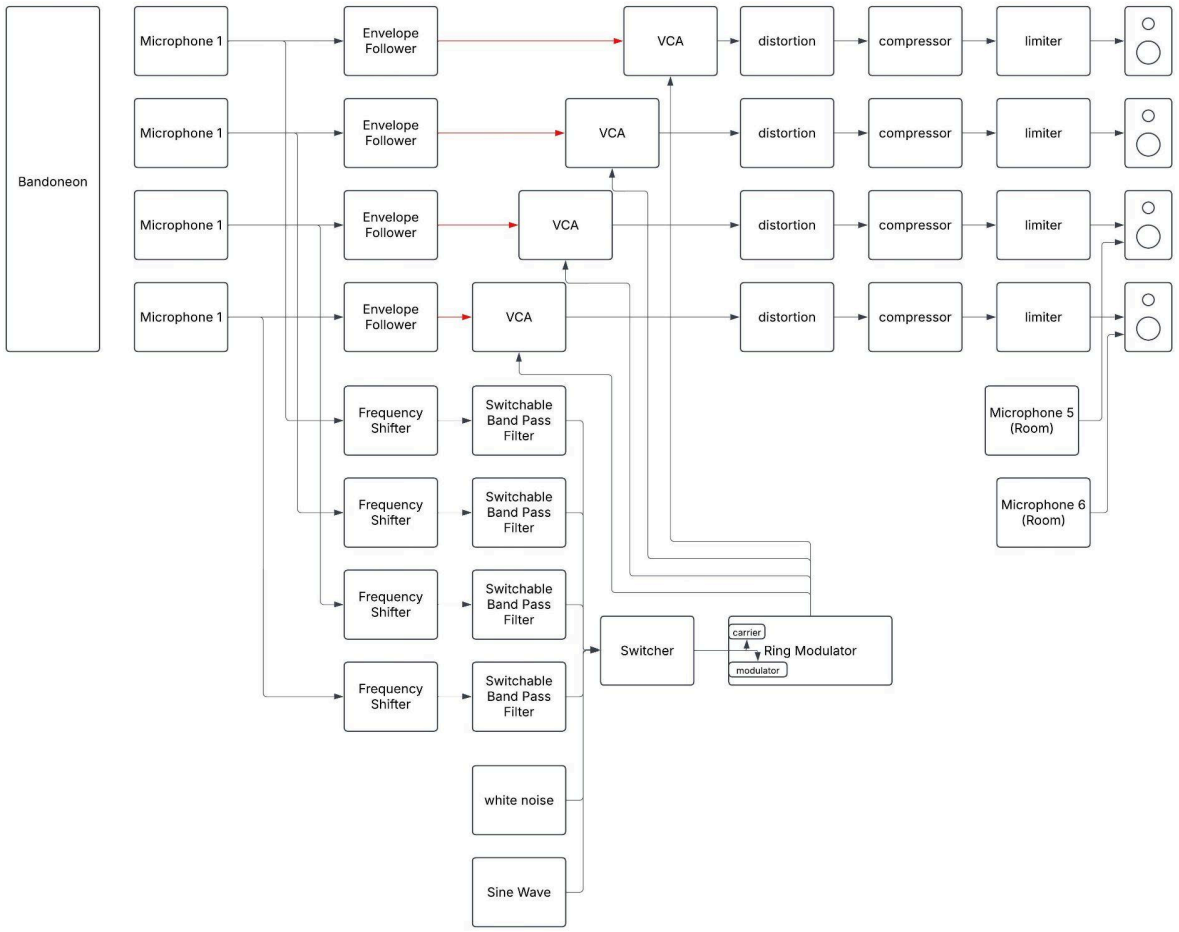
