14주차 결과보고서

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1. 실습 시간에 진행한 설계를 기반으로 Sequence Detector 1101 state machine을 구현하시오(Verilog source, simulation 결과 작성).

Sequence detector은 1101101이라는 sequence가 있을 때, 앞의 1101과 뒤의 1101을 각각 하나의 target sequence로 detect하는 overlapping detecting 방법이 있고, 앞의 1101만을 target sequence라고 detect하는 non-overlapping detecting 방법이 있습니다. 본 실습에서는 mealy machine과 moore machine을 이용하여 각각의 sequence detector Verilog 코드를 짜보았는데 이때, overlapping이라는 입력을 사용하여 overlapping이 0일 때는 non-overlapping 방법으로, 1일 때는 overlapping 방법으로 detecting하는 sequence detector을 구현해보았습니다. 다음 코드는 mealy machine 1101 sequence detector을 Verilog로 코딩한 내용입니다.

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<Figure 1> Mealy machine 1101 Sequence detector

위와 같이 코딩한 mealy machine 1101 sequence detector가 올바르게 동작하는지 알아보기 위해 다음과 같은 test bench를 만들어 simulation 결과를 확인해보았습니다.

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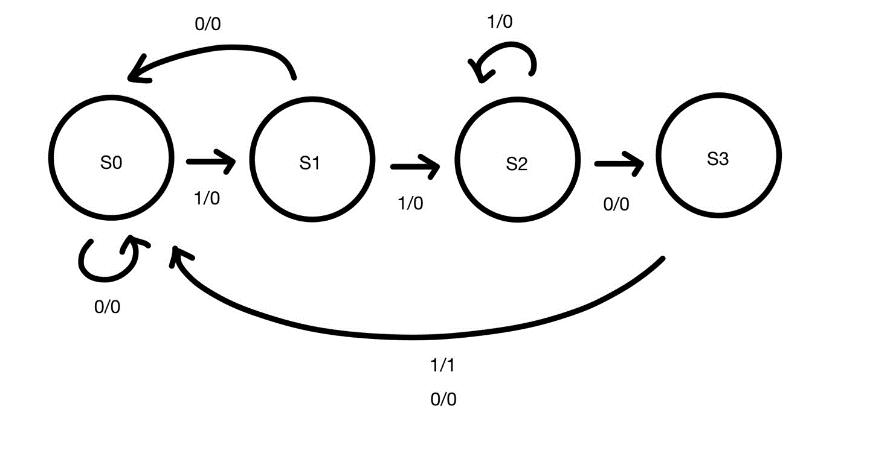
<Figure 2> Mealy machine 1101 Sequence detector test bench

![텍스트, 전자기기이(가) 표시된 사진

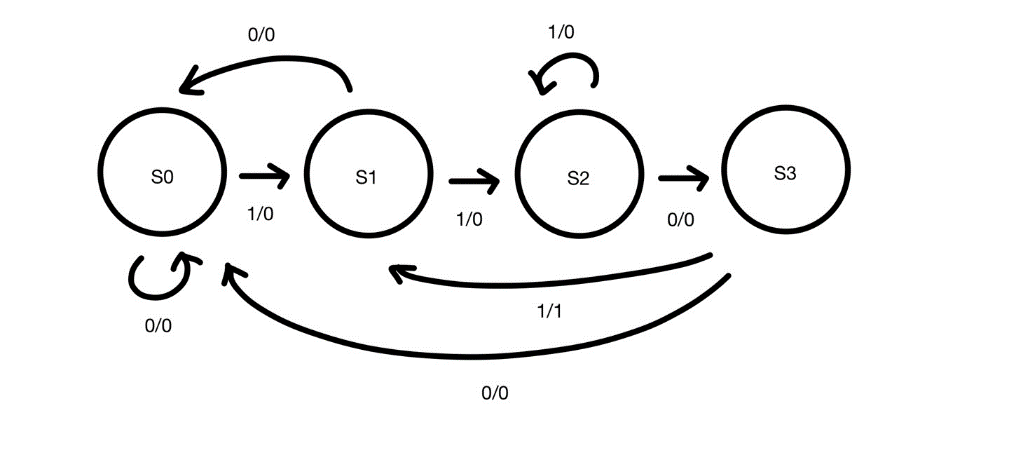
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<Figure 3> Mealy machine 1101 Sequence detector simulation 결과

이때, 400 ns를 기준으로 0 ns부터 400 ns까지는 입력 overlapping이 0이므로, non-overlapping sequence detector와 같이 동작하고 400 ns부터 800 ns까지는 overlapping이 1이므로, overlapping sequence detector와 같이 동작해야 합니다. Mealy machine의 경우, 1101이라는 target sequence를 관찰하기 위해 4개의 state가 사용되는데 아무런 sequence도 시작되지 않은 S0과 입력 1이 들어온 S1, 입력 11이 들어온 S2, 입력 110이 들어온 S3의 상태가 존재합니다. 이때, S3의 상태에서 입력이 1이 들어오면 1을 출력하여 target sequence가 들어온 것을 알려주고 S3의 상태에서 입력이 0이 들어오면 target sequence가 완성되지 못하였으므로 0을 출력하고 다시 S0의 상태로 되돌아갑니다. 위의 simulation 결과를 보면 non-overlapping sequence detector로 동작할 때는 1101 중 마지막 1이 들어왔을 때, 1을 출력하고 다시 S0의 상태로 만드는 반면, overlapping sequence detector로 동작할 때는 1101 중 마지막 1이 들어왔을 때, 1을 출력하고 S1의 상태로 만든다는 차이를 확인할 수 있습니다. 그 결과, 1101101이라는 입력이 똑같이 들어왔을 때 non-overlapping sequence detector는 앞의 1101의 target sequence만을 감지하고 overlapping sequence detector은 앞의 1101 뿐만 아니라 뒤의 1101의 target sequence까지 감지하여 1을 출력하는 것을 확인할 수 있습니다.



<Figure 4> non-overlapping 1101 mealy machine sequence detector의 state diagram(상태도)



<Figure 5> overlapping 1101 mealy machine sequence detector의 state diagram(상태도)

Non-overlapping mealy machine sequence detector와 overlapping mealy machine sequence detector은 위와 같은 상태표로 나타낼 수 있습니다. Non-overlapping sequence detector은 1101에서 마지막 1을 입력 받아도 S0의 상태로 세팅하고, overlapping sequence detector은 1101에서 마지막 1을 target sequence의 처음 1이 들어온 상태라고 인지하므로 S1의 상태로 세팅한다는 차이가 있습니다.

