More Fun For Organ Hobbyists

A NEW ELECTRONIC RECORD AND PLAYBACK CONCEPT

BY Herb Merritt, Bob Trousdale, and Ken Aultz

Many owners of two-manual theatre pipe organs are hobbyists who would like a playing device for their instrument.

Some contrive a roll player and connect it to the organ to play piano rolls. However, piano rolls rarely sound good on the organ and there are limitations: no stop changes, no expression, and no recording capability. Other hobbyists are lucky enough to acquire an organ roll player, such as the Moller Artiste, which can make stop and expression changes. But roll availability and condition are problems. Also, the music is dated as rolls have not been made since about 1930.

We wish to present a new electronic record and playback system, and describe the first two installations. This universal player records on magnetic tape all of the on-off electrical contact information (i.e. all keys, stops, shades, trems, etc.) made while an artist is performing and can play back this same information exactly. Copies of recordings can be made, over-dubbing is possible, and the system is relatively inexpensive. The universal player is intended for use with any two-manual theatre organ. It is applicable to any electro-pneumatic, direct electric, diode/transistor, or multiplexed switching system which uses a positive keying voltage and where a single switch contact is used for keys, stops, and controls. The universal player can handle a well-unified, two-manual theatre pipe organ with up to 11 ranks, 6 tuned percussions, 7 accompaniment traps, 5 pedal traps, 5 couplers, 5 trems, and 8 sound effects, all installed in two chambers. Other player systems exist, but are twice as costly or require that the organ switching system be changed to a multiplexed or computerized system, a considerable expense.

The universal player simply "adds on" to existing organ circuits. It consists of a card cage containing printed circuit boards which interface between the organ circuits and a standard stereo cassette tape recorder. To record information, a connection made to a given stop or key contact is monitored and the on-off electrical signal (voltage) caused by the organist's performance is picked up and recorded on magnetic tape by the player's RECORD sections. When the tape is played back, the PLAYBACK sections recreate these signals by switching organ rectifier voltage to duplicate the on-off voltage pattern over the same wire connection back to the given stop or key contact, thus causing the organ itself to be played. This means that during playback the information being read can be immediately recorded again (copied) onto a second tape deck. The universal player can be used for over-dubbing, in which, as an initial recording is played back into the organ, the organist can play along to add additional countermelody, accompaniment, flourishes, or whatever, and the net result may be re-recorded on the second tape deck. Over-dubbing is an "additive" process. However, with a simple modification to the player circuitry, it is also possible to erase (delete) channels previously recorded.

The universal player uses a standardized channel assignment for the keys, stops, and controls so that tapes made on one organ can be played back on another similar organ. However, not all channels are preassigned; 32 of the total of 320 channels can be assigned at the user's discretion. These optional channels can be used for second touches, special stops, or whatever. Because these 32 channels are not read on exchanged tapes, the player can be custom-tailored to each particular organ.

How It Works

The on-off electrical signals generated by key contacts, stops, etc., are encoded and recorded directly onto the two tracks of a standard audio cassette using a standard audio cassette deck. Each electrical signal is assigned and wired to a specific channel. The player consists of two completely independent sections which we can call L and R. Player L, recording on the left stereo track, has 128 channels with a scan rate of 42 scans per second and is used for the 122 manual keys. Player R, recording on the right stereo track, has 192 channels with a rate of 29 scans per second and is used for pedal keys, stops, shades, and trems. Two types of plug-in circuit boards are used: #1072 for tape I/O (input/output) and #1032 for each 32 channels of signal I/O. A total of two #1072 boards and ten #1032 boards, a card cage, a 5 VDC logic voltage supply, a simple control panel, and a standard stereo cassette deck or two complete the universal player system.