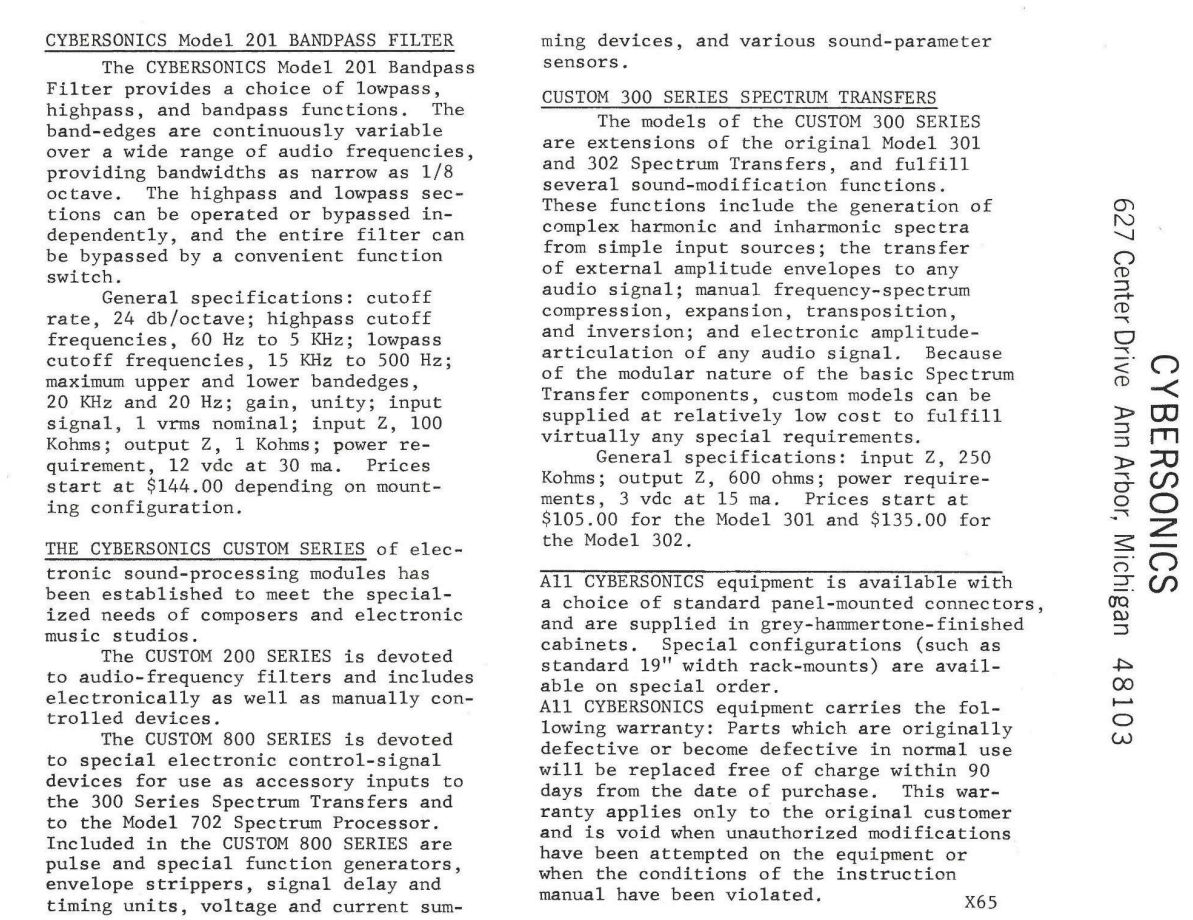