<Table 1> non-overlapping 1101 mealy machine sequence detector의 state table(상태표)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Current  state | Output | | Next state | |
| Input = 0 | Input = 1 | Input = 0 | Input = 1 |
| S0 | 0 | 0 | S0 | S1 |
| S1 | 0 | 0 | S0 | S2 |
| S2 | 0 | 0 | S3 | S2 |
| S3 | 0 | 1 | S0 | S0 |

<Table 2> overlapping 1101 mealy machine sequence detector의 state table(상태표)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Current  state | Output | | Next state | |
| Input = 0 | Input = 1 | Input = 0 | Input = 1 |
| S0 | 0 | 0 | S0 | S1 |
| S1 | 0 | 0 | S0 | S2 |
| S2 | 0 | 0 | S3 | S2 |
| S3 | 0 | 1 | S0 | S1 |

위의 <Table 1>과 <Table 2>는 각각 non-overlapping 1101 mealy machine sequence detector와overlapping 1101 mealy machine sequence detector의 state table(상태표)입니다. 두 표의 차이점을 회색으로 나타내었는데 앞서 설명하였다시피 non-overlapping sequence detector은 1101에서 S3 상태 다음에 입력이 1이 들어올 때 S1의 상태로 가지 않고 다시 S0의 상태부터 시작하고 overlapping sequence detector은 1101에서 S3 상태 다음에 입력이 1이 들어올 때 S1의 상태부터 시작하므로 위와 같은 차이가 존재하게 됩니다.

다음 코드는 moore machine 1101 sequence detector을 Verilog로 코딩한 내용입니다.

|  |  |
| --- | --- |
|  |  |

<Figure 6> Moore machine 1101 Sequence detector

위와 같이 코딩한 mealy machine 1101 sequence detector가 올바르게 동작하는지 알아보기 위해 다음과 같은 test bench를 만들어 simulation 결과를 확인해보았습니다.

|  |  |
| --- | --- |
|  |  |

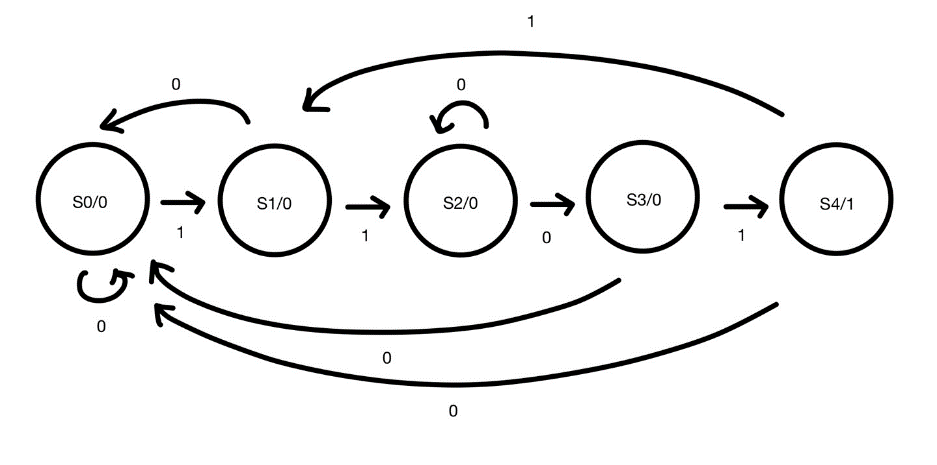
<Figure 7> Moore machine 1101 Sequence detector test bench