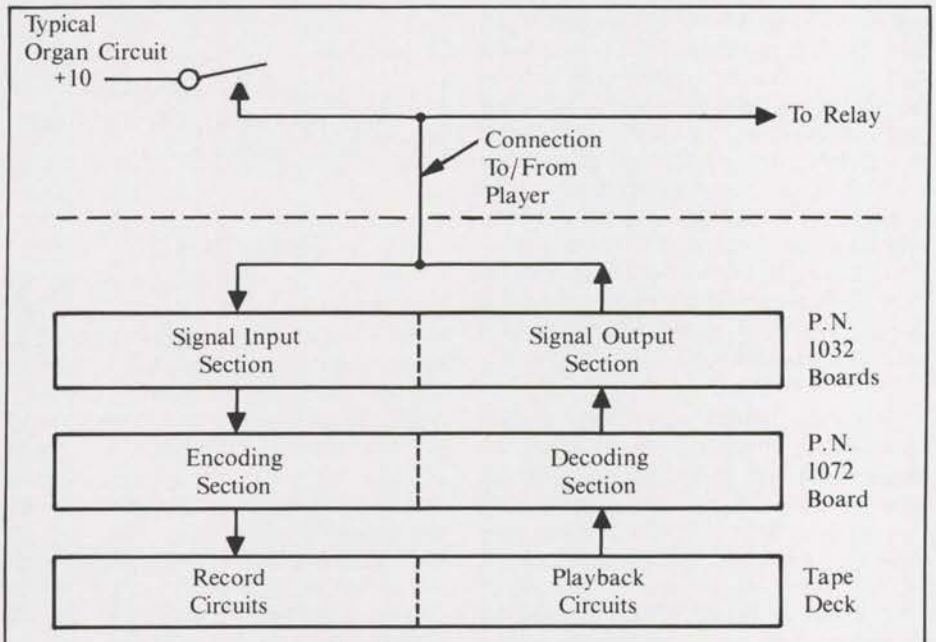


Fig. 1 Block Diagram of Universal Player

Figure 1 is a simplified block diagram of the system. A typical organ key, stop contact, swell contact, or button is connected to one of the interface pins of the player. Current flow on this wire is bi-directional; going into the signal input section of the player during record, and coming out of the signal output section during playback. During normal recording on a single tape deck, the deck will echo back the recorded signal. For this reason, the output section of the player is muted to prevent immediate re-recording of the signal, which would result in a rather undesirable "sostenuto." If two separate decks are used, however, the muting is turned off so that the playback from one deck will be passed through all of the player circuits and back to the record input of the other deck. Obviously, overdubbing can be done at this time if desired.

What distinguishes this player system is the method of encoding the organ information into a form recordable on a standard audio-quality cassette tape deck (The Trousdale Model 1053 and the new Peterson player both use this technology).

The player scanning system, mentioned previously, samples each organ circuit one-at a time at a high rate of speed. It then recycles back to the beginning and scans all the circuits again. Each individual scan is called a "frame", and consists of either 128 samples (for L) or 192 samples (for R). Upon playback of the frame, each tiny sample, or "data bit," is directed to an individual storage circuit which acts to "fill in the gap" from one frame to the next and thus reconstruct the original signal. The frames are repeated often enough so that the output signal can keep up with the fastest organ playing. At the beginning of each new frame, a series of special bits are recorded before the first data bit. These are "synchronization" bits and are needed to tell the playback circuits where the frame begins, and, therefore, which bit is which. It is evident that for a player system to be successful, it is imperative to keep careful track of each bit position in the frame so that a bit recorded for C doesn't play back as a C# because of a variation in tape speed, for example.

The high-density recording method used is one which has great tolerance for tape and tape deck vagaries. Although modern stereo decks are excellent for the reproduction of audio signals, they were not designed for handling digital signals particularly well. Tape signal "dropouts" or noise spikes, caused by imperfect tape, dirt, and the like, which are not obvious during audio reproduction can wreak havoc in a player system. Furthermore, the recording signal band width and phase shift characteristics must be carefully considered as they will limit both the maximum frame rate employed as well as the reliability of playback signal decoding and synchronization.