Figure 5: the diagram of the system used by Goldman et al. in 2017, including all performance-time modifications.

2) Cybersonics, Inc., William Ribbens, and the *Spectrum* family of circuits

Although much of the above discusses how *Mesa* exhausting itself in it own apparatus (to paraphrase Goldman) implies humans and shifting technologies as part of the apparatus, the reliance of different versions of *Mesa* on the technique and technology of ring modulation has also been put in clearer relief. Michelle Fillion, in the introduction to Mumma's essay collection (2015), writes that "In 1960 Mumma and electronic engineer William Ribbens founded Cybersonics, a small electronic design company in Ann Arbor for the design and production of sound-editing and processing equipment for live-electronic music, film, and television." (xxx). By 1965, the business had been incorporated (297, fn.2), and Ribbens was participating in performances at the ONCE festival (Mumma 1967, James 1987, Miller 2003, Weingarten 2009), specifically for Mumma's *Horn* (Mumma 2015, 55). That same year, Ribbens finished a Ph.D. at the University of Michigan (Ribbens 1965), started teaching in his department, and remained there until his retirement in 1999 (U. of M. 2018).



CYBERSONICS Model 201 BANDPASS FILTER

The CYBERSONICS Model 201 Bandpass Filter provides a choice of lowpass, highpass, and bandpass functions. The band-edges are continuously variable over a wide range of audio frequencies, providing bandwidths as narrow as 1/8 octave. The highpass and lowpass sections can be operated or bypassed independently, and the entire filter can be bypassed by a convenient function switch.

General specifications: cutoff rate, 24 db/octave; highpass cutoff frequencies, 60 Hz to 5 KHz; lowpass cutoff frequencies, 15 KHz to 500 Hz; maximum upper and lower bandedges, 20 KHz and 20 Hz; gain, unity; input signal, 1 vrms nominal; input Z, 100 Kohms; output Z, 1 Kohms; power requirement, 12 vdc at 30 ma. Prices start at $144.00 depending on mounting configuration.

THE CYBERSONICS CUSTOM SERIES of electronic sound-processing modules has been established to meet the specialized needs of composers and electronic music studios.

The CUSTOM 200 SERIES is devoted to audio-frequency filters and includes electronically as well as manually controlled devices.

The CUSTOM 800 SERIES is devoted to special electronic control-signal devices for use as accessory inputs to the 300 Series Spectrum Transfers and to the Model 702 Spectrum Processor. Included in the CUSTOM 800 SERIES are pulse and special function generators, envelope strippers, signal delay and timing units, voltage and current summing devices, and various sound-parameter sensors.

CUSTOM 300 SERIES SPECTRUM TRANSFERS

The models of the CUSTOM 300 SERIES are extensions of the original Model 301 and 302 Spectrum Transfers, and fulfill several sound-modification functions. These functions include the generation of complex harmonic and inharmonic spectra from simple input sources; the transfer of external amplitude envelopes to any audio signal; manual frequency-spectrum compression, expansion, transposition, and inversion; and electronic amplitude-articulation of any audio signal. Because of the modular nature of the basic Spectrum Transfer components, custom models can be supplied at relatively low cost to fulfill virtually any special requirements.

General specifications: input Z, 250 Kohms; output Z, 600 ohms; power requirements, 3 vdc at 15 ma. Prices start at $105.00 for the Model 301 and $135.00 for the Model 302.

All CYBERSONICS equipment is available with a choice of standard panel-mounted connectors, and are supplied in grey-hammertone-finished cabinets. Special configurations (such as standard 19" width rack-mounts) are available on special order.

All CYBERSONICS equipment carries the following warranty: Parts which are originally defective or become defective in normal use will be replaced free of charge within 90 days from the date of purchase. This warranty applies only to the original customer and is void when unauthorized modifications have been attempted on the equipment or when the conditions of the instruction manual have been violated.

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627 Center Drive Ann Arbor, Michigan 48103

Figure 6: A partial, undated catalogue for Cybersonics, the small business co-operated by William Ribbens and Gordon Mumma. Provided by and used with permission from Gordon Mumma.

Figure 6 displays a single-page advertisement provided by Gordon Mumma.[11] This includes some interesting detail concerning the model 302 spectrum transfer, one instance of which is visible in the Plaut and Dilley photographs from the summer 1967 recording session and remains housed at Wesleyan with the Tudor instruments. According to the ad, its functions include: "the generation of complex harmonic and inharmonic spectra from simple input sources; the transfer of external amplitude envelopes to any audio signal; manual frequency-spectrum compression, expansion, transposition, and inversion; and electronic amplitude-articulation of any audio signal." Although the double ring modulator circuit of figure 3 could definitely have fulfilled some of these operations, others, like "amplitude-articulation" must wait for a complete circuit study to be addressed.

3) Pure Data implementation of a *Mesa*-inspired setup

Sections of this project were informed by the development of various Pure Data patches (digital signal processing routines with visual representations, e.g. figures 7 and 8) which emulate the sonic characteristics of *Mesa* audible in the two recordings discussed previously. Comparison seems to

[11] Email with the author dated December 26, 2016.

suggest that roughly 90% of the piece is built around the careful co-management of the bandoneon input and a ring modulator.