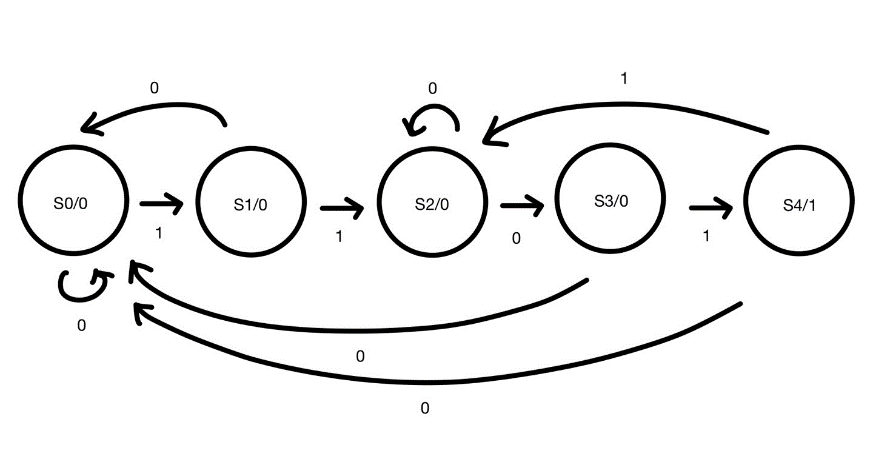
![텍스트이(가) 표시된 사진

자동 생성된 설명](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAeAB4AAD/4RDcRXhpZgAATU0AKgAAAAgABAE7AAIAAAAKAAAISodpAAQAAAABAAAIVJydAAEAAAAIAAAQzOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAOq5gOuCmO2YhAAABZADAAIAAAAUAAAQopAEAAIAAAAUAAAQtpKRAAIAAAADMzcAAJKSAAIAAAADMzcAAOocAAcAAAgMAAAIlgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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PAWb/4mj28Oz/8AAZf5B9Zp9pf+Ay/yMaitn+ydH/6GO3/8BZv/AImj+ydH/wChjt//AAFm/wDiaPbw7P8A8Bl/kH1mn2l/4DL/ACMaitn+ydH/AOhjt/8AwFm/+Jo/snR/+hjt/wDwFm/+Jo9vDs//AAGX+QfWafaX/gMv8jGorZ/snR/+hjt//AWb/wCJo/snR/8AoY7f/wABZv8A4mj28Oz/APAZf5B9Zp9pf+Ay/wAjGorZ/snR/wDoY7f/AMBZv/iaP7J0f/oY7f8A8BZv/iaPbw7P/wABl/kH1mn2l/4DL/IxqK2f7J0f/oY7f/wFm/8AiaP7J0f/AKGO3/8AAWb/AOJo9vDs/wDwGX+QfWafaX/gMv8AIxqK2f7J0f8A6GO3/wDAWb/4mj+ydH/6GO3/APAWb/4mj28Oz/8AAZf5B9Zp9pf+Ay/yMaitn+ydH/6GO3/8BZv/AImj+ydH/wChjt//AAFm/wDiaPbw7P8A8Bl/kH1mn2l/4DL/ACLWo/8AJOdD/wCv27/lDXOV3N/pmlnwDoyNr0KxreXRWT7NLhiRFkY2544/Ouf/ALJ0f/oY7f8A8BZv/iaHXguj/wDAX/kN4mC6P/wGX+RjUVs/2To//Qx2/wD4Czf/ABNH9k6P/wBDHb/+As3/AMTR7eHZ/wDgMv8AIX1mn2l/4DL/ACMaitn+ydH/AOhjt/8AwFm/+Jo/snR/+hjt/wDwFm/+Jo9vDs//AAGX+QfWafaX/gMv8jGorZ/snR/+hjt//AWb/wCJo/snR/8AoY7f/wABZv8A4mj28Oz/APAZf5B9Zp9pf+Ay/wAjGorZ/snR/wDoY7f/AMBZv/iaP7J0f/oY7f8A8BZv/iaPbw7P/wABl/kH1mn2l/4DL/IxqK2f7J0f/oY7f/wFm/8AiaP7J0f/AKGO3/8AAWb/AOJo9vDs/wDwGX+QfWafaX/gMv8AIxqK2f7J0f8A6GO3/wDAWb/4mj+ydH/6GO3/APAWb/4mj28Oz/8AAZf5B9Zp9pf+Ay/yMaitn+ydH/6GO3/8BZv/AImj+ydH/wChjt//AAFm/wDiaPbw7P8A8Bl/kH1mn2l/4DL/ACMaitn+ydH/AOhjt/8AwFm/+Jo/snR/+hjt/wDwFm/+Jo9vDs//AAGX+QfWafaX/gMv8jGrb8F/8j1of/X/AA/+him/2To//Qx2/wD4Czf/ABNbHhHS9Kj8aaM8WvwSut7CVjFtKCx3jjJXFHt4Po//AAF/5AsTBu1n/wCAy/yOW1D/AJCV1/12f+ZqvXQ32k6QdQuCfEVupMrZH2Wbjk/7NV/7J0f/AKGO3/8AAWb/AOJo9vDs/wDwGX+QfWYdn/4DL/IxqK2f7J0f/oY7f/wFm/8AiaP7J0f/AKGO3/8AAWb/AOJo9vDs/wDwGX+QfWafaX/gMv8AIxqK2f7J0f8A6GO3/wDAWb/4mj+ydH/6GO3/APAWb/4mj28Oz/8AAZf5B9Zp9pf+Ay/yMaitn+ydH/6GO3/8BZv/AImj+ydH/wChjt//AAFm/wDiaPbw7P8A8Bl/kH1mn2l/4DL/ACMaitn+ydH/AOhjt/8AwFm/+Jo/snR/+hjt/wDwFm/+Jo9vDs//AAGX+QfWafaX/gMv8jGorZ/snR/+hjt//AWb/wCJo/snR/8AoY7f/wABZv8A4mj28Oz/APAZf5B9Zp9pf+Ay/wAjGorZ/snR/wDoY7f/AMBZv/iaP7J0f/oY7f8A8BZv/iaPbw7P/wABl/kH1mn2l/4DL/I1fBH/ACD9d/690/8AQ6lqPSLrR9C0/UlXV0u5LqNURI7eRcYbOcsKq/2xZf8APU/98GvMlCc6s5qLs2uj7I8iUJ1K9ScYuza6NdF3L1FUf7Ysv+ep/wC+DR/bFl/z1P8A3waPZVOzD2NT+Vl6tlv+RGT/ALCLf+i1rmP7Ysv+ep/74Nbbaraf8IDHJ5h2/wBpsudp6+UtVGnPXRlxo1NfdZSoqj/bFl/z1P8A3waP7Ysv+ep/74NT7Kp2ZHsan8rL1FUf7Ysv+ep/74NH9sWX/PU/98Gj2VTsw9jU/lY/xl/x6aJ/16P/AOjXrl66zVZtH1uy07Osx2sltC0bpJbyNyXZuoGOhrM/snR/+hjt/wDwFm/+Jrqw1RU6SjJO930fd+R2YOqqVFQmne7+zLu/IxqK2f7J0f8A6GO3/wDAWb/4mj+ydH/6GO3/APAWb/4mun28Oz/8Bl/kdf1mn2l/4DL/ACMaitn+ydH/AOhjt/8AwFm/+Jo/snR/+hjt/wDwFm/+Jo9vDs//AAGX+QfWafaX/gMv8jGorZ/snR/+hjt//AWb/wCJo/snR/8AoY7f/wABZv8A4mj28Oz/APAZf5B9Zp9pf+Ay/wAjGorZ/snR/wDoY7f/AMBZv/iaP7J0f/oY7f8A8BZv/iaPbw7P/wABl/kH1mn2l/4DL/IxqK2f7J0f/oY7f/wFm/8AiaP7J0f/AKGO3/8AAWb/AOJo9vDs/wDwGX+QfWafaX/gMv8AIxqK2f7J0f8A6GO3/wDAWb/4mj+ydH/6GO3/APAWb/4mj28Oz/8AAZf5B9Zp9pf+Ay/yN74N/wDJX/D/AP13b/0W1Fanwl03TIfitoUlvrkNxIszbYlt5VLfu27lcUV+V8ZzU8bTa/l7NdX3PUwdRVINq+/VNfmeaUUUV+tnIFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAH1to//ACZtJ/2Bbj/0N6+Sa+ttH/5M2k/7Atx/6G9fJNABRRRQAUUUUAFFFFABWz4O/wCR60H/ALCVv/6NWsatnwd/yPWg/wDYSt//AEatAH0N+1f/AMgzwt/19T/ySvAPHv8AyUDWv+vt/wCde/8A7V//ACDPC3/X1P8AySvAPHv/ACUDWv8Ar7f+dAHP0UUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQB0dz/AMky07/sK3H/AKKirnK6O5/5Jlp3/YVuP/RUVc5QAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABWn4a/wCRs0n/AK/Yf/QxWZWn4a/5GzSf+v2H/wBDFAEOtf8AIf1D/r6k/wDQjVKrutf8h/UP+vqT/wBCNUqACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAK6Bf+Sayf9hdP/RLVz9dAv/JNZP8AsLp/6JagDn6KKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAsaf/yErX/rsn8xWn40/wCR61z/AK/5v/QzWZp//IStf+uyfzFafjT/AJHrXP8Ar/m/9DNAGJRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAHR6j/yTnQ/+v27/AJQ1zldHqP8AyTnQ/wDr9u/5Q1zlABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFbfgv/ketD/6/wCH/wBDFYlbfgv/AJHrQ/8Ar/h/9DFAGZqH/ISuv+uz/wAzVerGof8AISuv+uz/AMzVegAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACugb/kmsf8A2F3/APRK1z9dA3/JNY/+wu//AKJWgDn6KKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooA7f4N/8lf8P/8AXdv/AEW1FHwb/wCSv+H/APru3/otqK/J+Nv9+p/4P1Z34b4WcRRRRX6wcAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAfW2j/APJm0n/YFuP/AEN6+Sa+ttH/AOTNpP8AsC3H/ob18k0AFFFFABRRRQAUUUUAFbPg7/ketB/7CVv/AOjVrGrZ8Hf8j1oP/YSt/wD0atAH0N+1f/yDPC3/AF9T/wAkrwDx7/yUDWv+vt/517/+1f8A8gzwt/19T/ySvAPHv/JQNa/6+3/nQBz9FFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAdHc/8ky07/sK3H/oqKucro7n/AJJlp3/YVuP/AEVFXOUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAVp+Gv+Rs0n/r9h/8AQxWZWn4a/wCRs0n/AK/Yf/QxQBDrX/If1D/r6k/9CNUqu61/yH9Q/wCvqT/0I1SoAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAroF/5JrJ/wBhdP8A0S1c/XQL/wAk1k/7C6f+iWoA5+iiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKALGn/wDIStf+uyfzFafjT/ketc/6/wCb/wBDNZmn/wDIStf+uyfzFafjT/ketc/6/wCb/wBDNAGJRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAHR6j/AMk50P8A6/bv+UNc5XR6j/yTnQ/+v27/AJQ1zlABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFbfgv/AJHrQ/8Ar/h/9DFYlbfgv/ketD/6/wCH/wBDFAGZqH/ISuv+uz/zNV6sah/yErr/AK7P/M1XoAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAroG/wCSax/9hd//AEStc/XQN/yTWP8A7C7/APolaAOfooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigDt/g3/wAlf8P/APXdv/RbUUfBv/kr/h//AK7t/wCi2or8n42/36n/AIP1Z34b4WcRRRRX6wcAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAfW2j/8AJm0n/YFuP/Q3r5JoooAKKKKACiiigAooooAK2fB3/I9aD/2Erf8A9GrRRQB9DftX/wDIM8Lf9fU/8krwDx7/AMlA1r/r7f8AnRRQBz9FFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAdHc/8AJMtO/wCwrcf+ioq5yiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACtPw1/wAjZpP/AF+w/wDoYoooAh1r/kP6h/19Sf8AoRqlRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABXQL/yTWT/ALC6f+iWoooA5+iiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKALGn/wDIStf+uyfzFafjT/ketc/6/wCb/wBDNFFAGJRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAHR6j/yTnQ/+v27/AJQ1zlFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFbfgv/ketD/6/wCH/wBDFFFAGZqH/ISuv+uz/wAzVeiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACugb/kmsf/YXf/0StFFAHP0UUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQB2/wb/5K/4f/wCu7f8AotqKKK/J+Nv9+p/4P1Z34b4Wf//Z)