Those of us who are at all familiar with MIDI (Musical Instrument Digital Interface) or personal computer serial I/O will know that they utilize a serial form of data transmission consisting of individual code intervals of eight data bits plus a leading start bit and a concluding stop bit. **See Figure 2.** The eight data bits are either "high" or "low" depending on the information being transmitted, and hence there are cases when they may all be high or all be low. Thus the "start" and "stop" bits are needed in order to define when the code interval is occurring so that the receiving circuits may synchronize properly. A complete frame of information would consist of a number of these code intervals placed end-to end.

Unfortunately, this method of transmission is unsuited for direct recording of data on an audio tape deck. The wide variation of data-dependent waveshapes encountered is very difficult to accommodate, no provision exists for data error detection, and a tape drop-out or noise pulse would be devastating. Furthermore, tape wow and flutter would have to be very tightly controlled.

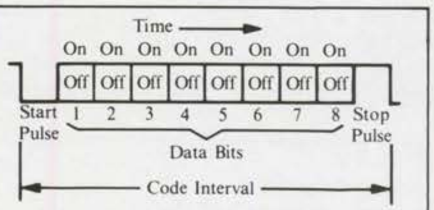


Fig. 2 Serial Data Transmission Method (As Employed by MIDI and Personal Computers)

Enter "GCR"

"Group Coded Recording" is the method utilized in the universal player. Here, instead of recording ten bits of signal for eight bits of data, five bits of signal are recorded for every four bits of data. There are no "start" and "stop" bits. Instead, synchronization is achieved directly from the data bits themselves. The bit patterns are so chosen that there will not be long strings of "on" or "off" bits. Tape dropouts or glitches are readily identified because of the inherent error detecting ability of the GCR method. In addition, the representation of "on" and "off" (ones and zeroes) is modified so that a "one" is recorded as a voltage change and a "zero" is recorded as no voltage change. This has the advantage that the playback signal is not level sensitive (inverting the signal will not change the information content).

The secret of success is to translate each group of four bits into a recordable group of five bits in such a way that no more than two "zeros" can occur in sequence (even if two codes are placed end-to-end). It turns out that there are seventeen such combinations out of a total of 32 possible five-bit codes. This is very fortuitous, since there are exactly sixteen possible combinations of the four input bits. The seventeenth GCR combination, therefore, makes an ideal code for use in frame synchronization. The remaining fifteen codes are therefore "illegal."

Table 1 lists the GCR conversion standard that was introduced over thirteen years ago and is used for high-density tape storage by the computer industry. The universal player uses this standard with the added 17th code. **Figure 3** shows the voltage waveform for a typical GCR sequence. The code interval shown represents the data sequence "0010."

The bit rate to the recorder is 7500 bits per second. This means that the recording tape voltage signal for the frame sync code, for example, is a 3750 cps square wave. The playback signal is not square, unfortunately, but has very rounded corners. This is caused by the effects of high frequency roll-off in the tape recorder, but special input circuits on the 1072 board act to reconstruct the original square shape.

Table 1.
Group Coded Recording Conversion Table

Data Value	Record Value
0000	11001
0001	11011
0010	10010
0011	10011
0100	11101
0101	10101
0110	10110
0111	10111
1000	11010
1001	01001
1010	01010
1011	01011
1100	11110
1101	01101
1110	01110
1111	01111
Sync	11111

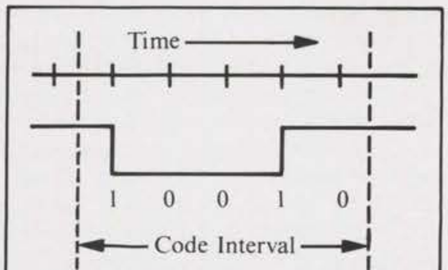


Fig. 3 Voltage Waveform for Typical GCR Code Sequence

The playback system checks the validity of the GCR codes. If an illegal code is detected or if 1's are too close together or too far apart, the unit goes into a "hold" state and maintains the last known legitimate value for the notes and/or stops until frame synchronization is re-established. In this way, the organ will continue to play uninterrupted through a tape glitch. It should be noted at this point, however, that no system like this is perfect and undetectable errors can slip through. For this reason, the use of good quality chromium dioxide recording tape (such as Maxell XLII) is recommended for use on cassette transports to minimize the error rate.