A long-standing actor in the history of electronic music (Bode & Moog 1972, Davies 1976, BBC 2012, and related to Baudry & Bonardi 2015), the ring modulator affords composers a fairly unique combination of signal processing behaviors. Most evident here is its capacity to blend musical material according to an inharmonic schema: where a mixer adds signals in the time domain, the ring modulator adds and substracts in the frequency domain. This points to the different signal processing needs of radio versus audio processing and the social mechanisms by which routines from the former are given musical meaning in the latter through the making of new musics.

Another important element of the ring modulator is its capacity to blend two envelopes together. As the envelope of the output is the product of the envelopes of the two inputs, it will only produce sound if both carrier and modulator are present. Although contemporary synthesis discourses would not identify ring modulation as a voltage-controlled process, in *Mesa* it undeniably provides gating / voltage-controlled attenuation in the most basic sense, where two voltages do control a third, audible, signal.

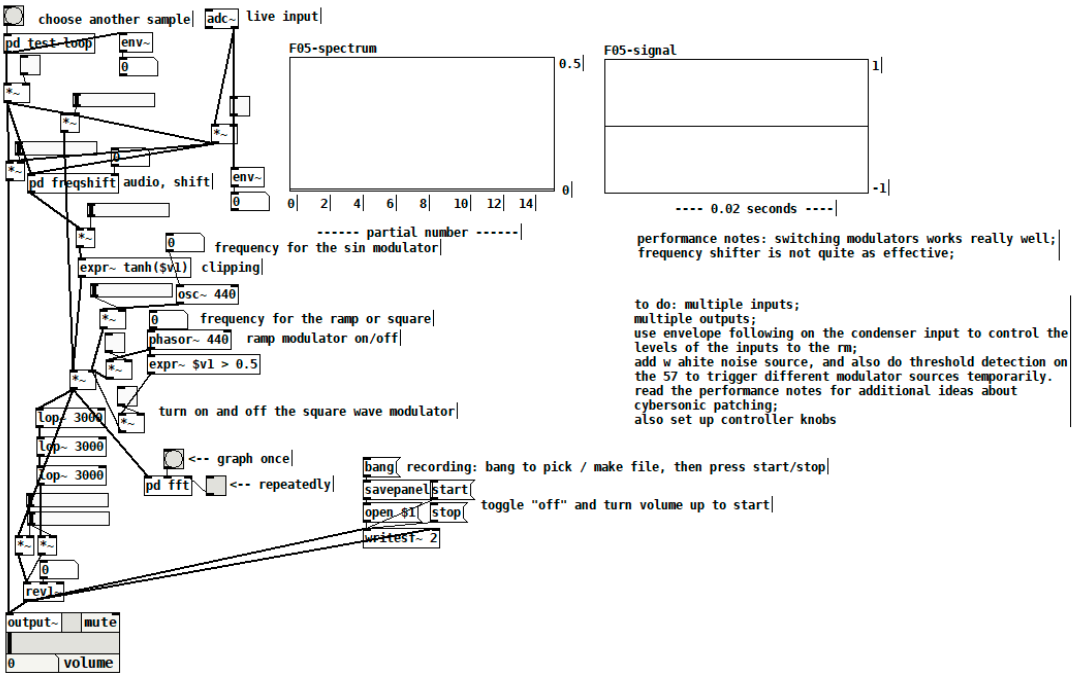

Figure 7: basicmesa8.pd, an experimental version of a digital Spectrum Transfer used to inform this study of the *Mesa* system by complementing archival material analysis with comparative listening. By the author.

Doubling up the ring modulating stage allows for varied control of musical parameters from one side of the instrument by the other and vice-versa. This setup was performed with Stuart Jackson on uilleann pipes instead of accordion on 6 January, 2026.