<Figure 8> Moore machine 1101 Sequence detector simulation 결과

Mealy machine 1101 sequence detector의 test bench와 마찬가지로, 400 ns를 기준으로 0 ns부터 400 ns까지는 입력 overlapping이 0이므로, non-overlapping sequence detector와 같이 동작하고 400 ns부터 800 ns까지는 overlapping이 1이므로, overlapping sequence detector와 같이 동작해야 합니다. Moore machine의 경우, 1101이라는 target sequence를 관찰하기 위해 mealy machine에서 사용되었던 4개의 state보다 하나 더 많은 5개의 state가 사용되는데 아무런 sequence도 시작되지 않은 S0과 입력 1이 들어온 S1, 입력 11이 들어온 S2, 입력 110이 들어온 S3, 입력 1101이 모두 들어온 S4의 상태가 존재합니다. 이때, S4의 상태가 되면 target sequence인 1101이 모두 들어온 것이므로 입력과 무관하게 1을 출력하게 되고, 입력에 따라 다음 상태가 결정되게 됩니다. 위의 simulation 결과를 보면 non-overlapping sequence detector로 동작할 때는 S4의 상태에서 1이 들어올 때 1을 출력하고 다시 S0의 상태로 만드는 반면, overlapping sequence detector로 동작할 때는 S4의 상태에서 1이 들어올 때 1을 출력하고 S1의 상태로 만든다는 차이를 확인할 수 있습니다. 그 결과, 1101101이라는 입력이 똑같이 들어왔을 때 non-overlapping sequence detector는 앞의 1101의 target sequence만을 감지하고 overlapping sequence detector은 앞의 1101 뿐만 아니라 뒤의 1101의 target sequence까지 감지하여 1을 출력하게 될 것입니다. 하지만 110의 상태에서 1의 입력이 들어오는 즉시 1을 출력하는 mealy machine과 달리, moore machine은 1101이라는 입력이 모두 들어오고 그 다음 clk의 상승 에지에서 1을 출력하므로 출력이 delay되는 것을 관찰할 수 있습니다.



<Figure 9> non-overlapping 1101 moore machine sequence detector의 state diagram(상태도)

<Figure 10> overlapping 1101 moore machine sequence detector의 state diagram(상태도)

Non-overlapping moore machine sequence detector와 overlapping moore machine sequence detector은 위와 같은 상태표로 나타낼 수 있습니다. Non-overlapping sequence detector은 S4의 상태에서 입력으로 1을 받아도 S1의 상태로 세팅하고, overlapping sequence detector은 S4의 상태에서 입력으로 1을 받으면 S2의 상태로 세팅하게 됩니다. 이러한 차이를 반영하여 두 개의 sequence detector의 state table을 작성해보면 다음과 같습니다.