Hardware

The player circuits obviously have a great deal to do, and a number of specialized integrated circuits are employed to achieve good performance with a minimum of hardware.

For the most part, high-speed CMOS and LSTTL bipolar circuits are used, powered by a small 5-volt power supply. To reduce component count, field-programmable logic devices are utilized in several areas. To handle the intricate GCR conversion logic, for example, bipolar read-only memories (PROMS) and programmable array logic devices (PALS) have been used extensively. Although these devices are custom programmed, they can be readily duplicated if necessary. Many electronic component distributors have the equipment for this purpose, and the devices are not "copy protected."

The circuit used at the output of the player for switching organ voltage (nominally 10 to 12 volts) is one of a large family of power driver integrated circuits on the market. These IC's have greatly simplified the probelm of interfacing between low-level chips and the real outside world of lamps, magnets, solenoids, relays . . . all running at high voltage, high current, or both, and many creating inductive kicks that could fry the average IC. The particular chip used here is the Sprague UDN2981A, which contains eight separate driver circuits, each capable of driving a 50-volt load drawing 500 milliamperes. Arc suppression (snubber) diodes are built into the circuit to handle inductive loads (which most organs seem to have). Most electronic organ relays, players, and combination actions on the market today utilize this chip or one of its relatives.

How About 4-Rank Organs?

It is evident that if a tape made on a ten-rank organ is played back on a four-rank organ, something has to give. The smaller organ simply does not have the resources of the larger organ, and many of the player interface pins will be left hanging with nowhere to be connected. To reduce this incompatibility, owners of smaller organs may take advantage of the "organ expander" board, which occupies the J14 slot of the player card cage. The expander board holds 43 isolated diodes which the owner may connect up to the player interface pins as needed. The expansion is accomplished by jumpering each "open" player pin (an empty pin corresponding to a stop not appearing on the target organ) over to a diode input on the "A" side of the expander board backplane connector. The diode outputs on the "B" side are bussed appropriately and then tied back to an occupied player pin leading to a switch that does exist. To make this a little clearer, please refer to **Figure 4.** This illustrates a typical expansion of one stop of a 4-rank organ. The basic substitution here on the solo manual is the 8' Trumpet for the 8' Tuba of the standard channel assignment. The other four 8' reeds are shown coupled through the expander board's isolation diodes to the Trumpet by means of the backplane jumpers (shown as dotted lines). This substitution is not rigid, however, and the owner is free to make other choices according to his tastes.

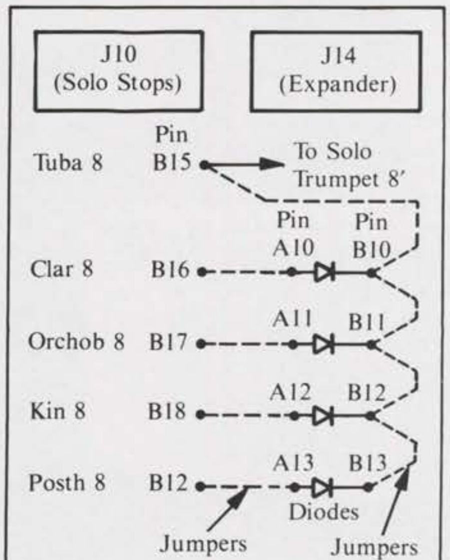


Fig. 4 Example of Organ Expansion for Wurlitzer Style 135 Solo 8' Trumpet

This "brute force" stop substitution system should solve the major problem areas. Obviously, if the source organ chooses a 2⅔ Tibia and nod 2⅔ pitched stop exists on the target organ, then we have to let that one go. However, substitutions of one 8' stop for several other 8' stops should work out very well.

It is important to use the diode isolation when strapping stops together. Otherwise, runs will occur, and tapes *recorded* on the smaller organ will not transport properly to other organs, and there may also be a problem of overloading the player driver circuits as well.