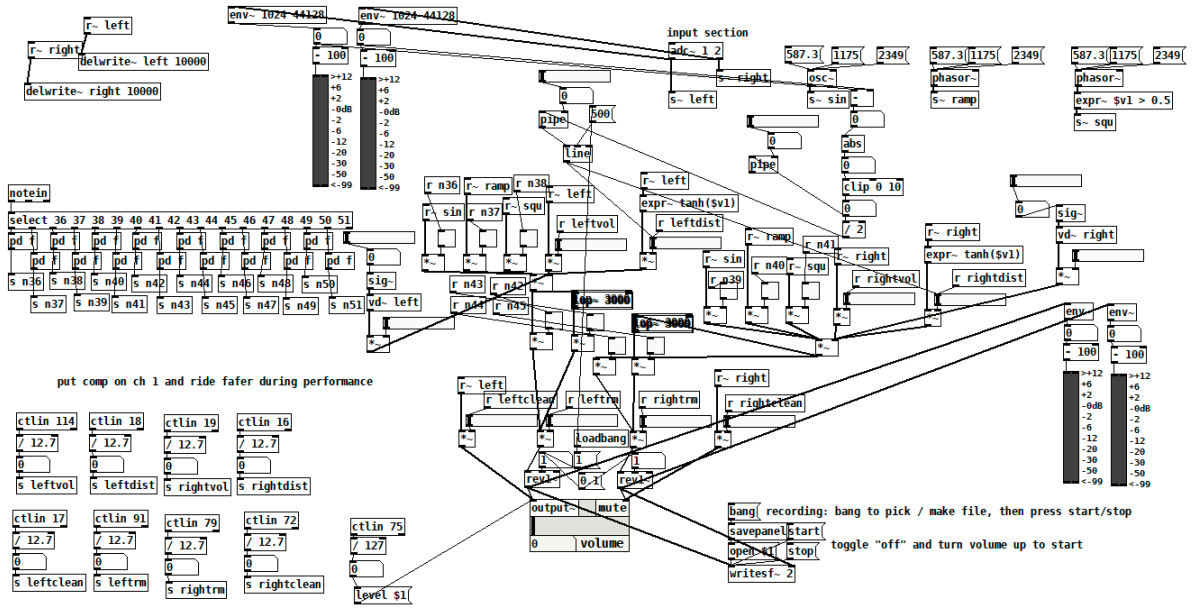

Figure 8: an experimental performance patch for *Mesa*, inspired by various aspects of the partial versions documentation collected in this project. A number of MIDI control inputs for knobs and switches (bottom and middle left) are patched for performance setups.

4) Anarchaeology as practice-based preservation

On 30 October 2019, I email Mumma asking if he would be willing to share the component values missing in figure 12. Mumma did not answer my question directly. Rather, on November 19th 2019, he wrote back that:

> In that particular diagram is somewhat like a recipe for a pizza, but without the minute details of the individual ingredients.[12] And those circuit ingredients were varied over time, according

[12] The extensively used connection between experimental music and cooking deserves its own article. For example, see Collins 2025, 38, or let me point to John Driscoll's unpublished 1985 essay *Electronics and Cooking*. Some selections: "If one knows electronics well there is a good chance they know cooking well." "A recipe is not how to make something, it is an idea of something. A schematic is not how to make something, it is an idea of something. Once you have mastered a dish there is the desire to change it." "One needs to stockpile electronic parts in order to be spontaneous. You always have more than you need for the job. Sometimes having certain parts in stock inspires new circuitry." "David Tudor once was using a particular circuit in performance and it failed, but ended up producing a unique sound in the process. Now he uses it without the power turned on in order to have it function properly." Mumma commented on Tudor's cooking in an email dated Oct. 25th 2019: "watching him in his kitchen preparing elaborate indian cuisine, was his show of careful finger and arm-virtuosity over a gas-burning stove. (He didn't like electric stove-tops because he couldn't se where the heat was.)" Tudor's spices are discussed in Goldman 2012, 57, fn21. Alexander Keefe's 2013 essay on Tudor's work with a Moog synthesizer in Ahmedabad, India, which opens with miscellaneous information about Tudor's cooking skills and includes a picture of one of Tudor's curry recipes with said spices. These culinary commentaries can be more than light-hearted—as Christian Wolff would mention during a 2017 event (for the AHRC-funded research project 'John Cage and the Concert for Piano and Orchestra') "music shouldn't be merely culinary- it shouldn't just taste good. It has to be in some way good for you as well". Tweeted by Ted Gordon on July 2nd 2017.