<Table 3> non-overlapping 1101 moore machine sequence detector의 state table(상태표)

|  |  |  |  |
| --- | --- | --- | --- |
| Current  state | Output | | Output |
| Input = 0 | Input = 1 |
| S0 | S0 | S1 | 0 |
| S1 | S0 | S2 | 0 |
| S2 | S3 | S2 | 0 |
| S3 | S0 | S4 | 0 |
| S4 | S0 | S1 | 1 |

<Table 4> overlapping 1101 moore machine sequence detector의 state table(상태표)

|  |  |  |  |
| --- | --- | --- | --- |
| Current  state | Next state | | Output |
| Input = 0 | Input = 1 |
| S0 | S0 | S1 | 0 |
| S1 | S0 | S2 | 0 |
| S2 | S3 | S2 | 0 |
| S3 | S0 | S4 | 0 |
| S4 | S0 | S2 | 1 |

위의 <Table 3>과 <Table 4>는 각각 non-overlapping 1101 moore machine sequence detector와overlapping 1101 moore machine sequence detector의 state table(상태표)입니다. 두 표의 차이점을 회색으로 나타내었는데 앞서 설명하였다시피 non-overlapping sequence detector에서는 S4에서 1이 들어와도 S1의 상태로 transition되는 반면, overlapping sequence detector에서는 S4에서 1이 들어오면 S2의 상태로 transition된다는 것을 알 수 있습니다. 또한 mealy machine과 달리, moore machine의 경우 출력이 입력과 현재 상태가 아니라, 현재 상태에 의해서만 결정이 된다는 것을 확인할 수 있습니다.

1. Sequence Detector 10101을 구현하시오(Mealy, moore machine 모두, 상태도 및 상태표 작성, Verilog 코드 및 simulation 결과 작성).

마찬가지로 10101 sequence detector을 구현할 때도 overlapping이라는 입력을 이용하여 입력 overlapping이 1이면 overlapping을 감지하는 sequence detector로, 0이면 overlapping을 감지하지 못하는 sequence detector로 동작하도록 하였습니다. 10101 sequence detector를 mealy machine과 moore machine으로 구현하였고, 각각의 경우에 대해 overlapping 입력을 이용하여 overlapping, non-overlapping detector machine으로 동작하게 하였습니다. 10101이라는 target sequence는 앞서 다룬 1101이라는 target sequence와 달리, sequence 내부의 반복되는 subsequence가 존재하고 더 길다는 점으로 인해 1101 sequence detector와 다른 state diagram과 state table을 관찰할 수 있을 것입니다. 다음 코드는 mealy machine 10101 sequence detector을 Verilog로 코딩한 내용입니다.

|  |  |
| --- | --- |
|  |  |

<Figure 11> Mealy machine 10101 Sequence detector

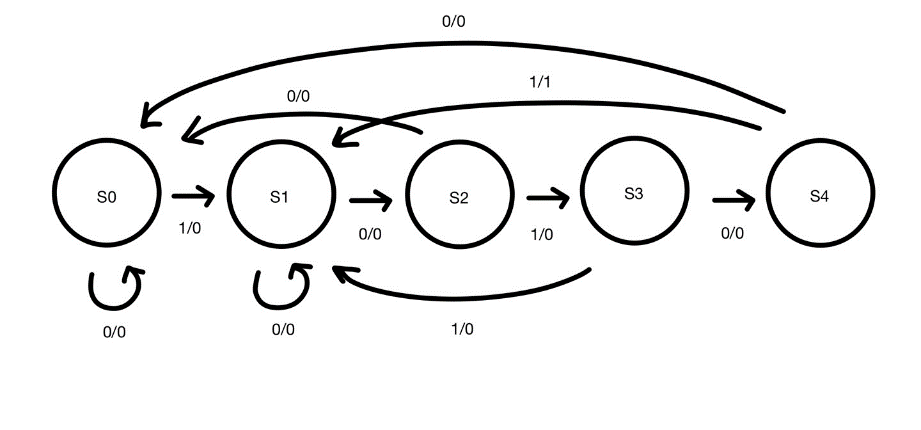
위와 같이 코딩한 mealy machine 10101 sequence detector가 올바르게 동작하는지 알아보기 위해 입력 in이 0과 1을 반복하는 test bench를 이용해 simulation 결과를 확인해보았습니다.