Player Installed On A Residence Organ

by Herb Merritt

Opus 1985 is a Wurlitzer Residence Pipe Organ Model RJ4, meaning Residence organ with a Junior roll player (105 note) and having 4 ranks (Oboe Horn, Open Diapason, Salicional, and Flute), which was shipped from the factory on October 29, 1928, to the Wurlitzer store in Cincinnati. It remained there until December 1930 when it was installed in the Gilligan Funeral Home, 2926 Woodburn Avenue in Cincinnati. In 1952 the organ was donated to All Saints Church in Montgomery, a suburb in Northeast Cincinnati. At that time the player, which was built into the upper portion of the straight rail console, was sawed off and discarded. In 1981 this church purchased a Baldwin electronic and I bought the pipe organ. The organ was complete except for the mutilation of the upper console. In 1982 I acquired the top portion of a scroll type two manual Wurlitzer console and fitted it to the top of the RJ4 console converting it to a horseshoe stop rail **(See Photo 1).** Percussions and toy counter were later acquired along with three additional ranks (Wurlitzer Tibia and Vox, and a Moller Clarinet) to obtain the present total of seven ranks.

Wurlitzer Residence Organs (only 11 were built) are different from the theatre organs in a few respects: the manual chests are shorter (72" versus 87"), the pipe scales are much smaller, and the pressures are lower (6" versus 10"). Further, since the organ once had a roll player, electrical connections to all keys and stops are available at a junction board in the console, a feature which made it preferable to install the universal player in the console. As there should be access to both sides of the player card cage, a hinged mounting was desirable. This type of mounting was inconvenient and so the card cage was hung on the inside end wall of the console on two studs thru aluminum angles

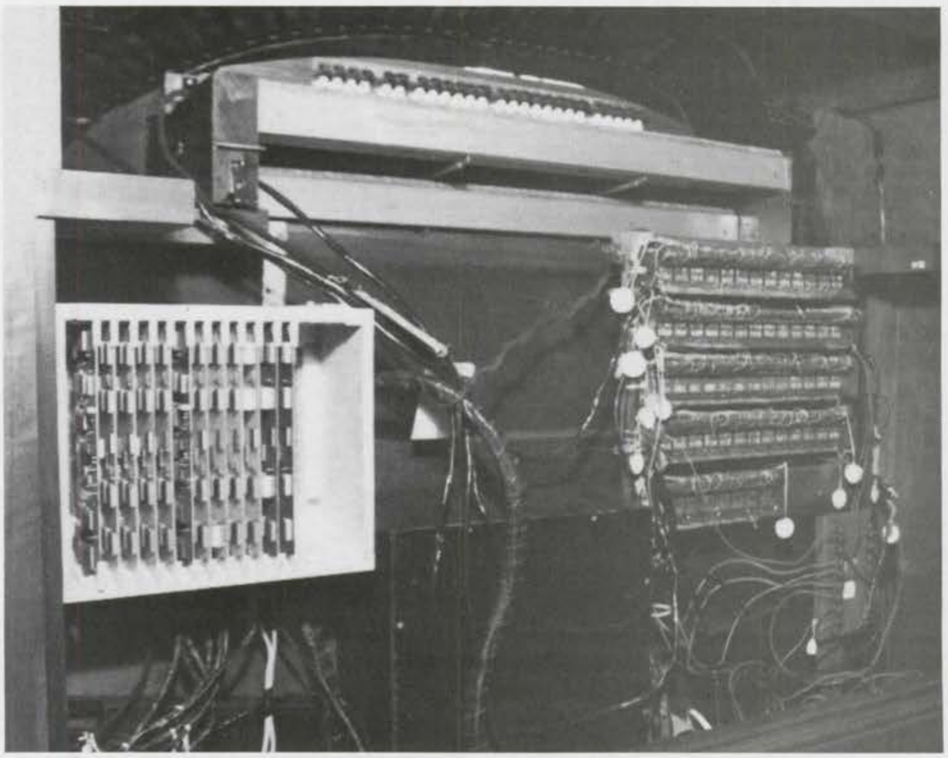
nels were not used. The 5 VDC (3 amp) logic supply was fastened to the bottom of the console and attaches thru a 2 wire disconnect to the card cage. The player card cage is permanently wired to the organ rectifier voltage. A basic Sony stereo cassette deck sits on the console along with the player control box which has LED indicators presenting run and stop status information for each track and a mute switch to select record or playback modes. During recording it is best to use two cassette decks with playback on one deck and the record cables Y'd for recording on both decks. Hence two tapes can be made simultaneously during a recording session. Further, over-dubbing is facilitated.