> to my continuing circuit-experiments. Because "transistor technology" was constantly evolving through the 1950s and 1960s, and some of those components were obtained from such as military surplus sources, it was unlikely any single unit of my designs would function in exactly the same way, or the acoustical results would be the same.[13]

Over the work's life, Mumma has repeatedly chosen not to divulge *Mesa*'s inner workings. Sixty years of people making, playing and thinking about *Mesa* points to the potential of maintaining communities of practice via "inscrutable" and "unstable" experimental artworks (Goldman 2020, 735). Live electronic music, seen through the lens of preservation, could be in part defined by its resistance to well-bounded understandings of artworks because the epistemological objects it produces almost seems to require reinvention and adaptation, rather than reading. In Mumma's words, what counts as a recipe? This line of questioning finds precedents in Siegfried Zielinski's anarchival and anarchaeological frameworks for media archaeology (2015). Zielinski defines these as such:

> anarchives are a complementary opposite and hence an effective alternative to archive. I consciously refer to them in the plural. Following a logic of plurality and wealth of variants, they are particularly suited to handle events and movements; that is, time-based sensations. Just as the anarcheological sees itself first and foremost as an activity, anarchives are principally in an active mode. They do not, however, lay claim to leadership. Nor do they claim to truthfully know where things come from and where they may be headed to. The origin is and remains a trap. Anarchives do not follow any external purpose; they indulge in waste and offer presents. Basically, they are indebted to a single economy, that of friendship. (121-122)

An anarchaeological approach to the maintenance of complex, relational human-technical media objects like *Mesa*—could acknowledge longstanding fringe practices of keeping your friends' work alive by showing, playing, and watching it in social contexts. The tacit knowledge of works like *Mesa* invites collaboration and communal (re)invention. Taken generously, this does not contradict musicologist and archival scholar Miriam Akkermann's assertion that "the main goal for archiving music compositions is usually to provide sufficient and substantial information based on which it is possible to develop a re-performance of the work" (2019, 4). Neither does it invalidate the extent to which Goldman, Pelz and Lecavalier achieved exactly that—which Mumma's blessing! no less—with their own 2017 performance. Rather, it expands both what, paraphrasing Mumma's metaphor, cooking can be, and what a recipe might look like.

Mesa exhausts itself in an apparatus that, for its richness of humans, machines, cryptic statements, and underdetermined signal processing routines, has yet to itself be exhausted in documentation—much of which may never emerge. Because so much of the above work is communal and reiterative (repeating, occasionally with minor variation, the word of the preceding scrutinizer) it invites interpretative and associative thinking. This mirrors the erratic, pragmatic, and subjective process of the artists being discussed. Working on unbounded objects which require variants, plurality and creative filling-of the-gaps encourages us to ask questions of how to preserve interpretative labor, in addition to how to evaluate good documentation. History of technology has repeatedly encouraged

[13] Throughout this essay, materials from Mumma are quoted with permission.

scholars to consider why technologies become obscured as much as why they become ubiquitous (Gooday 1998). If multimedia archives like the one leveraged in the above micro-level case study are a combination of unclearly valuable facts and interpretations with distinctions not necessarily clear to peer reviewers, archival acquisition staff, or their network of experts, then to what extent should the messy process of evaluation become part of the record itself? Is there an archival or museal architecture that encodes levels of interpretation and reimplementations? Anarchives, as a form of practice-based preservation, challenge boundaries between artist and documentarian because some artifacts are unknown or no-longer-known. Research can, in some cases, partially fill gaps, but when does this go against the spirit of an artwork?

5) Closing remarks

Building on Goldman's contextualization of *Mesa* (2020) I want to emphasize two final aspects of *Mesa*'s significance for contemporary scholarship beyond preservation. The first is *Mesa*'s role within the wider milieu of the Merce Cunningham Dance Company (MCDC) and David Tudor's practice. Founded 1953, the MCDC had only begun touring internationally in 1964. The MCDC had hired Mumma in August 1966 as a musician, sound engineer, and technical assistant with Cage and Tudor, prompting his move to New York (where the MCDC was based) in December of that year (Mumma 2015, 39). *Place*, the dance for which Mumma composed *Mesa* and which he played live with Tudor for all 30 or so performances after a 1966 premiere, is highly regarded within the MCDC cannon. It is described as one of Cunningham's most dramatic, violent, and successful pieces. According to Mumma, "for the dancers *Place* was exceedingly strenuous, literally a bone-bruise." (119) Dancer and choreographer Carolyn Brown would write in her 2007 book that "*Place* is a masterwork, and Merce is the master of it" (476). *Place*'s recurrence on their early world tours contributed to bringing the company an international notoriety. This notoriety, in turn, contributed to the MCDC's capacity to continue acting as a long-term supporter of live electronic and experimental musics through Tudor, Cage, and associated composers / performers. *Mesa* played a part in that. For Tudor in particular, *Mesa* represents one of the steps between the piano of his early career as a performer and the electronics of his life as a composer; the "fourth entry in Tudor's growing repertoire" in this shift according to You Nakai (2020, 231), one which helped Tudor conceptualize and build another important piece of his early repertoire (*Bandoneon!*, see Goldman 2012) and develop Tudor's relationship to Mumma.