![텍스트이(가) 표시된 사진

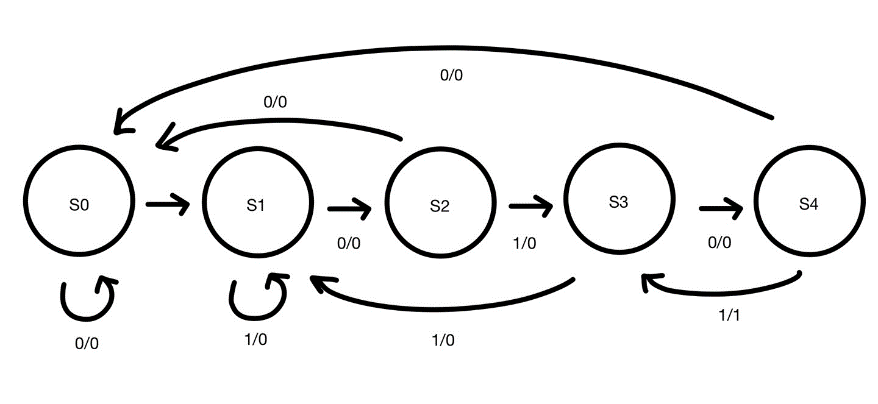
자동 생성된 설명](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAeAB4AAD/4RDcRXhpZgAATU0AKgAAAAgABAE7AAIAAAAKAAAISodpAAQAAAABAAAIVJydAAEAAAAIAAAQzOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAOq5gOuCmO2YhAAABZADAAIAAAAUAAAQopAEAAIAAAAUAAAQtpKRAAIAAAADNTQAAJKSAAIAAAADNTQAAOocAAcAAAgMAAAIlgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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U196OU1D/kJXX/XZ/5mq9dHfeEtTbULhg1lgysRm+hHc/7VQf8ACIap/esf/A+H/wCKpfWaH86+8X1zDf8APxfejDorc/4RDVP71j/4Hw//ABVH/CIap/esf/A+H/4qj61Q/nX3h9cw3/PxfejS8Ef8g/Xf+vdP/Q6lqbQNOk0LTNXbUprRBPEiRhLqNyx3eisaq/aYP+e0f/fYrypNTrTlHVXX5I8WbVTEVJw1V1qv8KJKKj+0wf8APaP/AL7FH2mD/ntH/wB9inyvsPll2JKKj+0wf89o/wDvsUfaYP8AntH/AN9ijlfYOWXYkoqP7TB/z2j/AO+xR9pg/wCe0f8A32KOV9g5ZdiSio/tMH/PaP8A77FH2mD/AJ7R/wDfYo5X2Dll2KHjf/kaZf8ArhB/6KSufrsvE2hXeq62byxlspIXghCsb2JTxGoPBbPUVk/8Ihqn96x/8D4f/iq7MNiKMaEIykk0l18jvweKoQw1OMppNJdV2MOitz/hENU/vWP/AIHw/wDxVH/CIap/esf/AAPh/wDiq6PrVD+dfedX1zDf8/F96MOitz/hENU/vWP/AIHw/wDxVFH1qh/OvvD65hv+fi+9GHRRRXQdQUUUUAFTRXlzAmyC4ljXOdqOQP0qGindrYVk9yz/AGlff8/tx/39b/Gj+0r7/n9uP+/rf41Wop80u4uWPYs/2lff8/tx/wB/W/xo/tK+/wCf24/7+t/jVaijml3Dlj2LP9pX3/P7cf8Af1v8aP7Svv8An9uP+/rf41Woo5pdw5Y9iz/aV9/z+3H/AH9b/Gj+0r7/AJ/bj/v63+NVqKOaXcOWPYs/2lff8/tx/wB/W/xo/tK+/wCf24/7+t/jVaijml3Dlj2J5L67mjKS3MzoeqtISDUFFFJtvcaSWx7b+yv/AMlO1D/sFyf+jI65z4/MyfHHW2RirKYCCDgj9yldH+yv/wAlO1D/ALBcn/oyOub/AGgf+S367/2x/wDRKUhnn/8AaV9/z+3H/f1v8aP7Svv+f24/7+t/jVaiq5pdyeWPYs/2lff8/tx/39b/ABo/tK+/5/bj/v63+NVqKOaXcOWPYs/2lff8/tx/39b/ABo/tK+/5/bj/v63+NVqKOaXcOWPYs/2lff8/tx/39b/ABo/tK+/5/bj/v63+NVqKOaXcOWPYs/2lff8/tx/39b/ABo/tK+/5/bj/v63+NVqKOaXcOWPYs/2lff8/tx/39b/ABo/tK+/5/bj/v63+NVqKOaXcOWPYs/2lff8/tx/39b/ABo/tK+/5/bj/v63+NVqKOaXcOWPYs/2lff8/tx/39b/ABrr/g67yfGjw08jM7NeglmOSeDXD123wa/5LJ4Z/wCv0fyNJtvcaSWx65+0b/yVXwT9V/8AR6189a1/yH9Q/wCvqT/0I19C/tG/8lV8E/Vf/R6189a1/wAh/UP+vqT/ANCNIZSooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACug8Cf8jxpn/XRv/QTXP10HgT/keNM/66N/6CaAOfooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigDb8F/8AI9aH/wBf8P8A6GKzNQ/5CV1/12f+ZrT8F/8AI9aH/wBf8P8A6GKzNQ/5CV1/12f+ZoAr0UUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABXQeBf+RxtP+uc3/ol65+ug8C/8jjaf9c5v/RL0Ac/RRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAHQeAv+SgaL/19p/OsGX/XP/vGt7wF/wAlA0X/AK+0/nWDL/rn/wB40ANooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACtPw1/yNmk/9fsP/oYrMrT8Nf8AI2aT/wBfsP8A6GKAIda/5D+of9fUn/oRqlV3Wv8AkP6h/wBfUn/oRqlQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAHQeBP+R40z/ro3/oJrn66DwJ/yPGmf9dG/wDQTXP0AFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAVt+C/wDketD/AOv+H/0MViVt+C/+R60P/r/h/wDQxQBmah/yErr/AK7P/M1XqxqH/ISuv+uz/wAzVegAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigD239lf/kp2of9guT/ANGR1zf7QP8AyW/Xf+2P/olK6T9lf/kp2of9guT/ANGR1zf7QP8AyW/Xf+2P/olKAPNqKKKACiiigAooooAKKKKACiiigAooooAKKKKACu2+DX/JZPDP/X6P5GuJrtvg1/yWTwz/ANfo/kaAPXP2jf8Akqvgn6r/AOj1r561r/kP6h/19Sf+hGvoX9o3/kqvgn6r/wCj1r561r/kP6h/19Sf+hGgClRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFdB4E/5HjTP+ujf+gmufroPAn/I8aZ/10b/0E0Ac/RRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAG34L/wCR60P/AK/4f/QxWZqH/ISuv+uz/wAzWn4L/wCR60P/AK/4f/QxWZqH/ISuv+uz/wAzQBXooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACug8C/8jjaf9c5v/RL1z9dB4F/5HG0/65zf+iXoA5+iiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKAOg8Bf8lA0X/r7T+dYMv+uf/eNb3gL/AJKBov8A19p/OsGX/XP/ALxoAbRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFafhr/kbNJ/6/Yf/AEMVmVp+Gv8AkbNJ/wCv2H/0MUAQ61/yH9Q/6+pP/QjVKrutf8h/UP8Ar6k/9CNUqACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooA6DwJ/yPGmf9dG/9BNc/XQeBP+R40z/ro3/oJrn6ACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAK2/Bf/I9aH/1/wAP/oYrErb8F/8AI9aH/wBf8P8A6GKAMzUP+Qldf9dn/mar1Y1D/kJXX/XZ/wCZqvQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQB7b+yv/yU7UP+wXJ/6Mjrm/2gf+S367/2x/8ARKV0n7K//JTtQ/7Bcn/oyOub/aB/5Lfrv/bH/wBEpQB5tRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAV23wa/5LJ4Z/6/R/I1xNdt8Gv+SyeGf+v0fyNAHrn7Rv8AyVXwT9V/9HrXz1rX/If1D/r6k/8AQjX0L+0b/wAlV8E/Vf8A0etfPWtf8h/UP+vqT/0I0AUqKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAroPAn/ACPGmf8AXRv/AEE1z9dB4E/5HjTP+ujf+gmgDn6KKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooA2/Bf8AyPWh/wDX/D/6GKzNQ/5CV1/12f8Ama0/Bf8AyPWh/wDX/D/6GKzNQ/5CV1/12f8AmaAK9FFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAV0HgX/kcbT/rnN/6JeufroPAv/I42n/XOb/0S9AHP0UUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQB0HgL/koGi/8AX2n86wZf9c/+8a3vAX/JQNF/6+0/nWDL/rn/AN40ANooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACtPw1/yNmk/9fsP/AKGKzK0/DX/I2aT/ANfsP/oYoAh1r/kP6h/19Sf+hGqVXda/5D+of9fUn/oRqlQAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFAHQeBP+R40z/ro3/oJrn66DwJ/yPGmf9dG/9BNc/QAUUUUAFFFFABRRRQAUUUUAFFFFABRRRQAUUUUAFFFFABW34L/5HrQ/+v8Ah/8AQxWJW34L/wCR60P/AK/4f/QxQBmah/yErr/rs/8AM1XqxqH/ACErr/rs/wDM1XoAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooA/9k=)