The only problem encountered was in the sequencing of electrical power at shutdown. If the organ rectifier and the player 5 VDC logic supply are switched off at the same time, a race condition occurs and the organ will "blip" (that is, some pipes will blow briefly). This is easily solved by providing two switches connected as shown in **Figure 5.** Turning the switches on and off in any order assures that the player power is always turned on first and turned off last.

Photo 1: Front view of RJA console. Note tape deck and player control on top of console.

Photo 2: Rear view of RJ4 console showing installation of card cage.

attached to the top and bottom of the cage **(Photo 2, rear view of console).** Therefore, with long cables and the removal of two wing nuts, the player cage can be lifted out and away from the console to service back plane wiring. Five 12' long cables were made from surplus 25 pair, 26 AWG telephone cable to connect the back plane to solo keys, accompaniment keys, pedal keys, horseshoe stops, and backrail stops. The cables were laced and hand wire wrapped to the back plane pins using a simple, homemade, wire wrap tool that applied a modified wrap in which one or two turns of the insulated wire is first wound around the pin for stress relief before the bare wire is wrapped. All cables cross an aluminum angle, attached to the bottom of the card cage, which was drilled with holes so that nylon tie wraps could be inserted to anchor the cables for stress relief. The other ends of the cables were laced, anchored to spreaders with tie wraps, and tack soldered to the spreader pins. Since this organ has no second touches, the 32 optional chan-



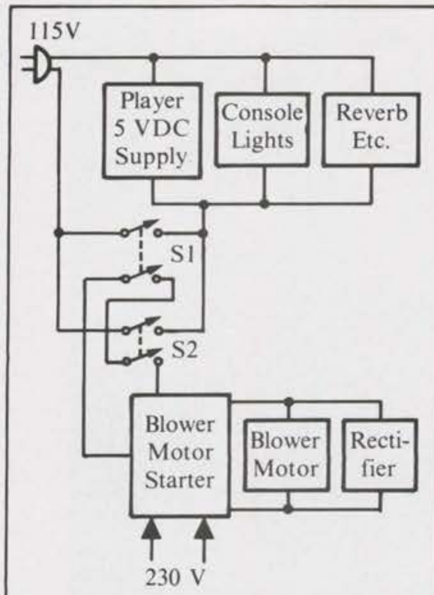


Fig. 5 Power Sequencing System for Universal Player and Pipe Organ

This player has performed extremely well. It permits a variety of high quality play for organ demonstrations at any time. Friends are entertained and amazed at the results. Organists are also entertained; they are delighted to be in the organ chamber and hear their play while a tape is re-played. In brief, this player provides exciting new dimensions to the theatre pipe organ hobby.

This organ also has a player piano roll player. The 61 holes from the center of an 88-note player piano tracker bar (piano #16C thru #76C) are directed to the three organ keyboards as follows: low 12 to pedal (C1 thru B12), next 19 to accompaniment (tenor C13 thru middle F#31), and 30 to solo (middle G32 thru top C61). Since this roll player and the universal player are connected to the organ in parallel, rolls can be played and recorded on cassette tape while registration and expression changes are added. These "improved rolls" contribute to the tape library for the universal player.

Player Installed on a Style E Wurlitzer

by Ken Aultz

The second installation of the universal player is on Opus 1712, a Style E Wurlitzer with the console of Plus 2074, a Style 220 Wurlitzer (see March/April 1987 THEATRE ORGAN).