Second, I want to elaborate on Goldman's summary of the relationships between transistorized electronics as a creative medium, Mumma, and *Mesa*. Mumma's liner notes for the 2002 Tzadik records re-release of *Mesa* read in part that "aspects of its binary musical architecture, the structural geometry of monolithic semiconductors used in its electronic circuits, the contours of its cybersonic

thresholds, and the expansive, eroded, mesa landscapes of the south-western United States."[14] *Mesa*'s transistorized circuits and the aestheticization of its technical means of musical production via the inclusion of one of its (supposedly) eleven circuit schematics as a score in Cage's collection of graphic scores *Notations* (1969, 199). The absence of component values in that schematic works to value technological interconnectedness for its aesthetic symbology rather than capacity for knowledge transmission. The latter (which is usually the point of the circuit diagram) can only be teased out with a fair amount of time and significant contextual knowledge. Ulla Wiggen's 1965 painting *Simultantolkning* and *Mesa* are doing similar things in mid-century culture: they are responding, visually and sonically, to the social object of electronics. To most people even today, these electronics remain as unstable and inscrutable as *Mesa* (Goldman 2020, 735). In Ina Blom's words on Wiggen, it is "as if the concrete act of handling electronic technologies in and through paint made them even less, not more, familiar." (2019)

In a later essay, Mumma would point to electronics as his medium of choice because they were, in a sense, the surplus materials to which he had access through his everyday within a communications-intensive society (1974). Paraphrasing Mumma, just as some turned abundant wood into guitars or developed singing techniques to imitate the running water which defined their everyday soundscapes, live electronic music is contributing to the folklore of such a communicating society (see also discussion in Teboul 2022). In other words, *Mesa* is not just important because it introduced Tudor to low-voltage circuitry, or because it helped the MCDC accumulate cultural capital, but also because it represents one of the first formal forays of circuitry into a nascent but already well respected European/American avant-garde composition community. That community, in turn, fits within large social and cultural trends underlying the United States' 20th century technoscientific project (Turner 2006).

Echoing Wiggen, Mumma's cybersonic composition may not have made electronics more familiar to his audiences, rather, I believe *Mesa* is most productively thought of as highlighting, through music, how profoundly strange yet engaging the controlled electrical phenomena inside solid state electronics appeared. This is reflected in the equally confounding nature of *Mesa*'s documentation. By better understanding the knowledge production (or perhaps, knowledge evasion?) mechanism underlying *Mesa*, we contribute to a larger undertaking of critically documenting and contextualizing that wider technoscientific project via one of its many materializations. This is what good pizza recipes do too—especially when they don't have the ingredients listed.

[14] It is important to remark that mesa is also an early transistor manufacturing geometry (Hoerni 1960, Riordan 2007), which refers to the Southwestern landscape features as well. Ironically it is possible that the transistors used by Mumma for *Mesa*'s circuitry may be in part or fully planar, rather than mesa design transistors. Mumma has not responded to my email asking if he knew of this at the time of naming this work (sent July 23 2023). Mumma's early 1960's work was in part supported by a research contract at the University of Michigan, where he contributed to project Vela Uniform (Mumma 1963). This DoD/DARPA project used a network of geological/acoustic sensors to detect nuclear test explosions (Bates 1961, 1962). Mumma's geological research employment would influence *Mesa* and other earlier works, namely the *Very Small*, *Small*, *Medium* and *Large Size Mograph* pieces of 1961-63. A 1994 piece by John Driscoll, who worked close to Mumma in CIE, titled *Cybermesa*, has no explicit relation to Mumma's *Mesa* (email to the author, 11/5/2024). There is also another Driscoll piece called *Second Mesa* (1983).

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