<Figure 12> Mealy machine 10101 Sequence detector의 simulation 결과

1101 sequence detector와 동일하게 0 ns부터 400 ns까지는 입력 overlapping이 0이고, 400 ns부터 800 ns까지는 입력 overlapping이 1가 되어 각각 non-overlapping, overlapping 10101 mealy machine sequence detector로 동작할 수 있게 하였습니다. Mealy machine에서 10101이라는 target sequence를 감지하기 위해서는 5개의 state가 필요합니다. 우선, S0은 target sequence 중 아무런 sequence가 시작되지 않은 상태를 의미하고, S1은 1의 입력이 들어온 상태를 의미하고, S2는 10의 입력이 들어온 상태를, S3는 101의 입력이 들어온 상태를, S4는 1010의 입력이 들어온 상태를 의미합니다. 따라서, non-overlapping 10101 mealy machine sequence detector에서는 101010101의 입력이 들어올 때, 앞의 10101만을 감지하여 1을 출력하고 overlap된 10101은 감지하지 못하므로 400 ns까지 출력 out은 단 한 번만 1을 출력한다는 것을 관찰할 수 있습니다. 하지만 overlapping 10101 mealy machine sequence detector에서는 101010101에서 overlap된 뒤의 10101까지 감지하므로 400 ns부터 800 ns까지 출력 out으로 두 번이나 1을 출력한다는 것을 관찰할 수 있습니다.



<Figure 13> non-overlapping 10101 mealy machine sequence detector의 state diagram(상태도)



<Figure 14> overlapping 10101 mealy machine sequence detector의 state diagram(상태도)

Non-overlapping mealy machine sequence detector와 overlapping mealy machine sequence detector은 위와 같은 상태표로 나타낼 수 있습니다. Non-overlapping sequence detector은 10101에서 마지막 1을 입력 받아도 S0의 상태로 세팅하고, overlapping sequence detector은 10101에서 뒤의 101을 target sequence의 처음 101이 들어온 상태라고 인지하므로 S3의 상태로 세팅한다는 차이가 있습니다.

<Table 5> non-overlapping 10101 mealy machine sequence detector의 state table(상태표)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Current  state | Output | | Next state | |
| Input = 0 | Input = 1 | Input = 0 | Input = 1 |
| S0 | 0 | 0 | S0 | S1 |
| S1 | 0 | 0 | S2 | S1 |
| S2 | 0 | 0 | S0 | S3 |
| S3 | 0 | 0 | S4 | S1 |
| S4 | 0 | 1 | S1 | S0 |

<Table 6> overlapping 10101 mealy machine sequence detector의 state table(상태표)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Current  state | Output | | Next state | |
| Input = 0 | Input = 1 | Input = 0 | Input = 1 |
| S0 | 0 | 0 | S0 | S1 |
| S1 | 0 | 0 | S2 | S1 |
| S2 | 0 | 0 | S0 | S3 |
| S3 | 0 | 0 | S4 | S1 |
| S4 | 0 | 1 | S3 | S0 |

위의 <Table 5>과 <Table 6>는 각각 non-overlapping 10101 mealy machine sequence detector와overlapping 10101 mealy machine sequence detector의 state table(상태표)입니다. 두 표의 차이점을 회색으로 나타내었는데 앞서 설명하였다시피 non-overlapping sequence detector은 10101에서 S4 상태 다음에 입력이 1이 들어올 때 S1의 상태부터 시작하고 overlapping sequence detector은 10101에서 S4 상태 다음에 입력이 1이 들어올 때 S3의 상태부터 시작하므로 위와 같은 차이가 존재하게 됩니다.

다음 코드는 moore machine 10101 sequence detector을 Verilog로 코딩한 내용입니다.