Unlike the Model RJ4 Wurlitzer, the Style 220 console does not have all the electrical connections available at a junction board in the console. Although all of the stops are available, the pedal and manual contacts are not. In light of this, the decision was made to locate the player at the relay. The relay on this organ is a conventional Wurlitzer relay and switchstack. The player was mounted on the side of the switchstack, and was cabled to the relay using standard 25-pair telephone cable. 26 AWG or smaller wire is recommended to keep keep the cable pile-up manageable on the back plane of the unit. Cable lengths should be long enough so the unit can be dismounted from the switchstack for ease of serviceability.

A player control box was built and, in the case of this installation, located in the music studio some 40 feet from the player unit. All the parts needed to construct the control box can be purchased from an electronics shop and are: 1 utility box, 2 toggle switches, 4 LED's, and 4 RCA phono plugs. It can be drilled out, assembled and wired in just a few hours. The actual time required to completely install the player was about 24 hours.

While considerable effort was made to standardize the pin assignments to achieve transportable tapes, there are two areas of "organ incompatibility" which can cause trouble with tape exchanging. The first is the xylophone and marimba reiteration functions. Strict definitions of how your organ "must" function must be followed if the tapes are to be transported. If not, you may end up with the xylophone playing thru every selection on the tape when, in fact, it should not be. These strict definitions can be obtained from any of the authors.

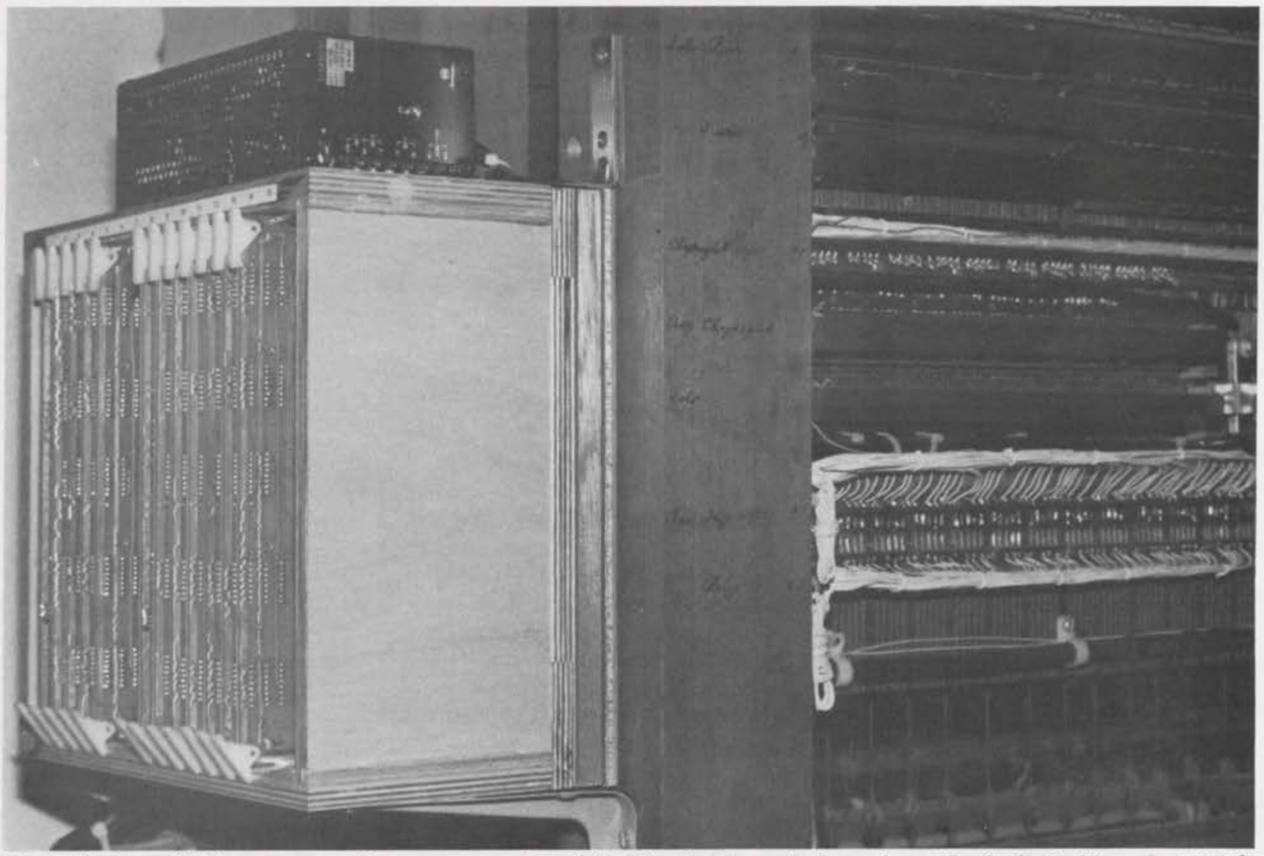


Photo 3: Record/Player system shown mounted on left side of relay switch stack on the Style E. Note the 5VDC logic power supply mounted on top of the system. *Photo courtesy of Photo Arts Studio. Covington, KY*

Photo 4: Typical example of the control box built for the Style E, showing the simple contols and 4 LEDs.
Photo courtesy of Photo Arts Studio. Covington, KY

The second, and potentially devastating, incompatibility problem is that of intramanual couplers. Few, if any, two-manual Wurlitzers had couplers from the factory, but a lot of folks have added them over the years. The problem comes from the fact that there are two common ways to create coupling with a conventional relay: Method A using diodes and Method B using separate key contacts. In order to insure transportability of tapes among organs the following rules must be followed: If your organ uses Method A, couplers switched from a single key contact (with diodes used to isolate signals), it should have its coupler stop switches wired to the player unit at the appropriate standarized pin assignment. If your organ uses Method B, couplers switched from separate fingers on the key contacts (like this Style E-220), it should not be wired to the player pins because the coupling information is already contained in the key contact information. The result of this compromise is that a tape made with Method A and played back on an organ using Method B will not couple but will at least be playable. A tape made with Method B and played back on an organ using Method A will couple perfectly. This coupling rule is one of the few compromises that had to be made to insure tape compatibility.

When recording a tape that will be played on another organ, the following guidelines will guarantee a pleasing tape:

1. Use of couplers should be minimized unless you are transporting to a known compatibly coupled organ.

2. Use care in registering the organ with single stops. If you register, lets say, a clarinet solo and the receiving organ doesn't have a clarinet, that manual will not play unless diode jumpering is used.

e. Minimize the use of second touches.

This brings us to another compromise that had to be made to keep the cost down. Since a small Wurlitzer does not have a second touch relay, to include all the second touch information would be costly and result in reduced system scan rate. For example, this Style E-220 has a total of eight second touch stops, and to use all of them would have almost doubled the cost of the player system. This was unacceptable. Therefore, in the standardization model, the use of second touches was deleted. However, the 32 optional channels can be used for second touches. Further analysis of the second touches on this Style E-220 organ revealed that the only second-touch stop that was absolutely needed was the ACCOMP 8' Style D Trumpet and the only octaves absolutely needed were octaves 2 and 3. This represents 24 notes of the Trumpet.

This brings us to my use of the optional 32 custom channels on the player. The 24 Trumpet second-touch keys were used as 24 of the 32 channels. Since this installation has a separate percussion chamber, the remaining eight channels were used for eight stages of percussion chamber expression. When a tape is transported to another organ, the custom channels are disabled by a toggle switch in the player control box as *that* organ will probably have other functions assigned to *its* 32 optional channels.

This tape exchange idea came into reality on March 5, 1988, when a tape recorded by Cincinnati organist Jack Doll, Jr. was made on my organ and transported to the Merritt 2/7 Wurlitzer and IT PLAYED BEAUTIFULLY. This exchange circuit was completed on March 29, 1988, when a tape was successfully played on my Wurlitzer that had been recorded on the Merritt instrument by Cincinnati organist, Van Jones. To the writer's knowledge, these tape exchanges were a first ever for organs with electronic players.

Readers interested in additional information on the Model 320 Universal Player, made by the Trousdale Organ Company, may contact any of the writers:

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