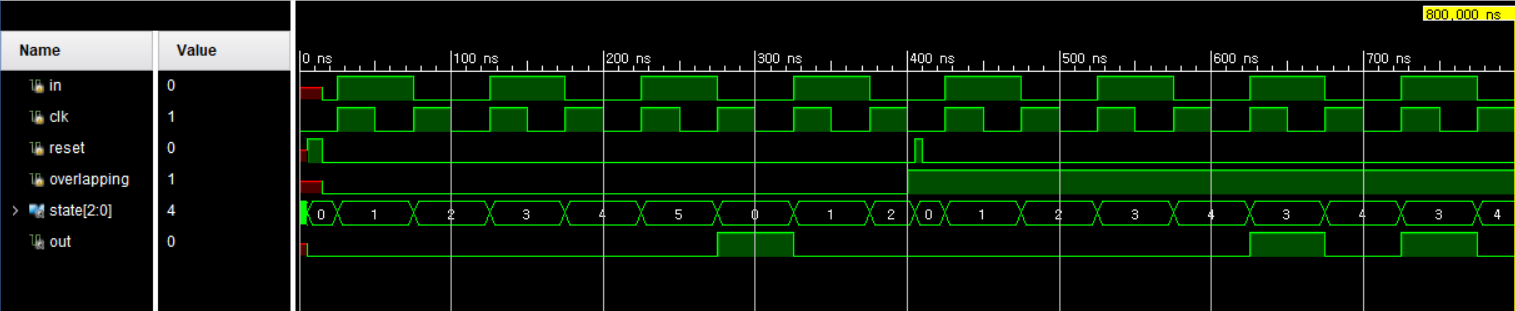
텍스트이(가) 표시된 사진

자동 생성된 설명테이블이(가) 표시된 사진

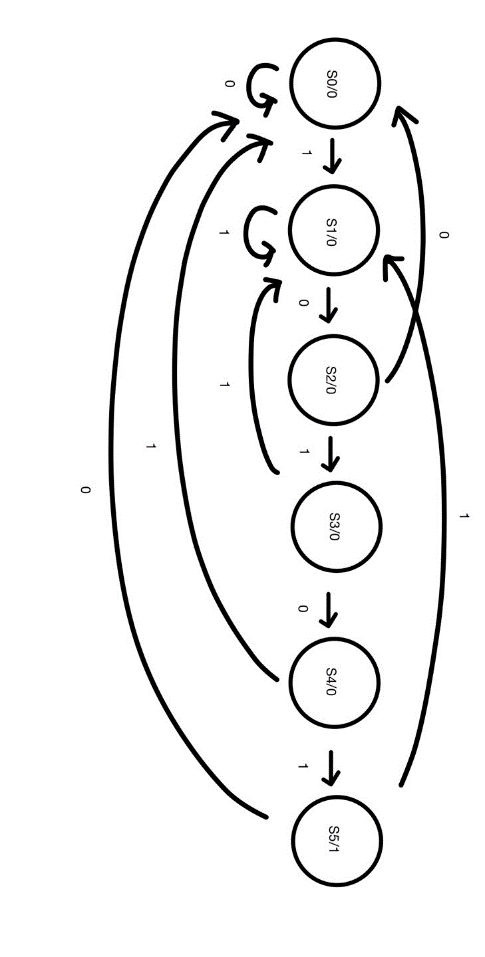
자동 생성된 설명

<Figure 15> Moore machine 10101 Sequence detector

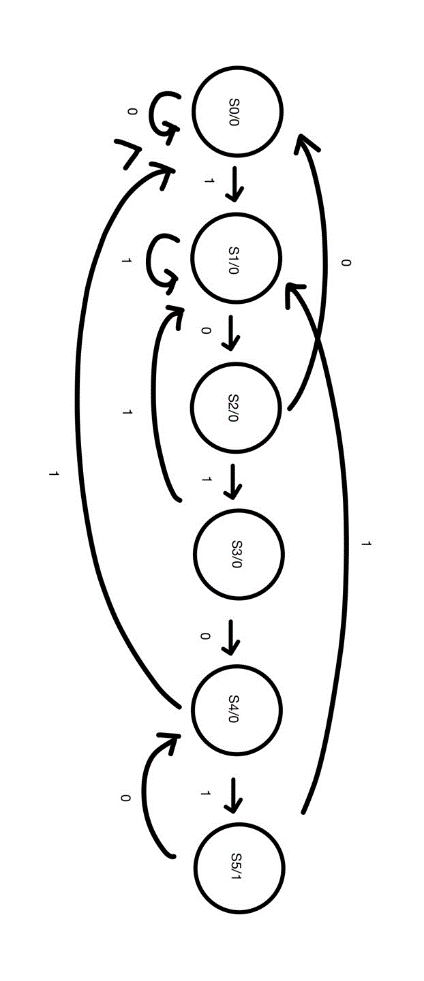
위와 같이 코딩한 moore machine 10101 sequence detector가 올바르게 동작하는지 알아보기 위해 입력 in이 0과 1을 반복하는 test bench를 이용해 simulation 결과를 확인해보았습니다.



<Figure 16> Moore machine 10101 Sequence detector의 simulation 결과

1101 sequence detector와 동일하게 0 ns부터 400 ns까지는 입력 overlapping이 0이고, 400 ns부터 800 ns까지는 입력 overlapping이 1가 되어 각각 non-overlapping, overlapping 10101 moore machine sequence detector로 동작할 수 있게 하였습니다. Mealy machine에서 10101이라는 target sequence를 감지하기 위해서는 5개의 state가 필요하지만 Moore machine에서는 이보다 하나 더 많은 6개의 state가 사용됩니다. 우선, S0은 target sequence 중 아무런 sequence가 시작되지 않은 상태를 의미하고, S1은 1의 입력이 들어온 상태를 의미하고, S2는 10의 입력이 들어온 상태를, S3는 101의 입력이 들어온 상태를, S4는 1010의 입력이 들어온 상태를, 마지막으로 S5은 모든 sequence가 다 들어온 10101의 입력이 들어온 상태를 의미합니다. 따라서, non-overlapping 10101 moore machine sequence detector에서는 101010101의 입력이 들어올 때, 앞의 10101만을 감지하여 S5의 상태가 된 후, 입력을 받아 다른 상태로 transition될 때 1을 출력하고 overlap된 10101은 감지하지 못하므로 400 ns까지 출력 out은 단 한 번만 1을 출력한다는 것을 관찰할 수 있습니다. 하지만 overlapping 10101 moore machine sequence detector에서는 101010101에서 overlap된 뒤의 10101까지 감지하므로 400 ns부터 800 ns까지 출력 out으로 두 번이나 1을 출력한다는 것을 관찰할 수 있습니다.

<Figure 17> non-overlapping 10101 moore machine sequence detector의 state diagram(상태도)



<Figure 18> overlapping 10101 moore machine sequence detector의 state diagram(상태도)

Non-overlapping moore machine sequence detector와 overlapping moore machine sequence detector은 위와 같은 상태표로 나타낼 수 있습니다. Non-overlapping sequence detector은 S5의 상태에서 0을 입력 받으면 S0의 상태로 세팅하고, overlapping sequence detector은 S5의 상태에서 0을 입력 받으면 S4의 상태로 세팅한다는 차이가 있습니다. 이러한 차이는 위의 simulation 결과를 통해서도 확인이 가능합니다.

<Table 7> non-overlapping 10101 moore machine sequence detector의 state table(상태표)

|  |  |  |  |
| --- | --- | --- | --- |
| Current  state | Output | | Output |
| Input = 0 | Input = 1 |
| S0 | S0 | S1 | 0 |
| S1 | S2 | S1 | 0 |
| S2 | S0 | S3 | 0 |
| S3 | S4 | S1 | 0 |
| S4 | S0 | S5 | 0 |
| S5 | S0 | S1 | 1 |

<Table 8> overlapping 10101 moore machine sequence detector의 state table(상태표)

|  |  |  |  |
| --- | --- | --- | --- |
| Current  state | Next state | | Output |
| Input = 0 | Input = 1 |
| S0 | S0 | S1 | 0 |
| S1 | S2 | S1 | 0 |
| S2 | S0 | S3 | 0 |
| S3 | S4 | S1 | 0 |
| S4 | S0 | S5 | 0 |
| S5 | S4 | S1 | 1 |

위의 <Table 7>과 <Table 8>는 각각 non-overlapping 10101 moore machine sequence detector와overlapping 10101 moore machine sequence detector의 state table(상태표)입니다. 두 표의 차이점을 회색으로 나타내었는데 앞서 설명하였다시피 non-overlapping sequence detector에서는 S5의 상태에서 0을 입력 받으면 S0의 상태로 transition되는 것과 달리, overlapping sequence detector에서는 S5의 상태에서 0을 입력 받으면 S4의 상태로 transition된다는 것입니다. 또한 위의 표를 통해 mealy machine과 달리, moore machine은 출력이 입력과 현재 상태가 아니라, 현재 상태에 의해서만 결정이 된다는 것을 확인할 수 있습니다.